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DIV. INSECTS.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 5

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
September 27, 1913.

THE SOUTHERN CORN ROOTWORM, OR BUDWORM.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

DISTRIBUTION.

The parent of the southern corn rootworm (*Diabrotica duodecimpunctata* Oliv.), or, as it is often termed, the budworm, is a yellow or greenish-yellow beetle having 12 black spots on the back, as shown in figure 1, *a*, from which its specific name, meaning "12-spotted," is derived. It is closely allied to the almost equally common striped cucumber beetle (*Diabrotica vittata* Fab.), and also to the parent of the even more destructive western corn rootworm (*Diabrotica longicornis* Say). Throughout the country east of the Rocky Mountains, extending from southern Canada southward to North Carolina, Tennessee, Arkansas, and Oklahoma, these 12-spotted and striped beetles together frequent squashes and pumpkins, often collecting in numbers in the blossoms. The 12-spotted species during late summer and fall also frequents, often in conspicuous numbers, the flowers of the various species of goldenrod (Solidago).

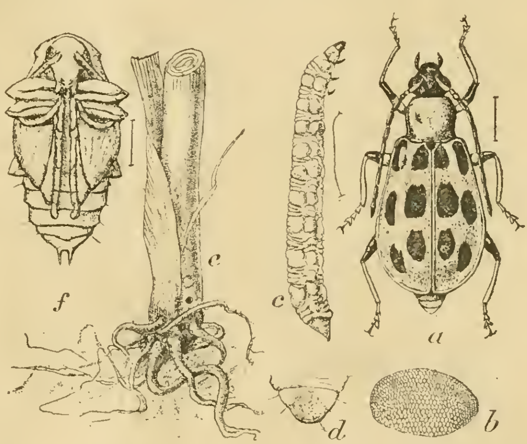

Fig. 1.—The southern corn rootworm (*Diabrotica duodecimpunctata*): *a*, Beetle; *b*, egg; *c*, larva; *d*, anal segment of larva; *e*, work of larva at base of cornstalk; *f*, pupa. All much enlarged, except *e*, reduced. (Reengraved after Riley, except *f*, after Chittenden.)

The larvæ (fig. 1, *c*) do not generally attack growing corn in sufficient numbers to cause any considerable injury, except perhaps locally, north of the States mentioned in the preceding paragraph, although in 1890 some damage was done in the southern portions of Illinois, Indiana, and Ohio. Southward from the latitude of these States to the Gulf, and extending into Mexico, however, serious ravages are of more or less frequent occurrence. The author reared the beetles from larvæ that were attacking late-planted corn at La Fayette, Ind., during July and early August, 1888, though there was no serious injury to the crop as a whole. A larva was also observed by the author in the act of eating into a stem of young wheat in the field, on October 11, 1890, in the same locality, but the species is not of importance as a wheat insect.

FOOD PLANTS OF THE LARVÆ.

It is probable that the larvæ have attacked corn in the Southern States for at least a century or more. Prof. A. L. Quaintance recorded them as feeding not only on corn but also on the roots of rye, garden beans, and southern chess (*Bromus unioloides*) in Georgia,[1] working serious injury to both corn and beans. The author observed the larvæ attacking young wheat at La Fayette, Ind., October 11, 1890, while Mr. E. O. G. Kelly observed the same thing to occur at Wellington, Kans., October 2, 1907. March 1, 1909, Mr. T. D. Urbahns, at Mercedes, Tex., found larvæ one-half inch in length on the roots of young alfalfa and from these reared adults March 19. April 20, 1911, Mr. George G. Ainslie found larvæ in abundance feeding on the roots of young oats about Jackson, Miss. Adults from these larvæ emerged May 17. The same observer reared adults from larvæ found feeding on the roots of barnyard grass (*Echinochloa crus-galli*) at Hurricane, Tenn., on July 12, 1912, the adults in this case emerging on July 21. The grass upon the roots of which the larvæ were feeding grew up among and between corn that had previously been attacked and killed by the pest.

Dr. F. H. Chittenden[2] states that larvæ or pupæ have been observed at the roots of corn, wheat, rye, millet (*Panicum miliaceum*), southern chess (*Bromus unioloides*), beans, goldenglow (*Rudbeckia* sp.), and sedges of the genera Cyperus and Scirpus. Larvæ have been found and reared by him from about the roots of Jamestown weed (*Datura stramonium*) and pigweed (Amaranthus), and it is not improbable that they feed on these plants.

Prof. E. Dwight Sanderson[3] reported the larvæ working upon the roots of Johnson grass (*Sorghum halepense*) where these roots at the time appeared older than those of the corn. Under date of February 19, 1907, Mr. Dick Hatcher, of Fross, Tex., through Repre-

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[1] U. S. Dept. Agr., Bur. Ent., Bul. 26, pp. 38–39, 1900.
[2] U. S. Dept. Agr., Bur. Ent., Circ. 59, p. 4, 1905.
[3] Entomological News, vol. 17, p. 213, June, 1906.

sentative Burleson of that State, informed the writer that the larvæ begin to work on the roots of Johnson grass during the latter part of July. They eat small holes under each joint, and by the latter part of November the roots are dead, and the Johnson grass, as he expressed it, "looks more like rotten sea grass than anything I can compare it to." This correspondent refers to their work on Johnson grass as being more beneficial than otherwise.

FOOD OF THE BEETLES.

The fully developed insect, or beetle (fig. 1, *a*), is a decidedly general feeder, eating readily almost any cultivated plant. A list of its food plants would be more interesting for what it did *not* include and if given in full would be entirely out of place in a publication of this character. Of grain and forage crops it has been observed to feed on corn, wheat, oats, rye, barley, buckwheat (probably), alfalfa, cowpea, soy bean, clover, timothy, milo maize, Kafir, pearl millet, vetch, Johnson grass, and rape.

DEPREDATIONS OF THE LARVÆ IN CORN.

Just when the southern corn rootworm, or budworm, as it is termed in the South, first began to attack corn is involved in obscurity. The writer several years ago[1] called attention to the fact that it was probably this insect to which a Mr. Charles Yancey,[2] of Buckingham, Va., referred when he described "a little white worm with copper-colored head" which, perforating the stalks of young corn "just below the surface of the ground," destroyed the growth. The budworm has certainly been accused of attacking corn in Virginia and other Southern Atlantic Coast States since long before the recollection of the oldest inhabitants. Quaintance[3] found excellent ground for believing that the pest was injurious in the cornfields of Georgia "many years before we find any reference to it in the literature of economic entomology." The first exact observations on the ravages of the larvæ (fig. 1, *c*) in growing corn, the identity of the pest being known at the time the observations were made, were by the writer and published shortly afterwards,[4] as follows:

> While in the South during the spring of 1886 we frequently heard of fields of young corn being seriously injured during some seasons by a small white worm which attacked the roots, usually during April. * * *
>
> On April 12 of the present year [1887] we were enabled to solve the problem by finding considerable numbers of these larvæ in the field of corn in Tensas Parish, La., where they were working considerable mischief by killing the young

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[1] U. S. Dept. Agr., Insect Life, vol. 4, p. 264. 1892.
[2] American Farmer, vol. 10, p. 3, 1828.
[3] Loc. cit., p. 36.
[4] Report of the Commissioner of Agriculture for 1887, p. 148, 1888.

plants. As observed by us, their mode of attack differed from that of their northern congener in that they did not appear to attack the fibrous roots or bury themselves in longitudinal channels excavated in the larger roots. On the contrary, they burrowed directly into the plants at or near the upper whorl of roots, which almost invariably resulted in the death of the plant. These larvæ were much more active than those of *longicornis*, and on being disturbed would make their way out of their burrows and attempt to escape by crawling slowly into crevices in the soil, or if it were finely pulverized they would work their way down into it out of sight. Often several individuals, varying greatly in size, would be found about a single plant. On the 20th of same month, in another field, we found the larvæ much more numerous and the crop injured fully 75 per cent. Plants here, 6 to 8 inches high, were withering up and discoloring. Both of these fields had produced cotton the preceding year.

April 27, 1888, serious attacks to young growing corn were observed on Perkins's plantation, near Somerset Landing, Tensas Parish, La., and on May 12 similar depredations were noted in the vicinity of Madison, Ark. Still later the author found the larvæ attacking late-planted corn at La Fayette, Ind., July 12, and on July 14 of the same year 595 of these larvæ were collected and placed in rearing cages, adults from which appeared August 2 and 3. In all of the localities just given, except the last, the ravages were on corn growing in the low damp lands. Throughout the South and even farther north the soil of the lowlands and depressions in fields is of a darker color than that of more elevated areas, hence the statement of farmers and planters that the pest is more destructive on the "black lands." Prof. H. Garman[1] stated that to his personal knowledge corn had been injured during the years 1889 and 1890 in Virginia, Alabama, Mississippi, Louisiana, Arkansas, Kentucky, Illinois, and Ohio.

LOSSES CAUSED BY THE LARVÆ.

As showing the magnitude of the losses caused by this insect, especially throughout the South, illustrations have been selected from notes and correspondence of the bureau. During May, 1906, the writer found that one-fourth to one-third of the young corn growing on the farm of the State Hospital for the Insane, at Columbia, S. C., was being destroyed by these pests. The damage was being done more especially on the low parts of the fields with black or gray soils. Under date of July 15, 1907, Mr. R. F. Haynes, of Cheoah, N. C., stated that the corn crop had been ruined in many places during the spring by a worm that burrowed into the plant just above the base of the roots. Under date of March 20, 1908, Mr. D. P. High, of Whiteville, N. C., stated that farmers in his neighborhood had difficulty in getting a stand of corn on their bottom lands by reason of the attack of these worms. In his opinion it was becoming the greatest cornfield pest, especially in cold, wet

[1] Psyche, vol. 6, p. 30, 1891.

springs, like the one of that year. A similar complaint was received, April 10 of the same year, from Mr. J. L. Hughes, of Chatawa, Miss., who stated that he had replanted his corn three times and the worms were still destroying his crop, although the stalks of corn were 6 inches to a foot in height. Under date of May 24, 1909, Mr. Sidney Johnson, Boydton, Va., sent specimens of the larvæ, with complaints of serious ravages in his neighborhood. March 21, 1910, Mr. Milton Mountjoy, Shacklett, Va., stated that frequently the corn in his neighborhood was ruined over great areas by this pest. Under date of July 30, 1910, Mr. C. L. Foster, of Dalton, Ga., complained of great damage to the corn crop of his section by this pest, and forwarded specimens. In some instances the corn had been replanted three times and still was so badly injured that there was little prospect of a crop. Mr. J. O. Taylor, writing under date of August 17, 1910, from Bastrop, La., stated that early planted corn during that season had been seriously damaged and in many cases destroyed by this rootworm or budworm, which he clearly describes, as well as its method of attack. July 15, 1912, Mrs. A. E. Ballah, of Philippi, W. Va., complained that her corn had been ruined that year by this pest. Writing under date of February 1, 1912, from Brandon, Ky., Mr. Robert B. Parker, statistical agent, stated that corn was damaged 50 per cent in his part of the country by these worms. In some fields they had destroyed as high as 75 per cent of the crop. May 27, 1912, Mr. George G. Ainslie found a portion of a cornfield near Hurricane, Tenn., that had been damaged fully 95 per cent by these larvæ. Under date of December 4, 1912, Mr. G. M. Goforth, county demonstrator, writing from Lenoir, N. C., stated that this worm caused a loss of thousands of dollars every year in his (Caldwell) county.

HABITS OF THE LARVÆ.

The actions of the very young larvæ are in a sense forecasted by the observations made by Quaintance on the method of oviposition. No one else appears to have observed the method of oviposition in the open fields, but Quaintance has found that the stylus-like ovipositor of the female is pushed down into the soil to a depth of from one-eighth to one-fourth of an inch and held there until the egg is forced down the extensible oviduct. This requires usually but a few seconds, and after moving a short distance the beetle may deposit another egg in the same manner.[1] Quaintance further states that larvæ, placed on the roots of corn at one end of a root cage, after the destruction of this corn made their way through the soil to a

[1] Mr. R. A. Vickery, in North Carolina, found that eggs were deposited in the soil by females in confinement without reference to the corn plants growing therein.

plant 10 inches distant. He also observed that larvæ may descend from 8 to 10 inches below the surface of the soil in search of food.

These observations are substantiated by Mr. George G. Ainslie, who studied the habits of the larvæ in the field at Hurricane, Tenn., during May, 1912. In this case, upon digging up the injured corn plants he found that the roots and stem below the ground were grooved, furrowed, and perforated. In many instances there was a distinct perforation into the base of the plant which cut off the crown, thus destroying the central leaves. The larvæ were found either in the partly decayed kernel or along the underground stem in the earth. Only occasionally were the larvæ found with their heads in these holes in the stem. Mr. Ainslie experienced difficulty in finding these larvæ, it being necessary to dig over the earth thoroughly for a considerable distance around each plant, some of the larvæ being found 4 inches from the injured plant and at a depth of 3 or 4 inches. The author also had observed this habit in the young larvæ in previous years, and there is always difficulty in reconciling the number of larvæ one can obtain in badly infested fields with the damage clearly to be charged to them. In many cases the hole made in the plant is not clean-cut, as shown in figure 1, *e*, but has somewhat the appearance of having been simply bruised. This is probably the work of the young larvæ, while the clean-cut hole is the work of those individuals that are larger and more fully developed.

The larvæ of the species under consideration, aside from the work while very young, as described by Mr. Ainslie, eat directly through the outer walls of the base of the plant into the heart of the plant, usually just above the base of the roots, as shown in figure 1, *e*. The term " rootworm " is somewhat of a misnomer, because these larvæ are not usually found in the roots, and as a rule do not feed within them, as is the case with the allied western corn rootworm (*Diabrotica longicornis*).

OVIPOSITION.

The females, which have passed the winter in the adult stage, commence egg laying soon after the first warm weather of spring. The statement of Quaintance that the eggs are usually all deposited within the space of two or three days, while perhaps true as a rule, is not entirely borne out by the observations of others. For instance, Mr. R. A. Vickery at Brownsville, Tex., found that one female deposited 102 eggs during January 18, 19, and 20; another female deposited 22 eggs, 9 on January 19 and 13 on January 28. There does, however, appear to be a tendency on the part of the individual female to complete oviposition within a few days; and this feature in the life history is of considerable economic importance, as it shows that the egg-laying season for the individual in spring is not long drawn out and that therefore remedial measures will be more effective than they would be otherwise. It has been generally observed, however, as between different females, that some contain eggs much less advanced than others, so that while the time required for the oviposition of a single individual may be very short, some individuals may have finished the process before others have begun. Even under such circumstances the egg-laying period can not be said to be exceptionally protracted.

SEASONAL HISTORY.

While it is possible that the insect may occasionally pass the winter as larva or pupa these instances have been observed too rarely to be considered otherwise than abnormal. Throughout the entire country, from Brownsville, Tex., northward, the insect normally passes the cooler months in the adult stage.

In southern Florida and southern Texas, where the insect remains active throughout the winter, the generations are but indistinctly defined. Northward, however, the species has a definite period of hibernation.

Mr. Vickery has observed the sexes pairing in North Carolina in November, and the author observed this at La Fayette, Ind., September 18, 1888, while Mr. Kelly made a similar observation at Manhattan, Kans. Mr. T. D. Urbahns found larvæ about half an inch in length in the roots of alfalfa at Mercedes, Tex., November 1, 1909, from which two adults developed November 19. Mr. Vickery has observed the males to fight each other most strenuously.

From the foregoing it would seem that pairing may sometimes take place during the late fall prior to the spring oviposition. Certain it is that many of the females are filled with fully developed eggs in very early spring, and, as will be shown, they have been frequently swept from wheat and oats, where they were observed to be feeding, before corn has even been planted.

This early appearance and feeding of the adults has been observed by Mr. Vickery at Winston-Salem, N. C., March 23, on rye, and at Statesville, N. C., March 29, on wheat; by Mr. Urbahns at Santa Maria, Tex., March 6, on oats; by Mr. George G. Ainslie at Nashville, Tenn., January 15, on wheat; and by Mr. C. N. Ainslie at Mesilla Park, N. Mex., April 1, on wheat. Adults were also observed by Mr. Urbahns at Mercedes, Tex., February 18, damaging young alfalfa by feeding on the leaves. At Lanes, Ga., March 3, and at Troy and Montgomery, Ala., March 5, they were observed by Mr. Vickery feeding on oats. Mr. George G. Ainslie observed them at Huntsville, Ala., April 14, feeding on oats; at Franklin, Tenn., February 15 to 18, feeding on wheat; and at Clemson College, S. C., February 20, feeding on oats. Quaintance reported that adults were in evidence at Experiment, Ga., March 12, and that they had become abundant on alfalfa by March 28.[1]

While all of these data may at first seem of little consequence, they bear directly, as will appear later, on what now seems to be the planter's only hope of eliminating the ravages of the pest in his cornfields. It is fair to suppose that these females deposit eggs in the fields as soon as there is food for the larvæ, and it is the larvæ from these eggs that become so destructive in the fields of young corn, especially in the South. The reason they are not equally injurious in the North may perhaps be that by the time oviposition begins in spring and the larvæ have hatched corn has become too advanced in growth to enable these young larvæ to penetrate the stem at the usual point of attack.

Mr. Vickery, who followed the species through the season at Salisbury, N. C., in 1909, settled the question of the number of generations that occur annually at that point, finding that there are two. All of the observations of the author and those of several of the men working under his direction have shown that this is generally true throughout the country where the adult hibernates, but may not apply in the far South, where hibernation does not take place.

Prof. Quaintance, at Experiment, in central Georgia, noted the first appearance of the larvæ attacking corn on May 2. The first pupa was found May 8, and the first adult, evidently of the new generation, May 12.

Mr. C. L. Foster wrote as follows from Dalton, in northern Georgia, on July 30, 1910:

> I am mailing you a sample of worm that is causing great damage to the corn crop of our country. When the corn plant is small these worms bore into the center of the stalk underneath the soil and kill the plant by destroying the "bud." When the plants are larger they bore into some of the larger roots, but more generally into the stalks among the roots, which does not kill the plant outright, but injures it so that it rarely produces corn to amount to anything. The plat where these were found has been planted three times this season, and there are very few stalks now on the plat but what have been injured by the worms. The worms were not so plentiful on July 23 as they were on July 6, when the samples first sent you were collected.

From the foregoing letter it would appear that the second generation of larvæ were at work in late June and July in northern Georgia.

Mr. George G. Ainslie studied the larvæ, at that time 3 to 6 millimeters in length, at Hurricane, Tenn., May 27 to 30, 1912. They must have been full grown by the latter date, as none could be found in the fields June 5, and a recently emerged adult was taken on June 14.

The author observed full-grown larvæ attacking late-planted corn at La Fayette, Ind., July 12, 1888, and in such enormous numbers

[1] Loc. cit.

as to enable him, two days later, to collect nearly 600 for experimentation. It was simply impossible that these could belong to the first generation, as he had frequently observed adults feeding on wheat in the fields in April and early May. One beetle was observed eating out the opening buds of a cherry tree, April 17, 1888. Besides, adults were secured in early August from these larvæ found attacking corn in July. Other adults were observed in the same locality feeding on volunteer oats, December 14, 1888. Clearly there are two generations in the latitude of northern Indiana.

Prof. Quaintance,[1] in central Georgia, found that in one case the period from egg to adult extended from March 14 to May 21, a total of 68 days. In another case this period extended only from April 25 to June 5, or 41 days. Mr. Kelly, at Wellington, Kans., found that the period from egg to adult was 40 to 45 days, while Mr. Vickery, at Salisbury, in western North Carolina, found that this period extended from August 27 or 29 to October 24, or about 58 days.

From all available information it appears that the egg period varies greatly and may require from 7 to 24 days, the larval period from 15 to 35 days, and that of the pupa from 7 to 13 days.

NATURAL ENEMIES.

The Biological Survey has found *Diabrotica 12-punctata* in stomachs of the following 24 species of birds: Bobwhite, *Colinus virginianus* (found in 15 stomachs, one of which contained 12); scaled quail, *Callipepla squamata;* California quail, *Lophortyx californicus;* prairie chicken, *Tympanuchus americanus;* wild turkey, *Meleagris gallopavo;* yellow-bellied sapsucker, *Sphyrapicus varius;* red-headed woodpecker, *Melanerpes erythrocephalus;* nighthawk, *Chordeiles virginianus;* scissor-tailed flycatcher, *Muscivora forficata;* kingbird, *Tyrannus tyrannus;* phœbe, *Sayornis phœbe;* wood pewee, *Myiochanes virens;* western flycatcher, *Empidonax difficilis;* Acadian flycatcher, *Empidonax virescens;* Traill's flycatcher, *Empidonax trailli;* least flycatcher, *Empidonax minimus;* red-winged blackbird, *Agelaius phœniceus;* meadowlark, *Sturnella magna;* Bullock's oriole, *Icterus bullocki;* cardinal, *Cardinalis cardinalis;* rose-breasted grosbeak, *Zamelodia ludoviciana;* cliff swallow, *Petrochelidon lunifrons;* white-eyed vireo, *Vireo griseus;* robin, *Planesticus migratorius.*

The most efficient of the insect enemies of this pest is the fly *Celatoria diabroticæ* Shim. (fig. 2), the maggot of which develops within the body of the adult insect, killing its host. This parasite is not sufficiently abundant, however, to exert much influence in reducing the numbers of the insect.

[1] Loc. cit.

As far back in the past as 1888 the author found larvæ of a click-beetle, *Dasterius elegans* Fab., a close relative of the wireworms, under circumstances that led him to suspect that they were feeding on the budworm. Since that time, also, they have been taken in association with the larvæ of this species and, though never observed in the act, it is not at all unlikely that they do feed upon and destroy the budworm. Mr. Ainslie also encountered them associated with the budworm in his investigations of the latter at Hurricane, Tenn.

REMEDIAL AND PREVENTIVE MEASURES.

After having made its way into the crown of the young corn plant there is no remedy for the work of the pest. The shoot is ruined past all recovery, and the plant will only throw up worthless "suckers," which produce no ears and scant fodder. Fertility of the soil, or the lack of this, does not appear to have any influence on the amount of damage produced.

FIG. 2.—*Celatoria diabroticæ*, a fly parasite of the southern corn rootworm beetle. Much enlarged. (From Chittenden.)

Garman[1] states that of the seriously ravaged fields of corn examined by him one had been grown to tobacco and another to oats the previous year, while a third had been devoted to corn. The ravaged fields observed in Louisiana and Arkansas by the author had all been devoted to cotton the previous year. It would appear, therefore, that crop rotation has little if any effect in protecting fields of corn from the attack of the larvæ.

In the light of all the information at this time available it would seem that the farmer's only hope of relief from the ravages of this pest in the cornfields lies in so timing his planting in spring as not to subject his crop to severe attack. Quaintance, in central Georgia, secured eggs in March and April, 1900; Urbahns found young larvæ at Mercedes, Tex., March 1, 1909; George G. Ainslie observed larvæ attacking oats at Jackson, Miss., April 20, 1911. The author saw them damaging corn at Somerset Landing, La., April 12, 1887, and April 27, 1888; at Madison, Ark., May 12, 1888, and at Columbia, S. C., on May 4, 1906. At the last point the ravages of the larvæ were equally as serious as had been observed years before at Somerset Landing, La., and Madison, Ark., but at Columbia the writer was informed that corn planted after the middle of May escaped injury from the pest. Nearly all of the complaints of injuries from this budworm coming to us from the South refer to damage to the crop early in the season, March or April, although to the northward early May is

[1] Psyche, vol. 9, p. 45, 1891.

included. It would seem, therefore, that there might be a possibility of preventing much of the loss to corn growers in that section of the country by planting corn at a date that would bring the young plants above ground at a time after most of the eggs had been deposited, and not so late as to invite attack from the second generation, which is evidently abroad in the fields in late June and early July in northern Georgia and in July in northern Indiana.

Unfortunately heretofore the bureau has had neither the funds nor the men to carry out an extended investigation of this insect throughout its range of destruction. Now, with field laboratories at Columbia, S. C.; Nashville, Tenn.; Greenwood, Miss.; Brownsville, Tex.; and a temporary field station at Lakeland, Fla.—all equipped for this sort of work and in the hands of experienced men—we hope, with the cooperation of farmers and planters, to learn definitely whether it is not possible through practical measures to prevent the greater part of these ravages, and save or greatly reduce the losses caused by the budworm.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1913

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September 27, 1913.

THE WESTERN CORN ROOTWORM.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The western corn rootworm (*Diabrotica longicornis* Say) derives its common name from the fact that the larva (fig. 1) was first observed attacking the roots of corn in the Middle West. Its larval habits, its life cycle, and the appearance of the adult insect (fig. 2) are all entirely different from those of the southern corn rootworm (*Diabrotica duodecimpunctata* Oliv.), though the worms themselves are exceedingly alike in appearance. In figure 1 the larva is extended at full length, as when feeding, having been drawn from living individuals.

The beetles (fig. 2) in life are about the size of the striped cucumber beetle (*Diabrotica vittata* Fab.), but smaller and less robust than the southern corn rootworm, and are entirely of a green or yellowish-green color, except the eyes, which are black. The farmer will be most likely to observe these feeding among the silk of the ears and the pollen of corn during late August and September, though the writer has seen them enter houses in the country at night, being attracted by the evening lamps. An abundance of these beetles in a cornfield should be a distinct warning that the field should not be planted to corn the following year, but that it should be devoted to wheat, oats, barley, rye, or to any crop other than corn.

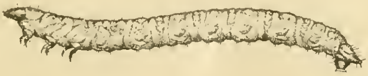

Fig. 1.—The western corn rootworm (*Diabrotica longicornis*): Larva, or "worm." Much enlarged. (Original.)

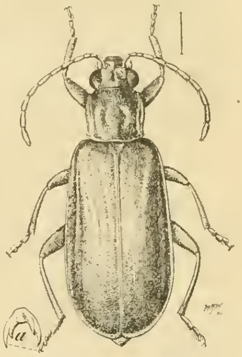

Fig. 2.—The western corn rootworm: Adult, or beetle; *a*, claw of hind leg. Much enlarged. (Original.)

SEASONAL HISTORY.

The eggs (fig. 3) are minute, yellowish-white objects, having to the unaided eye much the appearance of minute grains of white sand.

They are deposited mostly in late August and in September, in shallow crevices in the ground, more often among the brace roots of the corn. These eggs hatch the following May and June, and the larvæ, always nearly white in color, attack the roots of the corn and never burrow into the lower stem as does the southern budworm. (See fig. 5.) After completing their growth the larvæ abandon the corn roots and construct earthen cells in the soil, within which they change to pupæ (fig. 4), which are white like the larvæ, and then, during late July and August, to adults or beetles. There is therefore only one generation annually. The beetles may perhaps live over winter in extreme southern Texas, but they do not do so farther north, where they are of the greatest economic importance.

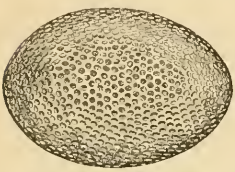

FIG. 3.—The western corn rootworm: Egg. Highly magnified. (Original.)

DISTRIBUTION.

The species occurs from Nova Scotia southward to Alabama and Mexico, westward to southern Minnesota and South Dakota, and thence south to southern New Mexico.

Curious enough, but a matter of decided economic importance, is the fact that its area of destructive abundance does not include all of the territory which it inhabits. The greatest destruction has been wrought, so far as known, in Illinois, Indiana, Ohio, Iowa, Missouri, South Dakota, Nebraska, Tennessee, and probably Kentucky.

HISTORY OF THE INSECT AND ITS RAVAGES.

The beetle was described in 1823 by Mr. Thomas Say, from specimens taken by him while connected with the Maj. Long expedition to the Rocky Mountains, and its habitat was given by him as the Arkansas Territory.[1]

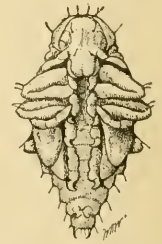

FIG. 4.—The western corn rootworm: Pupa. Much enlarged. (Original.)

No facts concerning the habits of this insect were recorded until the year 1866, when specimens of the beetles were referred to Mr. B. D. Walsh by Prof. W. S. Robertson, of Kansas, who found them in large numbers on imphee or sorghum, their natural home being a large thistle. Mr. Walsh, in acknowledging the receipt of the specimens, stated that he had taken three specimens many years before on flowers in central Illinois.[2] Eight years later, in August, 1874, Mr. H. Webber, of Kirkwood, Mo., sent some larvæ and pupæ to Prof. Riley, with the complaint that the former were burrowing into the roots of his corn and doing considerable damage. In July,

[1] Journ. Acad. Nat. Sci. Phila., vol. 3, p. 460, 1823.

[2] Practical Entomologist, vol. 2, p. 10, 1866.

1878, Prof. Riley[1] again received larvæ, this time from Mr. G. Pauls, of Eureka, Mo.,[2] and from these he reared adult beetles on the 14th of the following month.

During the spring of 1874 the writer began to collect Coleoptera in the vicinity of Waterman, Dekalb County, Ill., but during this and the following two years obtained only a single beetle of this species. This single specimen, taken by the writer in the summer of 1874, was captured in a field of corn, and the failure to secure more individuals during the next two years will indicate the rarity of the insect at that time. Within seven or eight years, however, it had become so abundant throughout the neighborhood, and indeed on the same farm, then as now owned by the writer, as to render it impossible to secure more than a single full yield of corn without changing for a year to some other crop. Up to that time corn had generally been successfully grown on the same ground for a number of consecutive years. The writer's observations in Dekalb County reflect with surprising accuracy the conditions that obtained throughout the corn-growing sections of Illinois, as shown by the information brought together by Dr. S. A. Forbes, then as now State entomologist[3] of Illinois. May, 1884, the writer ceased to be connected with Dr. Forbes's office and became associated with the Division of Entomology of this department and was soon thereafter transferred from Illinois to La Fayette, Ind.

FIG. 5.—Work of the western corn rootworm in roots of corn; at right, rootworm in situ. (Original.)

The principal damage, as previously indicated, is caused by the larvæ, and since 1882, in localities where no preventive measures have been used, the damage to the corn crop has been very serious. In 1885 Mr. Moses Fowler, of La Fayette, Ind., owner of an extensive tract of land, estimated his loss during that season through the ravages of the pest at $16,000, or about 15 per cent of the entire crop. On the basis of this estimate the loss sustained in 24 of the corn-

[1] American Entomologist, vol. 3, p. 247, 1880. (Note.—See "Roots of corn injured by some unknown insect." American Entomologist, vol. 2, p. 275, 1870.)
[2] Report of the Commissioner of Agriculture for 1878, p. 208, 1879.
[3] 14th Rept. State Ent. Ill., pp. 10–31, 1883.

producing counties of that State for that one year would amount to nearly $2,000,000.[1] Although the pest is much more destructive on high or tile-drained lands, Prof. Forbes in 1886 reported serious injury to a field in southern Illinois which had been under water for three weeks during the spring.[2] There is no indication that the insect is susceptible to meteorological influences, although the effect of its ravages is aggravated by an extremely dry season. In fact, the extreme effect of the larva upon the plants is very similar to that of severe drought.

Under date of March 7, 1887, Mr. B. F. Ferris, Sunman, Ind., a close observer, communicated with the writer as follows:

> There has been for a number of years something, I know not what, working at the roots of our corn, so that in some seasons the corn does not have roots sufficient to support it, anything like a fresh breeze blowing it down, there being scarcely any brace roots.

Sunman is in southeastern Indiana, close to the White and Ohio River Valleys, which connect with the lower Big Miami Valley in western Ohio, and when the writer was transferred from Indiana to Ohio, June 1, 1891, he at once became interested in learning whether this corn rootworm had extended its depredations into the cornfields of Ohio. The first report of injuries came from Sater, Hamilton County, in the extreme southwestern part of the State, during September, 1892, the charge being that the beetles ate the silk from the ears of sweet corn before the kernels had become fertilized.

A careful survey of extreme western Ohio during the summer of 1893 revealed the beetles in cornfields throughout the country drained by tributaries of the upper Wabash River, and throughout the valley of Big Miami River, but not beyond, to the northward or eastward. A similar survey, made in the summer of 1894, revealed the pest in the region of the upper Maumee River in the northwestern part of the State and in the valley of the Little Miami River on the east. In 1895 the pest had reached the Scioto River Valley, almost if not quite halfway from east to west across the State, and from Columbus southward to the Ohio River; while in the opposite direction its range extended from Columbus more or less irregularly northwestward to the Michigan line in Fulton County. Still later it appeared farther eastward, in the upper valley of the Muskingum River. There was no guesswork in these surveys, as they were carefully made in person by the writer, who rode over the country each year when the adult insects were abroad, examining fields and noting the presence or absence of the beetles. The following year these observations were verified through larvæ found at work by the writer or observed and sent to him by farmers.[3]

[1] Indiana Agricultural Report, p. 188, 1885.
[2] Entomologica Americana, vol. 2, p. 174, 1886.
[3] Ohio Agr. Exp. Sta., Bul. 68, pp. 39–41, maps 1–2.

It has been thus the writer's good fortune to follow personally the destructive spread (though not the actual diffusion) of the species throughout three States and from the years 1874 to 1902, both inclusive.[1]

During the years 1911 and 1912 an outbreak of this insect was studied in the Duck River Valley, middle Tennessee, by Mr. George G. Ainslie. In 1913 the same observer found the larvæ attacking corn in the bottom lands of the Tennessee River about Chattanooga, Tenn.

The pest appears to be making its way into and throughout the bottom lands of rivers flowing through the Southern Atlantic and Gulf States, precisely as it has been observed to do in Indiana and Ohio.

DIFFICULTY IN DETECTING INJURY TO CORN.

As will have been noted, the work of the larvæ is very obscure and few farmers are likely to detect them at work in the roots during June and July, while it would be simply impossible for the farmers, even if they did discover them, to connect them definitely with the little green beetles that swarm in the silk of the ears during summer and early fall.

FOOD OF THE BEETLES.

In the cornfield the food of these beetles is made up of corn silk and pollen. Rarely do they eat of the unripe kernels at the tips of the ears, and then only when birds have previously pecked into these kernels. Outside the cornfields the writer has found them in the blossoms of thistle, sunflower, goldenrod, cucurbits, cotton, clover, and rose, and on the leaves of cucumber and beans, while the species has been reported to him as eating into ripe apples where the skin had been previously ruptured by other causes. Dr. Forbes has found spores of fungi and pollen of smartweed in their stomachs. More recently Mr. George G. Ainslie has found the beetles feeding on the leaves of corn and on the pollen of the evening primrose and asters.

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[1] *Changed conditions that may have caused a change of habit in the insect.*—As the writer well remembers, the principal crop in many portions of Illinois, especially throughout the prairie country, up to 1862 was spring wheat. Influences of the Civil War at that time brought the price of pork up to a point where its production became a most profitable occupation for the farmer. At the same time wheat growing declined rapidly, the acreage being devoted to corn in order to afford food for the increasing number of hogs. In those days crop rotation received scant attention from the ordinary farmer, and corn was more often than otherwise planted year after year on the same ground. How soon it was, after this change in the principal crop from wheat to corn, that these beetles, attracted to the cornfields perhaps by the enormous amount of pollen found there as well as by the equally inexhaustible food supply offered by the silk, began to deposit their eggs and develop in these fields, it is not possible to say. We do know, however, from the records already given, that injuries from the larvæ began to be noticed in 1874, about 10 or 12 years after this change in production of wheat and corn took place, thus giving us at least a clue to the primary causes which seem to have changed the food of the insect to a cultivated crop.

EFFECTS OF ATTACK OF THE LARVÆ.

The initial effect of the work of the larvæ in the roots of corn is a shortening of the ears, leaving long tips devoid of kernels. As the infestation and injury increase, plants fail to develop ears, and finally a dwarfing of the stalks occurs. The appearance of the crop is precisely the same as it would be if the land were impoverished. Indeed many farmers, ignorant of the real trouble, claim that their soil has "run out" and is incapable longer of producing corn. One farmer insisted that his corn was damaged by careless cultivation. For this reason much injury may be done by the pest before it is recognized at all.

NATURAL ENEMIES.

The Biological Survey has found specimens of *Diabrotica longicornis* in stomachs of the nighthawk (*Chordeiles virginianus*) and the wood pewee (*Myiochanes virens*).

The natural enemies of this species are exceedingly few, the principal one being the parasitic fly *Celatoria diabroticæ* Shim., figured in Bulletin 5 of this department as an enemy of the adult of the budworm. Mr. George G. Ainslie, however, has found that the beetles are attacked by the so-called chinch-bug fungus, *Sporotrichum globuliferum*. The larvæ of the click-beetle *Drasterius elegans* Fab. are also frequently found among those of this species and may destroy some of them.

CROP ROTATION AS A PREVENTIVE MEASURE.

In all of the history of this, one of the most destructive pests in the cornfield, there is not an instance on record in which corn has been injured when planted on land following a crop of small grain, such as wheat, rye, barley, or oats. Except on grounds subject to overflow, which prevents a rotation of crops so that corn is or must be grown for two or more successive years, this pest is one of the easiest to control. Two instances only need be cited in order to prove this fact.

In Dekalb County evidence of the protection afforded by the rotation of crops is afforded on a much larger scale. On a farm of 4,600 acres owned by Hon. Lewis Steward, near Plano, rotation of crops has been the regular rule; 1,600 acres of this land was planted to corn this year, and 700 acres were carefully examined by Mr. Webster. In August only 10 acres of this entire tract was found affected by the corn rootworm, and this was where, in the rearrangement of the fields, a small tract of ground happened to have been planted to corn the previous year. All about Mr. Steward's place, on farms where rotation was not systematically practiced, the damage done was serious and general.[1]

[1] Quotation from 14th Rept. State Ent. Ill., p. 29, 1885.

The second instance is that of Mr. Moses Fowler, previously mentioned on page 3. At the time referred to (1885) the Fowler estate, comprising a single tract of about 18,000 acres, near Fowler, Ind., was farmed by tenants and there were about 10,000 acres of corn growing on the premises. Some of the fields were but slightly injured and these were such as had either produced oats or grass within two or three years. Other fields were damaged from 10 to 75 per cent or more. Mr. Fowler, the following spring, directed his tenants to sow 5,000 acres of the worst infested fields to oats and the remainder of the 10,000 acres were sown to oats the second year. Thereafter no attempt was made to grow corn two successive years on the same ground, and as a result the pest was eliminated and no further damage was sustained.

What one man can do, who has control of thousands of acres, a community can also accomplish if the people combine and follow a similar course of procedure.

Dr. Forbes, in his thorough and painstaking investigations of the insect in Illinois, has found many similar instances of the efficiency of crop rotation in eliminating the insect from cornfields. These data have been supplemented by later studies of the writer and by other observations made by him extending over the same period in other States; so that there is no longer the slightest doubt of the efficiency of this measure, which is now considered essential to good farming.

POSSIBLE EXCEPTIONS TO EFFICIENCY OF CROP ROTATION.

In this period of nearly 40 years only a few possible exceptions to the effectiveness of crop rotation have come to the writer's knowledge. One of these came from a farmer in northern Illinois whom the writer knew personally and who in 1886 complained of the attack of these larvæ on his corn, which was planted on ground that had been devoted to clover and timothy the year previous. This farmer was familiar with the pest and its work and sent specimens of the larvæ. The only explanation that could be offered for this unusual injury was that the beetles forsook the cornfields after the pollen had ceased to fall from the tassels and the silk of the ears had become too dead and dry to afford them food, and that some of the females which had not already finished oviposition made their way to the clover field, fed in the blossoms, and oviposited in the soil, thus giving rise to the larvæ that the next year attacked the corn which followed the clover crop in this field.

The second complaint came from a farmer in Indiana who for two years had fed considerable corn fodder to stock in a pasture of blue grass and timothy. After plowing up this ground and planting it to corn he reported that the crop was attacked by these worms. In this case no specimens accompanied the complaint.

It goes without saying that the beetles are found and must develop where very little corn is grown, but time has shown that there is little danger to be apprehended from these.[1]

Quite recently Mr. C. N. Ainslie, of this bureau, has found slight injury to corn in fields in Nebraska where this crop has followed small grain.

DEPREDATIONS ON LAND SUBJECT TO OVERFLOW.

The frequent submergence during fall, winter, or early spring, even for weeks at a time, of fields in which the eggs of these beetles have been deposited does not seem to affect such eggs in the least. Throughout the country north of the Ohio and Arkansas Rivers it is these low bottom lands that are kept most continuously in corn, and therefore it is here that in later years the danger from the pest is greatest. This is not, so far as now known, true of the lower Mississippi Valley, for the reason that planters there rotate with cotton, otherwise the ravages of the insect would probably be felt there as well as in the more northern States, as the writer has observed the beetles feeding on the pollen of the cotton bloom. Thus we see that throughout the country it is only where crop rotation is neglected that damage is at all to be feared.

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[1] *Possible origin of a corn-feeding race.*—It will be noticed that Mr. B. D. Walsh, the first State entomologist of Illinois, found three of these beetles in central Illinois many years prior to 1866 (Practical Entomologist, vol. 2, p. 10, 1866). Mr. Ottoman Reinecke, of Buffalo, N. Y., wrote the author in 1893 that he had, prior to 1880 and for some years, collected the beetles in abundance on willow along the margin of a creek near the city during July and August; while Mr. W. H. Harrington wrote the author years ago of his finding them in Nova Scotia. Thus it is clearly shown that the eastward advance each year, as previously recorded, does not represent the real advance of the species. It represents the advance of a race that feeds on the pollen and silk of corn, some of whose larvæ develop in the roots, the adults from these spreading from field to field and under favorable conditions giving rise to myriads of worms that feed on the roots and destroy the crop. The origin of this race appears to have been the prairie country in Illinois, which in many places begins at the Mississippi River and extends into northwestern Indiana. It is true that the first reports of injury to the roots of corn by the larvæ came from Eureka and Kirkwood, Mo., both of which are near St. Louis; but just across the Mississippi River in Illinois are wide stretches of prairie country which near the river are subject to overflow.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1913

DIV. INSECTS.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 14

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
February 28, 1914.

(PROFESSIONAL PAPER.)

THE MIGRATORY HABIT OF HOUSEFLY LARVÆ AS INDICATING A FAVORABLE REMEDIAL MEASURE. AN ACCOUNT OF PROGRESS.

By Robert H. Hutchison,
Scientific Assistant.

INTRODUCTION.

In the proceedings of the third meeting of the General Malarial Committee held at Madras in November, 1912, there is given a summary of a paper on "Insect Psychology" by Prof. L. M. Howlett. From his experiments with fruit flies, the stable fly, and mosquitoes he comes to the conclusion that "we must regard insects not as intelligent beings consciously shaping a path through life, but as being in a sort of active hypnotic trance." Also, that "once we discover the stimuli or particular conditions which determine a mosquito's actions we hold the key to the position, since we can then apply our knowledge to the mosquito's undoing." The second statement might have been made as general and inclusive as the first. One often hears expressed a general proposition to the effect that the problem of the control of any insect is very largely a problem of its behavior. If its habits are known, some means of control are usually not far to seek. Thus in the warfare against the common housefly there are two important lines of attack based on a knowledge of the habits of the adults. In the first place, advantage is taken of their feeding and drinking habits in the use of such things as sour milk, formalin and milk, beer and sugar, the fly poisons, etc., as bait for traps or as poisons. Secondly, a knowledge of the egg-laying habits of the female leads to the use of covered fly-tight receptacles for manure, garbage, or other fermenting material. Both of these methods are based on a knowledge of the habits of the adults. The question now presents itself, Is there any phase of the behavior of the larvæ which may afford a line of attack? Do they have any characteristic habit of which advantage may be taken in attempts to destroy them?

THE MIGRATORY HABIT

One need make only a few observations on the behavior of housefly larvæ to discover an excellent example of what Prof. Howlett calls "a sort of active hypnotic trance." This is to be found in the migratory habit which is so much in evidence during the prepupal stage. The habit has long been known and repeatedly mentioned in the literature. Thus Newstead (1907)[1] found that "deep down at the sides, in the cooler portions of the receptacles, the pupa or chrysalis stage occurred in enormous numbers, looking like small heaps or collections of reddish berries."

Griffith (1908) found that "the larvæ remained in the hottest part of the heap, but the pupæ were all found near the surface where it was cooler."

Jepson (1909), in certain rearing experiments in which moist bread was used as food, found that "the larvæ rarely left their feeding ground till fully fed, when they left the moist mass of bread for the surrounding dry area and there pupated."

Herms (1911) states that "the growing stage requires from four to six days, after which the maggots often crawl away from their breeding places, many of them burrowing into the loose ground just beneath the manure pile, or crawling under boards or stones or into dry manure collected under platforms or the like. * * * The larvæ often pass three or four days in the prepupal or migrated stage before actually pupating."

R. I. Smith (1911) says "it was very apparent that the maggots which swarmed through the manure were inclined to congregate in certain corners or crevices and pupate in a mass. * * * Scattered pupæ were discovered around the edges of the piles of cow manure and even in the soil underneath where the maggots had burrowed before pupating."

Hewitt (1912) states that "when full grown the mature larva usually leaves the moist situation in which it has developed for one of a drier nature, often crawling for several yards in search of some dry and sheltered crevice. Here it rests for a short time preparatory to changing into the pupal stage."

If any further evidence were needed to demonstrate such an habitual mode of action I might mention the following observations: During the past few months it has been my duty to assist in carrying out an extensive series of experiments in testing the value of various chemicals in treating manure with a view to the destruction of the larvæ present. The manure is placed in large cages and the chemical to be tested is sprinkled over it. The bottom of the cages consists of a galvanized iron pan with sides 1 foot high. In the floor of the pan are nine small holes. The sides of the cages above the

[1] Numbers in parentheses refer to dates in the bibliography, p. 11.

pan are of two layers of screen wire 2 inches apart. Now it was found in the very first experiments that larvæ were escaping from the cages, and it was seen that they found their way out through the holes in the floor of the cages and also through the screens at the sides. The numbers so escaping were surprising. It often happened that several hundred crawled out of the cage during 24 hours. They were found in the vessels placed beneath the cages to catch any drippings. By day the light was sufficient stimulus to prevent them from crawling out at the sides, but at night they were actually seen, with the aid of a flash light, making their way through both thicknesses of screen wire and dropping into the vessel below.

Moreover, in examining manure heaps on the open ground I have many records showing this "tendency to congregate" at the edges of the piles near the ground. About two cartloads of horse manure had been piled out on the open ground for five or six days during August, and at the end of this time it was hauled away. I examined the ground where the heap had been and found many pupæ, not in the center of the area formerly covered by the heap, but around the margin. Some were found on the surface, doubtless shaken out of the manure at the time of removal; others were found buried a half inch or more in the soil, where the larvæ had burrowed just previous to pupation.

In another case some 50 cubic feet of manure had been heaped up in a pile the base of which covered an area about 4 feet square. After the pile had stood three days larvæ were found swarming in the warm, moist parts of the heap near the top and some distance in from the sides. After eight days the entire pile was torn apart and gone over carefully in search of pupæ. None was to be found in the upper parts of the heap where I had previously seen great numbers of larvæ. In fact none was found until the very lowest layers were exposed. Here about 9,000 were collected. Not more than 100 were found below the soil. The mass of pupæ were scattered in little heaps about the margin. They were just outside the moist area of the manure, yet sufficiently protected from drying and sunlight by the overhanging straw. The explanation of their presence in such a position is, of course, that the larvæ, just before pupating, had migrated from the moist feeding grounds to a drier region more favorable to the resting stage. The examination of many other piles of manure showed the very same conditions existing, the only difference being in the number of pupæ collected.

Altogether some 50 or more heaps of manure on open ground have been examined. Each one contained from 40 to 50 cubic feet of manure. Some contained much long straw, others very little straw or bedding of any kind. The puparia are not hard to find nor hard to collect because of their occurrence in masses at the edges of piles. Here are some of the figures obtained from a count of the pupæ collected from different piles: 7,000, 1,500, 10,000, over 12,000, 4,500, 6,000, 6,700, 30,000, etc.

In a recent article in the American Journal of Public Health, Levy and Tuck make the following statement: "We therefore announce the biological fact that the house fly does not pupate in manure if the full-grown larvæ can find any means of reaching and entering the earth." They claim that "the adult larvæ *regularly* leave the manure heap" and that they "enter the earth whenever it is possible for them to do so." To be sure, larvæ may and often do burrow into the ground before pupating—witness Dr. Terry's observations at Jacksonville, Fla., where he found larvæ and pupæ in the ground of soil-floor stables—but that they do so *regularly* is open to serious question. The figures given above are for puparia collected *above the surface* of the ground and *in the manure*. After the removal of the heaps, examination of the ground revealed only a very small percentage beneath the surface. The fact that some were found there shows that it was not the compact nature of the soil which prevented the majority from burrowing and that there was no reason why all could not have done so if such were their regular habit. It would seem that Levy and Tuck have put too much emphasis on this one point. A broader view, including all the phases of the migration of these creatures, is necessary and will not detract from the importance or value of the "maggot trap" which they have devised.

It is quite certain that the migrating habit is deeply ingrained and highly characteristic of housefly larvæ. A consideration of the known facts in the case will enable one to draw some inferences as to "the stimuli or particular conditions" which determine this mode of action. It has been noted that a sort of "wanderlust" seizes the larvæ just before pupation. It must be, therefore, that the migration is initiated in response to internal stimuli incident to the maturing of the larval stage and the onset of the metabolic changes preparatory to the transformation to the pupal stage. The course and direction of their travels are determined largely by external stimuli. It is quite evident that as pupation draws near they flee the very moist regions of a manure heap and seek the comparatively dry regions. If no such dry places are to be found in the manure, they will leave it to pupate in the ground or in cracks or crevices, under boards or stones, in loose material of any kind. Dr. Terry found both larvæ and pupæ in the soil of dirt-floor stalls. The larvæ were found in that part of the floor kept moist by the urine, while the pupæ were found in a ring in the drier soil outside the moist center. Further proof that moisture acts as a stimulus in determining their choice of a place for pupation is given below.

It is well known that they avoid light, and the rapidity with which they disappear from view when exposed to light through the disturbing of their feeding grounds is a familiar sight. The observation mentioned in which larvæ were seen crawling out through the screened sides of cages at night, but never during the day, is a case in point.

They avoid the extremely hot portions of manure heaps. Thermometers inserted from 6 to 12 inches toward the center of a heap will register anywhere from 110° F. to 170° F., which, of course, would be fatal. The hotter the pile the nearer the surface are the larvæ to be found. They also avoid the moldy parts of the heap. They seek, as it were, the safety of the middle region between the heat and mold of the center and the exposure to sunlight and dryness of the exterior. Doubtless other conditions also have an influence in determining their actions.

The habit of seeking the comparatively dry regions near the edge of manure heaps at the time of pupation is an adaptation of great advantage in that the adult fly at the time of emergence is thus afforded an easy path to freedom. It prevents the drowning of the imagines and insures the quickest possible expansion and drying of the wings. At least this is the teleological explanation. Yet it can not be claimed that these are intelligent acts, nor that the future is consciously provided for. We have here indeed a "battalion of somnambulists" acting in blind response to various internal and external stimuli.

THE BEARING OF THE MIGRATORY HABIT ON THE PROBLEM OF CONTROL.

So far as I have been able to determine, Levy and Tuck were the first to take advantage of the migratory habit in an attempt to destroy the maggots. In their paper published in July, 1913, they report two experiments. In the first they placed manure in a barrel in the bottom of which several holes had been bored, with the result that on the following day thousands of maggots were found in the tub placed beneath, and the number seemed to increase for three days. In a second experiment the bottom of the barrel was replaced by stout wire gauze. The results of this trial are not given.

It was not until the beginning of November that I learned of their work, and it was near the end of the month before I had an opportunity of reading the article. I had already carried out two experiments during the summer at Arlington, Va., and others during the fall at Audubon Park, New Orleans, La. The possibility of taking advantage of the migrating habit was suggested to me by experience with larvæ escaping from cages used in other experiments. The results of the experiments were beyond my best expectations, and in the hope that they may be of some interest to others they are here reported in some detail.

A large galvanized iron pan, measuring 5 by 3 feet, with sides 4 inches high, was made. In this stood a container on legs 8 inches high. This container measured 4 by 2 by 2 feet. The sides and bottom were of heavy wire, ¼-inch mesh, supported by a light wooden framework. Twelve cubic feet of manure well infested with eggs and larvæ were placed in this container and sprinkled with water. Water was also poured into the pan below to the depth of about 1 inch. Surrounding and covering both pan and container was a fly-tight inclosure made of a large cage, 6 by 6 by 6 feet. This prevented further infestation of the manure, and an arrangement of traps at the top of the cage made it possible to capture and keep a record of any flies that might emerge. At the time for the emergence of flies the sides of the cage were darkened with black cloth in order to drive the flies into the traps at the top. Each day the larvæ were collected from the pan and counted, and each day the manure in the container was sprinkled thoroughly with water and the pan was washed out and again partly filled with water to drown the larvæ which fell into it. The records of Experiment No. 1 are summed up briefly in Table I.

TABLE I.—*Migratory habit of housefly larvæ; Experiment No. 1.*

Date.	Larvæ collected from pan.	Flies from traps.	Date.	Larvæ collected from pan.	Flies from traps.
1913			1913		
Aug. 27	337		Sept. 6	0	88
28	715		7		102
29	1,550		8		23
30	[1] 10,000		9		19
31	[1] 8,000		10		9
Sept. 1	2,160		12		5
2	670	3	15		6
3	263	18			
4	([2])	8		23,999	303
5	304	22			

[1] Approximate. [2] Collected on following day.

A few flies at the time of emergence fell into the water of the pan and were drowned. Allowing for these and for the few which may have escaped from the cage during the opening and shutting of the door, the total number of flies may be placed at 350. It will be seen from these figures that out of a possible total of 24,350 24,000, or a little more than 98 per cent, were destroyed through the catching of the larvæ in the manner described.

A second experiment was started on September 16. The manure used was from the same source as in the first experiment and contained practically the same proportion of straw. The same amount was used, viz, 12 cubic feet. The only respect in which this experiment differed from the first was in the fact that the manure in the container was not sprinkled with water at any time, except for a light shower on September 19 and another on September 22. Much of this rainfall failed to reach the manure in the container because of the covering of the cage. A comparison of the results of this experiment with those of the first indicate the importance of moisture as a stimulus.

TABLE II.—*Migratory habit of housefly larvæ; Experiment No. 2.*

Date.	Larvæ collected from pan.	Flies caught in traps.	Date.	Larvæ collected from pan.	Flies caught in traps.
1913			1913		
Sept. 17	15	....	Sept. 30	....	64
18	132	....	Oct. 1	....	80
19	168	....	2	....	125
21	894	....	3	....	52
22	427	....	4	....	78
23	35	....	6	....	84
24	0	....	7	....	44
27	....	43	8	....	22
28	....	43			
29	....	33		1,671	668

Allowing for the few larvæ and adults which may have escaped, the totals may be given in round numbers as 1,700 larvæ and 700 adults. Thus from a possible total of 2,400, 1,700, or about 71 per cent, were destroyed. In passing it is unnecessary to point out that here 700 flies *did* pupate in the manure in spite of the fact that they had every opportunity to leave it.

With the approach of cold weather the work against the housefly was transferred to the experiment station at Audubon Park, New Orleans, La. Some other experiments of a similar nature were carried out here with smaller containers and cages. The strong wire baskets of the kind commonly seen in markets and stores for the display of fruits and vegetables made first-rate "maggot traps." The baskets used were 16 inches in diameter and 16 inches high and stood on legs 9 inches high. A galvanized-iron pan 2 feet square was made for this to stand in, and over all this was placed a cage consisting of a light wooden framework covered with black cloth. The top of the cage was covered by boards in which was an opening for the attachment of flytraps.

The third experiment was started on November 13. The basket was filled with manure taken from stables on November 12. The manure, which contained very little straw or bedding of any kind, was packed firmly in the basket and sprinkled with 4 quarts of water. The iron pan below was partly filled with water. The cage with its traps was not put in place until November 18, thus exposing the manure to possible infestation for a period of five days. The manure was sprinkled daily as long as larvæ appeared.

TABLE III.—*Migratory habit of housefly larvæ; experiment No. 3.*

Date.	Larvæ collected from pan.	Flies caught in traps.	Date.	Larvæ collected from pan.	Flies caught in traps.
1913.			1913.		
Nov. 14	162	....	Nov. 27	....	3
15	656	....	28	....	2
16	1,950	....	29	....	2
17	2,650	....	Dec. 1	....	2
18	1,240	....	2	....	8
19	40	....	3	....	5
20	(1)	7	4	....	6
21	12	0	5	....	15
22	0	0	6	....	10
23	0	0	7	....	3
24	0	0			
25	0	4		6,710	69
26	....	2			

[1] Collected on following date.

Out of a possible total of 6,779 there were destroyed 6,710 larvæ, that is to say, about *99 per cent* were destroyed before they reached the pupal stage.

The percentages obtained in these experiments clearly demonstrate the habitual nature of the migration. They also demonstrate the efficiency of the maggot trap which is designed to take advantage of this mode of action. The question immediately arises whether the trap which appears so successful in an experimental way on a small scale can be adapted to the handling of manure in a practical way and on a large scale. Every consideration points to the probability that it can and that it will afford "an additional weapon of great value." However, the final verdict as to the value of the maggot trap must wait upon the solution of certain practical problems. To point out some of these here is to suggest lines for further investigation.

(1) In the first place, there must be determined what form, size, and construction of trap will give the best results. The answer to this will depend largely on the particular conditions obtaining at any given stable, such as the amount of manure produced daily, the arrangements for drainage, etc. It will also depend on the answer to the following problems:

(2) How deeply may manure be heaped in a trap without interfering with the migration? It will probably be found that the depth will make little difference, provided that the manure is kept moist, and provided that avenues of escape are afforded at the sides as well as at the bottom. The importance of providing a way of escape at the sides was not taken into consideration by Levy and Tuck in their preliminary experiments.

(3) How long must manure be kept in a maggot trap before it is entirely free from larvæ? This is a very important question from a practical standpoint, and one will find scant suggestion as to the answer in the literature on the life history and habits. The housefly

breeds preferably in horse manure, but it has never been determined just how long a given lot of manure continues to be an attractive place for egg laying, nor for how long a period fly larvæ will continue to appear in it. It is obvious that the maggot trap would not be practical if the infestation of the manure were daily renewed for a long time. Under ordinary conditions the drying of the surface of a heap of manure probably limits the period of egg laying to the first day or two of exposure. But in a maggot trap the manure must be kept wet in order to insure the greatest amount of migration. Would not such a moist surface be daily reinfested and maggots continue to appear in the manure as long as any fermentation were in progress? As a matter of fact, the period of infestation appears to be rather short, and even under the most favorable conditions maggots will rarely be found in a given lot of manure after 10 or 12 days' exposure. In support of this claim some experimental data may be given here.

A fourth experiment was carried out in the same manner as experiment No. 3, except that no cage was used to cover the trap at any time. The manure in the basket was thus continuously exposed to flies and the surface was kept moist by daily sprinkling. The larvæ were removed from the pan each day and counted and the pan was again partly filled with water. The manure used was taken from stables on November 12 and the experiment started on the same date. Larvæ began to appear in the pan on November 13 and continued daily to the 24th, as shown in Table IV.

TABLE IV.—*Migratory habit of housefly larvæ; Experiment No. 4.*

Date.	Larvæ caught.	Date.	Larvæ caught.
Nov. 13	14	Nov. 20	1,040
14	2,230	21	560
15	[1] 6,000	22	465
17	[1] 5,000	23	140
18	2,530	24	36
19	2,070		

[1] Approximate.

The manure contained little straw or other bedding and was very attractive to the flies as evidenced by the heavy infestation (about 20,000 from a little more than a bushel of manure). Yet no larvæ were to be found in the manure after 12 days.

Examination of heaps of manure on open ground has shown in many cases that at the end of eight days only pupæ were to be found in the manure. Even in cases where the manure was especially attractive to the flies, by reason of active fermentation and the absence of straw, all were found to have reached the pupal stage by the tenth day. Any device for applying the principle of the maggot trap on a large scale must take this time factor into consideration.

(4) The disposal of the maggots is another practical consideration. If the larvæ were allowed to drop to the ground they would burrow into it to pupate there and nothing would be gained. It would be necessary to have some sort of vessel, e. g., a concrete basin, beneath the trap. This should have vertical sides and contain an inch or more of a weak disinfectant or of water covered with a film of oil. If such a basin were connected with a sewer or cesspool the maggots collecting in it could be flushed out each week without the necessity of handling them in any way and without any offensive decomposition.

That the maggot trap possesses certain advantages is obvious and ought to lead to many attempts to develop it along practical lines. Cheapness would be one of its strong points. Practically the only cost would be the initial one for the construction of the trap and of a basin or receptacle for catching and disposing of the maggots. Very little additional time or labor would be required in operating it. The sprinkling of the manure would be a very small part of the daily routine of removing the manure from the stables. Proper arrangements for the disposal of the maggots would require only a few minutes' attention at long intervals.

Incidentally it may be noted that the maggot trap offers a convenient and easy means to the investigator or teacher who wishes to collect coprophagous larvæ in large numbers. In the experiments just reported the larvæ of *Musca domestica* L. were the most numerous, but in addition there were also collected larvæ of *Stomoxys calcitrans* L., of Homalomyia, of certain Sarcophagidæ, and doubtless of others. The total numbers collected were so large that no attempt was made to determine the relative abundance of the various forms.

SUMMARY.

Observations and experiments show that the migratory habit is deeply ingrained and highly characteristic of housefly larvæ.

The migratory habit appears in the prepupal stage in response to various internal and external stimuli.

Of the external stimuli, moisture is perhaps the most important in determining the direction of their travels and the choice of a place for pupation.

The migratory habit is an adaptation of great advantage in that it insures to the issuing adult the easiest and quickest escape.

This deep-seated habit offers an important point of attack in the attempts to control the pest.

Experiments with maggot traps show that 98 or 99 per cent of the total number of larvæ can be made to leave the manure, provided it is kept moist. Even from comparatively dry manure as many as 70 per cent can be destroyed.

The development of the maggot trap into an efficient weapon in the warfare against the housefly involves the working out of certain practical points, viz, the size and structure of the trap, the time necessary to keep the manure in the trap to rid it of maggots, the disposal of the larvæ, etc.

REFERENCES TO LITERATURE.

GRIFFITH, A. 1908. The life history of house-flies. Pub. Health, London, v. 21, p. 122–127, May.

HERMS, W. B. 1911. The house fly in its relation to public health. Univ. Cal. Col. Agr. Exp. Sta., Bul. 215, p. 513–548, 15 figs., May.

HEWITT, C. G. 1912. House-flies and How They Spread Disease. Cambridge. 122 p., illus. (Cambridge manuals of science and literature.)

HOWLETT, L. M. 1913. Insect psychology. Proc. Third Meeting of the General Malaria Committee held at Madras Nov. 18, 19, and 20, 1912. Simla, p. 32–33.
Summary of paper read at this meeting.

JEPSON, J. P. 1909. Some observations on the breeding of Musca domestica during the winter months. Rpts. to the Local Govt. Bd. [Gt. Brit.] on Pub. Health and Med. Subjects, n. s. no. 5, p. 5–8.

LEVY, E. C., and TUCK, W. T. 1913. The maggot trap—a new weapon in our warfare against the typhoid fly. Amer. Jour. Pub. Health, v. 3, no. 7, p. 657–660, illus., July.

NEWSTEAD, ROBERT. 1908. On the habits, life-cycle and breeding places of the common house-fly (*Musca domestica*, Linn.). Ann. Trop. Med., Liverpool, v. 1, no. 4, p. 507–520, pl. 44–49, Feb. 29.
Reprinted from Preliminary report issued by the Health Committee of the City of Liverpool, Oct. 3, 1907.

SMITH, R. I. 1912. The house fly (*Musca domestica*). No. Car. Agr. Exp. Sta., Col. Agr. & Mech. Arts., Ann. Rpt. 34, p. 62–69, figs. 13–14.

TERRY, C. E. 1912. Extermination of the housefly in cities; its necessity and possibility. Amer. Jour. Pub. Health, v. 2, p. 14–22, Jan.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 15

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

October 16, 1913.

A SEALED PAPER CARTON TO PROTECT CEREALS FROM INSECT ATTACK.

By William B. Parker, *Entomological Assistant.*

ECONOMIC IMPORTANCE OF THE PROBLEM.

During an investigation of the insects attacking dried fruits at Sacramento, Cal., during 1912, the infested condition of packed cereals was brought to the writer's attention. The economic importance of these infestations is greater than at first appears. The purchaser usually returns infested packages to the grocer. The grocer returns them to the mill where they were prepared. The mill screens the cereal and sells it as feed. Thus the condition of the cereal itself is the cause of a disagreeable feeling on the part of the consumer and occasions a loss of time to the grocer and a considerable loss financially to the miller.

Besides this intrinsic loss, the consumer may demand of the grocer another "brand" in the hope of finding a cereal which is not infested by insects, or, by jumping to the sudden conclusion that all cereals are infested during the summer, may forego the use of breakfast foods for a time. The exact financial loss due to these conditions can not be accurately determined, but extensive observations lead to the belief that it is much greater than most millers suppose.

PRELIMINARY OBSERVATIONS.

Examinations of infested packages taken in grocery stores, warehouses, and mills showed that the majority of infestations commenced at the ends of these packages, or where a small hole had been broken in the edge, due to rough handling. The cereal in these packages was sterilized prior to being packed, so that the insects which caused the infestation must have deposited their eggs after, or shortly before, the cereal was packed. The presence of the confused flour beetle (*Tribolium confusum* Duv.) inside of the ends and the presence of small openings at the corners of many packages led to the conclusion that if cereals were run directly from the sterilizer into cartons, which in turn were properly sealed, infestation would not in most cases take place. This theory was strengthened by statements from grocers to the effect that certain packages which were carefully sealed were not returned to them because of the presence of insects.

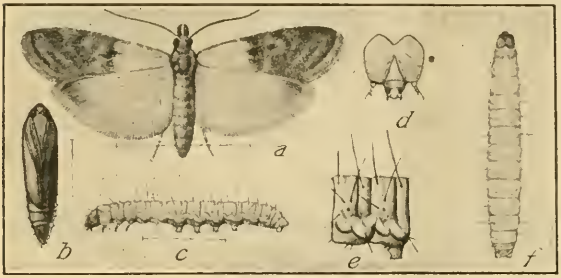

FIG. 1.—The Indian-meal moth (*Plodia interpunctella*): *a*, Moth; *b*, pupa; *c*, larva; *f*, same, dorsal view; *d*, head, and *e*, first abdominal segment of larva. *f*, Somewhat enlarged; *d*, *e*, more enlarged. (After Chittenden.)

INSECTS CONCERNED.

There are several insects which attack stored cereal products. Among the more important are the Indian-meal moth (*Plodia interpunctella* Hübn.) (fig. 1), the Mediterranean flour moth (*Ephestia kuehniella* Zell.) (fig. 2), the meal snout-moth (*Pyralis farinalis* L.), the saw-toothed grain beetle (*Silvanus surinamensis* L.), the confused flour beetle (*Tribolium confusum* Duv.) (fig. 3), the granary weevil (*Calandra granaria* L.), and the rice weevil (*Calandra oryza* L.). These are the principal insects which are likely to infest packed cereals.

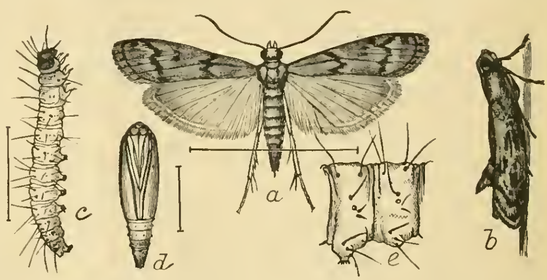

FIG. 2.—The Mediterranean flour moth (*Ephestia kuehniella*): *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva. *a–d*, Enlarged; *e*, more enlarged. (After Chittenden.)

There is an erroneous opinion with some people that the cereals become infested by spontaneous generation. This, however, is impossible; and when any insects are found in packages it is because the eggs, larvæ, or adults have gained access to the cereal after it has been sterilized.

EXPERIMENTS IN CALIFORNIA.

Using the foregoing observations as a basis, the following experiments were conducted, the idea being to test the efficiency of a cheap sealed carton.

A cereal was sterilized to such an extent that when it was placed in a package the temperature developed was 180° F. The packages themselves were sterilized before being filled, but had there been any insects or eggs in them the heat from the cereal would undoubtedly have killed them.

When the ends of the packages were being fastened, the glue was not placed near the corners, so that if it were possible to leave an opening there by accident, the opening would be left in this experiment. All of the packages were regularly closed by gluing the ends, but some of them were covered by a piece of label paper (fig. 7) so that there were no openings where an insect could enter without piercing the label. Some of the labels were put on with glue and some with flour paste.

Eighteen of these packages, nine labeled and nine not labeled, were distributed in two wooden boxes. Between them flour and meal that

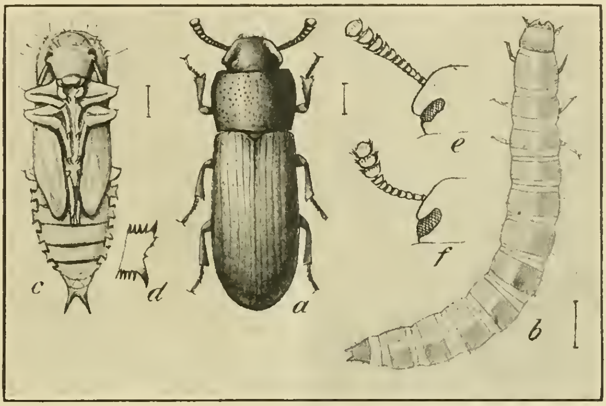

FIG. 3.—The confused flour beetle (*Tribolium confusum*): *a*, Beetle; *b*, larva; *c*, pupa; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of *T. ferrugineum*. *a–c*, Much enlarged; *d–f*, more enlarged. (After Chittenden.)

were badly infested by the confused flour beetle, the saw-toothed grain beetle, and the Mediterranean flour moth were packed. This infestation of the boxes was very carefully done, and when the experiment was observed on November 10, 1912, the outsides of all of the packages were literally alive with insects. The condition of the contents of eight of them is recorded in Table I.

TABLE I.—*Recorded conditions of infestation or noninfestation found in packages of cereal opened Nov. 10, 1912.*

No. of package.	Not labeled.	Label pasted.	Label glued.
1	Infested, containing web and adults		
2	....do		
3	....do		
4	....do		
5		No infestation	
6		....do	
7			No infestation.
8			Do.

A similar observation was made on January 24, 1913, the results of which are shown in Table II.

TABLE II.—*Conditions of infestation or noninfestation of 10 packages of cereal left until Jan. 24, 1913.*

No. of package.	Not labeled.	Label pasted.	Label glued.
9	Infested, containing web and adults		
10	....do		
11	....do		
12	....do		
13	....do		
14		No infestation	
15		....do	
16			No infestation.
17			Do.
18			Do.

The results of this experiment seem very conclusive. Figure 4 shows the relative infestation on the outside and inside of the labeled and nonlabeled packages. These packages were all placed under the same conditions and given every chance to become infested.

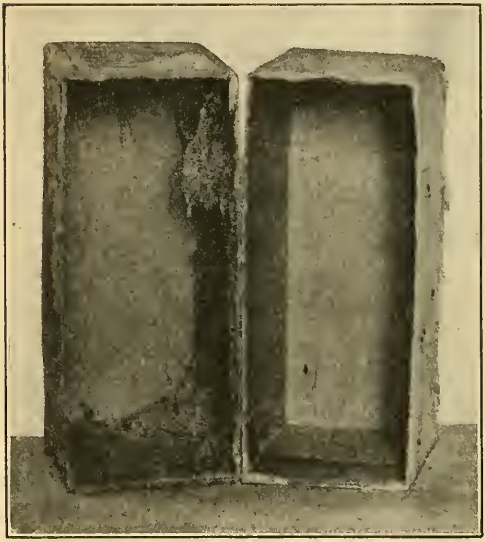

FIG. 4.—Results of experiments with cartons. The one on the left shows severe infestation; the one on the right had a thin label pasted on the outside and is not infested. The webs and adults of the infesting insects are shown on the outside of both cartons. (Original.)

The thorough infestation of nonlabeled packages and the absence of infestation in the labeled packages clearly indicate the efficiency of the label in preventing the insects from entering the cartons.

These experiments do not prove that insects are incapable of boring into the carton, thus infesting the cereal, but they do prove that when placed in regions of severe infestation the ordinary paper carton will become infested while the sealed carton will not.

WHERE INFESTATION TAKES PLACE.

In the process of sterilization the cereal is heated to a sufficiently high temperature to cause the death of all insect life, but following this process there are several ways in which it may become infested.

While on an elevator (see fig. 5) the cereal may be infested by eggs, larvæ, or adults of the several insects dropping or crawling into it. Warehouses are usually more or less infested by insects which crawl around on the packages. The grocer's storeroom and shelves are also places where infestation takes place. Unless put into insect-proof carton the cereal, therefore, is subject to infestation from the

FIG. 5.—Cereal elevator which leads from sterilizer to packing room. Infestation may easily take place here. (Original.)

time it comes from the rolls or the sterilizer until it is sold to the consumer. Infestation may, of course, take place after the package is opened by the purchaser, but this does not concern the manufacturer.

DRYING THE CEREAL.

After the cereal has been sterilized it may contain too much moisture to be packed, and a drying process then becomes necessary. In the case of cereals which are not flaky and to which agitation is not injurious, a sterile chute with baffles (fig. 6), through which hot,

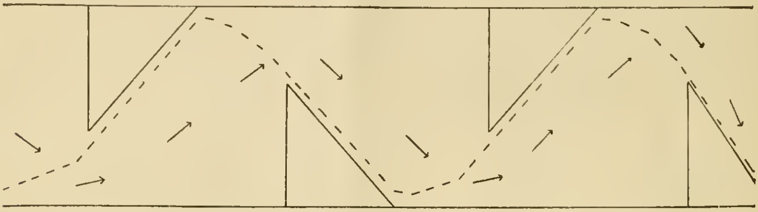

FIG. 6.—Diagram of chute with baffles for cooling cereal. (Original.)

dry air is blown, would be effective. The air is thus placed in contact with the falling cereal. In the case of flaky cereals a belt elevator is necessary, but this can be inclosed and the hot air used as in the former case. Both elevators should be so constructed that they can be readily sterilized with air at a temperature above 180° F. This should be occasionally done as precaution against infestation.

THE SEALED CARTON.

The sealed carton may be made of a stiff, though perhaps a cheaper, grade of cardboard than is used when the cardboard itself is printed. The printed label should be made in three pieces, namely, two ends, which lap over the edges and extend a short distance down the side; and a side piece, which securely covers the edges of the end pieces. (See fig. 7.) One sealed carton was observed which had a strip of paper pasted across the corners before the ends were put on. This further insures the resistance of the carton to insect attack and is advisable, provided the cost is not too great.

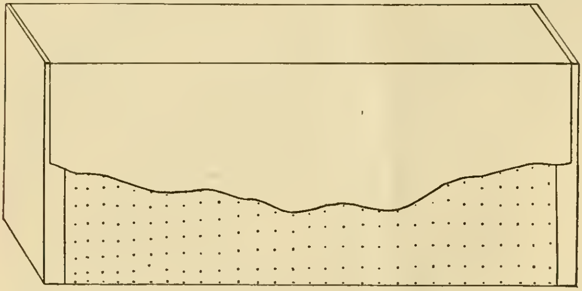

FIG. 7.—Diagram of carton, showing method of applying label to protect inclosed cereal from insect attack. (Original.)

A sealed package was observed on which the ends of the carton were not as firmly glued as they would have been had the package not been labeled. The looseness of this end caused a break in the label, which, of course, ruined the seal of the package. Care in the proper sealing of the ends of the carton before applying the label will remedy this defect.

The extra cost of a sealed package over the ordinary one will vary with the labor or machinery available and the cost of materials. It has been estimated at 1 cent for a 2-pound package, but it is best determined by each miller for his particular locality. With right management the cost should not prove excessive, while the use of the well-made sealed package will minimize the chance of infestation. The improved appearance of such a package, also, renders it more attractive to the prospective buyer.

PACKAGES OTHER THAN SEALED CARTONS.

Other forms of packages have been suggested, the most promising one being a sealed paper bag placed inside of an ordinary carton.

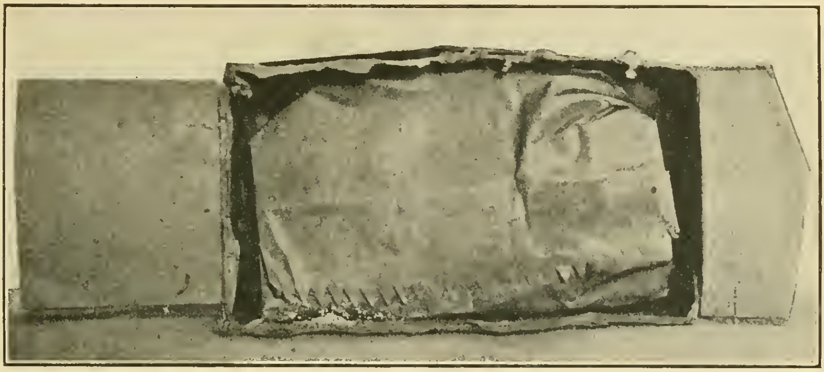

FIG. 8.—Carton with paper bag inside. Note larva on cover, and loose cereal which it has webbed together. (Original.)

Although this forms a barrier to insects which have crawled through the openings in the corners of the carton, it places them with little or no food firmly against a thin wall of paper through which they would be very likely to force their way.

Furthermore, it was observed that the ends of the paper bags were not readily sealed; small openings were left in many cases. One firm using this package reported that about as many of this type were returned infested as of the old-style packages.

Again, the small amount of cereal spilled between the bag and the carton is used by a larva, as shown in figure 8, and, in any event, the presence of insects on the top of the bag would be sufficient cause for the return of the package.

SUMMARY.

The foregoing observations and experiments have brought out several points:

(1) Cereals may become infested before they are packed, after the packages are placed in warehouses, and in the grocery stores.

(2) Insects find their way in at the small holes which are usually present at the corners of unsealed packages or at holes accidentally punched in the sides.

(3) Thorough sterilization[1] at 180° F. kills all insect life; and if the cereal is run from the sterilizer either through a sterile cooler or directly into sterile packages and immediately sealed, it will not become infested unless the package is broken.

(4) Sterilization of the knocked-down cartons before packing and cleanliness with regard to the exclusion of insects from the packing room will greatly facilitate the preparation of sterile packages and is strongly recommended.

(5) It is absolutely necessary that all machinery connecting the sterilizer and the packages be free from insects. If the cereal is passed through chutes or conveyors which can not be sterilized or are not kept sterile, it will, through these sources, become infested even though the cereal was previously sterile and was packed in sterile packages.

[1] The writer has not extensively investigated sterilizers, but the following description, furnished through the kindness of Mr. Bert D. Ingles, of a sterilizer used by a large flour mill in California may be of interest here. "In this sterilizer the screw conveyor is 6 inches in diameter and handles approximately 500 pounds of cereal per hour. The steam is held at 160 pounds pressure, which is equal to 370.5° F. A machine 8 feet long will heat the cereal under these conditions to 180° F. in two minutes without any difficulty. Such a sterilization does not injure the cereal."

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 19

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 24, 1914.

(PROFESSIONAL PAPER.)

THE GRAPE LEAFHOPPER IN THE LAKE ERIE VALLEY.

By Fred Johnson, *Agent and Expert.*

INTRODUCTION.

For several years past the grape leafhopper, *Typhlocyba comes* Say (fig. 1), has been increasing in destructive numbers throughout the vineyards of the Lake Erie Valley, and since 1910 it has been recognized as a serious menace to the grape-growing interests of that region. During the years 1910 and 1911 vineyard experiments for the control of this pest were conducted by the members of the field laboratory force stationed at North East, Pa., working under the direction of Mr. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. Owing to the pressure of work involved in the conduct of numerous vineyard experiments against this pest, and also against the rose-chafer (*Macrodactylus subspinosus* Fab.) and the grape-berry moth (*Polychrosis viteana* Clem.), it was impossible to make a detailed study of the life history of the grape leafhopper during those seasons. As most of these field experiments had been brought to a successful termination at the close of the season of 1911, the investigations for the season of 1912 were devoted largely to life-history studies of this pest. In this work, which was carried on at the field laboratory at North East, Pa., the writer was assisted by Mr. E. R. Selkregg in the recording of the data bearing upon the various stages of the life history of the insect.

Fig. 1.—The grape leafhopper (*Typhlocyba comes*): Adult, winter form. Greatly enlarged. (Original.)

The following pages contain a record of these life-history studies, together with a short historical account of the part this insect has played as an enemy of the grapevine in other grape-producing sections of the United States and Canada. A detailed account is given of its habits and destructiveness, the kinds of remedies that have been devised for its control, and the nature of the spray equipment and spray material which, in recent experiments, have proved most effective in holding the pest in check.

HISTORY.[1]

The first published record of this insect was made in 1825, when specimens from Missouri were described under the name *Tettigonia comes* by Thomas Say. It was next mentioned by Fessenden in 1828 as being a serious pest in Massachusetts. In 1841 T. M. Harris, in his Massachusetts report for that year entitled "Insects Injurious to Vegetation," gives a detailed description of the insect and an account of its habits, life history, and injury to the grapevine. These observations of Harris coincide quite closely with those recorded by the more recent workers who have taken up the study of this pest. Since the date of Harris's report the grape leafhopper has become increasingly prominent as a vineyard pest, and in almost all parts of this country and Canada it has, at some time or other, appeared in sufficient numbers to prove a real menace to the grape-growing industry. Although frequent mention of its injurious occurrence in many parts of the country since 1841 is to be found in entomological literature, but little original study, from an economic point of view, seems to have been bestowed upon this insect, for most of the references have the appearance of being taken from Harris's account.

During this time, however, a great variety of forms of this species had been collected, and as a result no less than six different specific names had been given it. In 1898 the subfamily Typhlocybinæ was the subject of a special study by Prof. C. P. Gillette, who worked out the synonymy of the insect as follows:

Typhlocyba comes Say, 1825.
Variety *basilaris* Say, 1825.
Variety *vitis* Harris, 1831.
Variety *affinis* Fitch, 1851.
Variety *vitifex* Fitch, 1856.
Variety *ziczac* Walsh, 1864.
Variety *octonotata* Walsh, 1864.
Variety *coloradensis* Gillette, 1892.
Variety *maculata* Gillette, 1898.
Variety *scutellaris* Gillette, 1898.
Variety *rubra* Gillette, 1898.
Variety *infuscata* Gillette, 1898.

By 1897 it had become so serious a vineyard pest in California as to be placed next in destructive importance to the grape Phylloxera (*Phylloxera vastatrix* Planch.) and was the subject of a detailed

[1] The titles of papers and books, and their places of publication, are not given under this and other headings, but may be found in the Bibliography, pp. 43-47, by looking for the year indicated and, under that, for the author.

study by Prof. C. W. Woodworth. In 1901 Slingerland made a very complete study of the life history of the eastern form, *Typhlocyba comes* Say, and of remedial measures for its control, in the vineyards of Chautauqua County, N. Y., publishing the results in 1904. In 1908 Prof. H. J. Quayle conducted a similarly thorough investigation of the western form in the vineyards of California. Investigations of more recent date have been carried on in Chautauqua County, N. Y., by F. Z. Hartzell, in 1912, and by the Bureau of Entomology, United States Department of Agriculture, at North East, Pa. (See Johnson, 1911 and 1912, in Bibliography.)

ORIGIN AND DISTRIBUTION.

Since *Typhlocyba comes* and its several varieties are of common occurrence on native grapevines in the wild state almost everywhere that the grapevine is found throughout the United States and Canada, and since this species is not recorded as occurring in Europe, it is doubtless a native American species.

It was first recorded from Missouri in 1825, and since that date it has been reported as occurring in destructive numbers in nearly every State in which cultivated grapevines are grown, either in a commercial way or for home use. The following statement by Slingerland in regard to its occurrence is taken from Bulletin 215 of the Cornell Experiment Station, pages 84–85:

> In nearly all discussions of the insect enemies of the grape during the past seventy-five years, the grape leafhopper has been put in the front rank with the most destructive ones. The records show that it has deserved a prominent place in the rogues' gallery of grape pests in Massachusetts since 1828, in New York since 1856, in Illinois since 1871, in Michigan and California since 1875, in Ohio since 1888, and in New Mexico, Colorado, North Carolina and Minnesota since 1890. Destructive local outbreaks have also occurred in other States.

FOOD PLANTS.

During the growing season of the grapevine the grape leafhopper apparently confines its attacks entirely to the foliage of this plant. Early in the spring, however, before the grape leaves commence to unfold, the adult leafhoppers feed on the new foliage of almost any and all plants with which they come in contact, whether it be the foliage of trees and shrubs in woodlands or the weeds and grasses in the more open sod and pasture lands. The following is a list of trees, shrubs, and weeds the foliage of which showed evidence of feeding by the adults in the spring of 1912: Beech, maple, wild cherry, wild apple, hawthorn, dogwood, wild plum, hornbeam, hackberry, honeysuckle, wild grape, Virginia creeper, raspberry, thimbleberry, blackberry, strawberry, goldenrod, nettles, wild columbine, and a great variety of weeds and grasses. Along ravines and woodlands bordering badly infested vineyards, where large numbers of the adults hibernate, the low-growing foliage of underbrush and shrubs will have nearly all of the green coloring matter extracted by this pest and present a whitened or sometimes brown appearance before the spring migration of the insect takes place. Those adults which winter in the vineyards feed upon the green blades and leaves of grasses, weeds, and the various plants that are grown as cover crops. When the leaves of the cultivated grapevine commence to unfold there is a wholesale migration from the foliage of the wild plants, and even from the foliage of wild grapevines, to that of the cultivated vines, amounting in the course of a week or so, from about May 10 to 25 in the region of the Lake Erie Valley, to a complete desertion of the foliage of all plants other than those of the wild varieties of grape and possibly the Virginia creeper. The percentage of hibernating adults remaining on the wild grapevines is very small compared with the number found there before the spring migration to the vineyards has taken place.

It has been observed that in seasons when the infestation throughout the vineyard area of the Lake Erie Valley has been light, some of the thinner-leaved varieties, such as Delaware and Brighton, are apparently more heavily infested and suffer more from the attacks of this pest than do the thicker-leaved varieties, such as Concord and Niagara. On the other hand, when these insects are very numerous throughout a large vineyard area but little if any difference in respect to the amount of injury to the different varieties can be observed. Usually vines of weak-growing varieties suffer most from attack by this pest, yet it has been observed, in run-down Concord vineyards in which the foliage was sparse, that reproduction of the leafhopper during the summer of 1912 was not so great on such vines, even where the overwintering adults were very numerous in spring, as in adjacent vineyards where vines of the same variety were more vigorous and the foliage was more dense.

Although many observations have been made to determine if this insect reproduces on the foliage of plants other than the wild and the cultivated grape, all the evidence secured has been of a negative nature. Attempts were made to rear nymphs on the foliage of the raspberry, which appears to be a favorite food plant of adults when they leave hibernating quarters in the spring. A large number of adults were confined in Riley cages containing raspberry plants. Although much of the foliage was whitened as a result of their feeding and many of the adults lived until about the middle of July, there was no appearance of nymphs at any time during the season upon the foliage of these plants. All observations during this investigation indicate that this insect reproduces only on the foliage of the wild and cultivated grapes, and that where vines of cultivated varieties are available it shows a preference for them and reproduces more freely upon them than upon the wild species.

CHARACTER OF INJURY AND DESTRUCTIVENESS.

The grape leafhopper injures the grapevine by attacking the foliage. It is a sucking insect in both the nymphal and adult stages and injures the plant by inserting its threadlike proboscis (fig. 2) into the underside of the leaf and extracting the juices therefrom. The result of these punctures, and more especially the removal of the juices, is first evidenced by a yellowing or whitening in patches on the upper surface of the leaf (fig. 3), which later turns brown, and finally the leaf falls from the vine prematurely. Where the injury is severe, the whole leaf dries up and becomes almost functionless long before the normal ripening period of the fruit arrives. This arrested functioning of the foliage as a result of attack by this pest has a tendency, when the injury is severe, to check the development of the entire vine, frequently to such an extent that the cane growth is considerably shortened, the size of the crop of fruit reduced, and the quality rendered inferior by a reduction of its sugar content. During very dry seasons the fruit on heavily infested vines is badly spotted by the droppings of the adult insects.

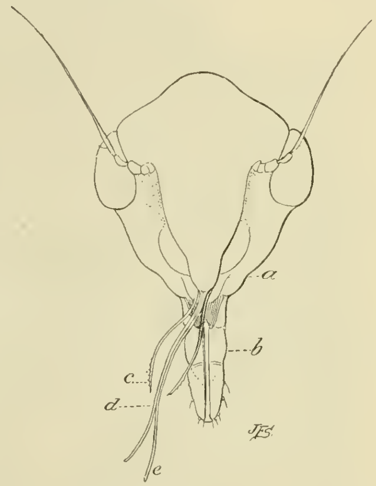


FIG. 2.—Head of grape leafhopper, showing mouthparts: *a*, Labrum; *b*, labium; *c*, mandibles; *d*, maxillæ; *e*, maxillary seta. Greatly enlarged. (Original.)

The overwintering winged adults commence to attack the new leaves of the vines when the shoots are a few inches in length. Usually the sprouts starting from the base of the vine and the new growth along the lower trellis are the first parts to be attacked. When large numbers of the adults are present feeding on this new growth, patches of yellow soon appear on the upper surface of the infested leaves, and in a short time these injured areas dry down and become brown (fig. 4), and the leaves assume a crumpled appearance, the result being a stunting of the badly infested shoots. During this time shoots higher up on the vine, being less heavily infested, have made a stronger growth which, where the vines are vigorous, soon overshadows the stunted, badly infested shoots along the lower trellis. Consequently it frequently happens that this growth on the lower trellis develops few or no long, normal, healthy canes.

This condition is of considerable importance, since it is from the healthy, well-ripened canes springing from the lower trellis that the fruiting canes for bearing the next season's crop are selected. For the first season or two that a vigorous vineyard is infested, this stunted condition of the bearing canes is overlooked by all but the most observant vineyardists. With each additional season of heavy infestation, however, it becomes increasingly difficult to secure well-placed, robust, bearing canes, and there is a corresponding decline in the quantity and quality of the crop until in some instances the

FIG. 3.—Grape leaf showing first evidence of whitened spots resulting from feeding of adult grape leafhoppers in early summer. (Original.)

crop yield is so reduced that it pays little more than the season's cost of operating the vineyard.

OCCURRENCE AND DESTRUCTIVE OUTBREAKS.

In speaking of the occurrence of this insect Slingerland has said: "It has its periods of great destructiveness and comparative obscurity, or its 'ups and downs,' like most of our insects." It may exist on vines in limited numbers in some grape-producing section for several seasons without attracting much attention either in regard to its presence or its injury to the foliage of the vines. During these periods serious injury to the vines or to the crop yield is confined to a few rows of vines adjacent to ravines, woodlots, or rough pasture lands. This limited amount of injury usually attracts little attention and no attempt is made by the vineyardist to hold the insect in check. Then a series of seasons favorable to its development may occur, and there appears to be a steady yearly increase in numbers and further encroachment into the infested vineyards. Finally it becomes so abundant and thoroughly disseminated throughout the vineyard

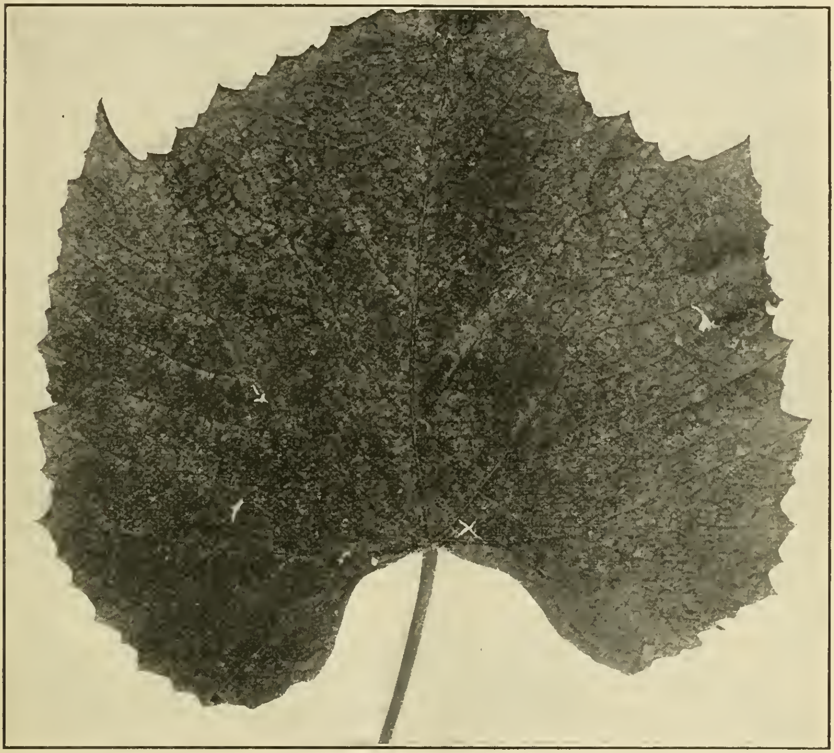


Fig. 4.—Grape leaf in advanced stages of injury. Areas between veins have turned a reddish brown. (Original.)

area, and its destruction is so obvious, that it attracts general attention, and the so-called "outbreak" causes considerable alarm among the vineyardists. Such "outbreaks" have been recorded from many States, as is indicated in the quotation from Slingerland under the caption "Origin and distribution." The same author states that "outbreaks" have occurred at frequent intervals in various parts of the State of New York as follows:

In Wyoming County in 1860; in the Hudson Valley in 1865, 1867, 1882, 1887, and 1897; on Crooked Lake in 1880; in Jefferson County in 1887 and 1888; in central New York in 1895 and 1899; and in Chautauqua County in 1900 to 1904.

During the period from 1897 to 1904 the writer of this paper resided at Westfield, N. Y., during the summer months and had the opportunity to observe the development of the outbreak of 1900 to 1904. There was not a sudden appearance of this pest in a single season, but a steady increase in numbers for several consecutive seasons preceding the so-called outbreak of 1900. On the other hand, during the summer of 1903 there was an apparent sudden disappearance of the insect from many vineyards which during the two previous seasons had been badly infested and suffered serious injury to the foliage during the seasons of 1901 and 1902. In fact, after the season of 1904 this pest disappeared from the vineyards of this area of serious infestation to such an extent that treatment was deemed unnecessary. For several years after this disappearance in destructive numbers of the insect from the vineyards in the vicinity of Westfield, N. Y., its occurrence in vineyards throughout the Lake Erie Valley was not considered of sufficient importance to warrant treatment. In 1909, however, during the conduct of vineyard experiments at North East, Pa., the appearance of this pest in injurious numbers was again observed in portions of several widely separated vineyards throughout the township. In the latter part of the season of 1910 the area of serious injury was much more widespread and its increase was viewed with alarm by vineyardists, and in the season of 1911 a number of the more progressive growers equipped themselves to fight the pest. During 1911 the injury wrought by the pest was greater than in preceding years, and the infestation was more widespread. The summer was unusually hot, and this resulted in the development of an almost full second brood which worked great injury to the vines late in the season. Immense numbers of adults went into hibernation, and large numbers of them emerged and made their appearance in the vineyards in the spring of 1912. Early in the season of 1912, on account of the presence of so many overwintering adults, there was every indication that the injury by this pest would be very great. There was an apparently normal development of the first brood of nymphs, and by the middle of the summer the injury in many vineyards was quite severe. Fortunately, however, the months of July and August were unseasonably cool. The low temperatures which prevailed during these two months so greatly retarded the development of the nymphs of the first brood that only a small percentage of the adults transforming from them deposited eggs for a second brood of nymphs. Hence there was not such a great increase in numbers of the insect during the latter end of the season of 1912 as there was at the end of the hot season of 1911. Nevertheless the injury done by this pest to many vineyards was very great. The injury to the foliage, coupled with the coolness of the summer, resulted in badly infested vineyards, in a retardation of the cane growth, in a lack of proper development of the size of the berries in the cluster, and in a deficiency in the sugar content of the fruit. For these reasons the aggregate injury by this pest during the season of 1912 was fully as great as in that of 1911.

Thus far mention of the destructiveness of this pest has been confined to the vineyard areas of the Eastern States. For more than 25 years this species, *Typhlocyba comes*, including a western variety, *coloradensis* (fig. 5), has caused an enormous amount of injury to the grapevines in the vineyards of California, where it has been recorded as an injurious grapevine pest since 1875. Prof. H. J. Quayle, in Bulletin 198 of the California Experiment Station, states in regard to its destructiveness that "with the exception of the Phylloxera, the vine hopper is undoubtedly the most destructive insect pest of the vine in the State. It is more uniformly present than any other insect attacking the vine, and each year in some parts of the State it occurs in very great numbers, and in such sections it levies a heavy tax upon the vineyard interests."

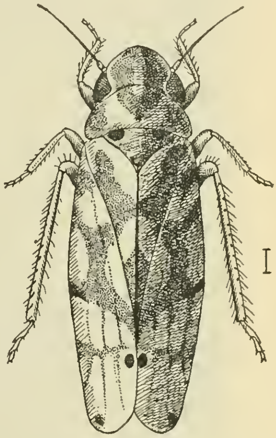


FIG. 5.—A western variety of the grape leafhopper, *Typhlocyba comes* var. coloradensis: Adult. Greatly enlarged. (Author's illustration.)

Thus it is evident that, taken in the aggregate, the injury sustained by the vineyard industry of the East and the West must amount to an enormous sum. It should be remembered, too, that the injury caused by this pest is not confined to the crop of a single season. It frequently happens that a heavy infestation of one or two seasons' duration may so stunt the growth of the vine that its full fruiting capacity may be reduced for several seasons. In fact, if special efforts for the resuscitation of badly injured vines are not undertaken they may never regain their former productive value. Hence the loss to the vineyardist not only consists in the crop shrinkage, but also in the additional cost of the fertilization and care required to get the vine back into full bearing condition.

ALLIED SPECIES.

In the region known as the Chautauqua and Erie grape belt, which includes a narrow strip of territory stretching along the southern shore of Lake Erie from Silver Creek, N. Y., to Harbour Creek, Pa., there are approximately 40,000 acres of vineyard, over 90 per cent of which are of the Concord variety. The species of leafhopper found in injurious numbers in the vineyards throughout this region is *Typhlocyba comes*. Although occasional specimens of other varieties and species may be found, their presence in numbers sufficient to work a great amount of injury has not been observed. The other species most commonly found associated with *T. comes* is *T. tricincta* Fitch (fig. 6,*b*). This species, when present, is more likely to be found on the foliage of Delaware, Catawba, Brighton, and some of the wild species of grapevine growing along ravines or in woodlands. It is readily distinguished from *comes* by the larger size and by the fact that it has three broad black bars situated as follows: One just back of the head, another about midway across the elytra, and

FIG. 6.—The two species of grape leafhopper most common in vineyards of the Great Lakes Region: *a, Typhlocyba comes; b, Typhlocyba tricincta.* Greatly enlarged. (Original.)

the third at the tips of the elytra. Nymphs of *tricincta* (fig. 7) have two black spots back of the eyes and two on the thorax.

While making trips through the vineyard areas along the shore of Lake Erie as far west as Sandusky, Ohio, it was observed that in the Ohio vineyards east of Cleveland *Typhlocyba tricincta* was present in greater numbers than in the vineyards of Chautauqua County, N. Y., and of Erie County, Pa., although more than 80 per cent were still *Typhlocyba comes.* In the vineyards west of Cleveland *T. tricincta* was present in greater numbers than in the vineyards east of that city. This condition also existed in the vineyards surrounding Sandusky, Ohio. In vineyards on Kelleys Island, North Bass, South Bass, and Middle Bass Islands both *T. comes* and *T. tricincta* were very abundant and there were also a number of other species and varieties in abundance which were not common in vineyards on the mainland, the most common being *T. vulnerata* Fitch. It should be stated that in the vineyards east of Cleveland, Ohio, the vines are nearly all of the Concord variety, whereas west of that city there is a considerable percentage of Catawba and of Early Ohio, while around Sandusky, Ohio, and upon the islands the percentage of the Concord variety is small, Catawba being the variety most commonly

FIG. 7.—Three nymphs of *Typhlocyba tricincta* on underside of grape leaf: *a*, Cast skin of nymph. Enlarged. (Original.)

grown, as also Delaware, Ives Seedling, Elvira, and a number of other varieties used in wine making. In the vineyards on the mainland around Sandusky *T. tricincta* was the species present in destructive numbers. *T. comes* was also present, but only in small numbers.

Observations in the vineyards of Michigan during the seasons of 1911 and 1912 showed that *T. tricincta* is the predominant species in vineyards surrounding Lawton and Paw Paw and in the vicinity of Benton Harbor and St. Joseph. In the vineyards of Michigan *T. comes* is present in even smaller numbers than in the vineyards about Sandusky, Ohio.

Although the development of these two species seems to be almost identical, adults of *T. tricincta* brought from the vicinity of Dover, Ohio, in the spring of 1912 produced a brood of nymphs which matured to adults. These adults, in turn, produced nymphs which developed to adults of the second summer brood. Observations in the vineyards of Ohio and Michigan, however, during August of 1911 and of 1912 indicate that this species produced a much smaller number of second-brood nymphs than did *T. comes* in the vineyards surrounding North East, Pa.

It should be added that a very large percentage of the grapevines grown in the Michigan vineyards are of the Concord variety, and that on these vines *T. tricincta* is the predominating species, whereas in the vineyards of the Chautauqua and Erie grape belt, where the Concord is the leading variety grown, *T. comes* is the predominant and destructive species.

Little, if any, effort has been made thus far by the vineyardists of Michigan to control *T. tricincta*, although in the season of 1911 it was quite destructive in many vineyards. Several vineyardists in the vicinity of Lawton and Paw Paw were planning to combat it with a tobacco-extract spray in 1912, but although there was a heavy infestation of overwintering adults in the spring these failed to produce a large enough brood of nymphs to injure the vines seriously, thus rendering a spray treatment unnecessary.

DESCRIPTION.

THE ADULT OR WINGED FORM.

The adult grape leafhopper (*Typhlocyba comes* Say) (see fig. 1, p. 1) is an insect about one-eighth of an inch long. The original description of the insect by Say, made in 1825 (see Bibliography), is as follows:

Pale yellowish with sanguineous spots. Inhabits Missouri.

Body pale yellowish; head, a transverse sanguineous line, profoundly arcuated in the middle, and a smaller transverse spot before; eyes fuscous; thorax with three sanguineous spots, the lateral ones smaller and the intermediate one arcuated; scutel, a sanguineous spot at tip; hemelytra yellowish white spotted with sanguineous; spots arranged two at base, of which the outer one is small and the inner one elongated and abruptly dilated on the inner side at tip; two upon the middle, of which the outer one is elongated in a very oblique line; the two behind the middle, of which the inner one is obliquely elongated, and the outer one smaller and interrupted; and a transverse linear one near the tip, ramose upon the nervures; feet whitish.

Length to the tip of the hemelytra one-ninth of an inch.

The line and spot on the head and the spots of the thorax are sometimes obsolete, but are always visible, and the latter are sometimes connected by curving toward the anterior edge of the thorax. The spots of the hemelytra are also sometimes slightly interrupted, or connected into four oblique bands.

In winter the color markings are deep salmon-red. After the insects have fed upon the foliage of the grapevine for a short time the color becomes paler and is displaced by a light yellow. In the newly transformed adult these yellow markings are hardly discernible (fig. 8), the whole body being very light straw color. In a short time, however, they become more pronounced. Along toward the middle of August the salmon color begins to appear, first as a light tint on the thorax and at the base of the elytra and in a short time extending to the tips of the wings. As the season advances the salmon color deepens until the insect takes on the more pronounced red markings of the wintering adult.

THE EGG.

The eggs of the grape leafhopper are not more than three-fourths of a millimeter long and are slightly curved (see fig. 10, *d*). They are semitransparent, with a yellowish tinge, and are very difficult to locate, since they are deposited beneath the epidermis of the underside of the grape leaf, which in most varieties is covered with a heavy pubescence. It is very difficult to detect them with the naked eye even after the most careful search. They may be located, however, with the aid of a hand lens or dissecting microscope by examining the underside of the leaf in bright sunlight. Under these conditions the eggs appear as slight shiny elevations under the epidermis. By carefully scraping away the pubescence covering this area the outline of the egg may be more plainly discerned. Figure 9 is an enlarged photograph showing the outlines of two eggs beneath the epidermis of a leaf of Concord grape. The eggs are extremely delicate and are very easily crushed when an attempt is made to remove the thin, semitransparent layer of leaf skin or epidermis underneath which they have been tucked by means of the slender ovipositor of the female (fig. 11). Figure 12 shows the anal segment of a male of the same species, with its genital armature.

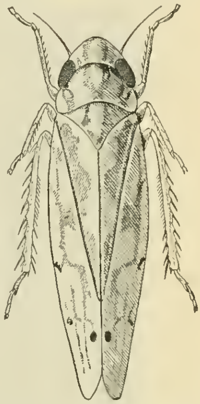


FIG. 8.—Adult grape leafhopper, summer form, showing the lighter shade of color markings of the elytra. Greatly enlarged. (Original.)

The eggs are usually deposited singly over the surface of the leaf, sometimes in or near the ribs and veins, but usually in the spaces between them. They do not appear to be placed in any regular order, but occasionally several may be found in close proximity. In one instance, in the leaf of a Clinton vine, three eggs were found quite close together with the long axis of all extending in the same general direction. Slingerland mentions finding the eggs laid from six to nine in a row in leaves of the Clinton grape. In this variety the leaf is less fleshy and has less pubescence than have the leaves of nearly all of the other varieties of grapes grown in the East. Examinations of the location and proximity of eggs in thin-leaved species of wild grapevines did not bear out the supposition that deposition in rows is general in the thin-leaved varieties, for in all other cases where eggs were found on them they were deposited with an apparent disregard for regularity of position.

Among vineyardists there is commonly a mistaken idea that the small, transparent globules that are seen on the new growth of the grapevine, especially in the early summer, are the eggs of the grape leafhopper. These are not eggs but are small drops of sap which exude from the rapidly growing leaves and tendrils.

THE NYMPH.

The young grape leafhopper, or nymph, when it hatches from the egg, is very minute, white in color, and of the same general form as

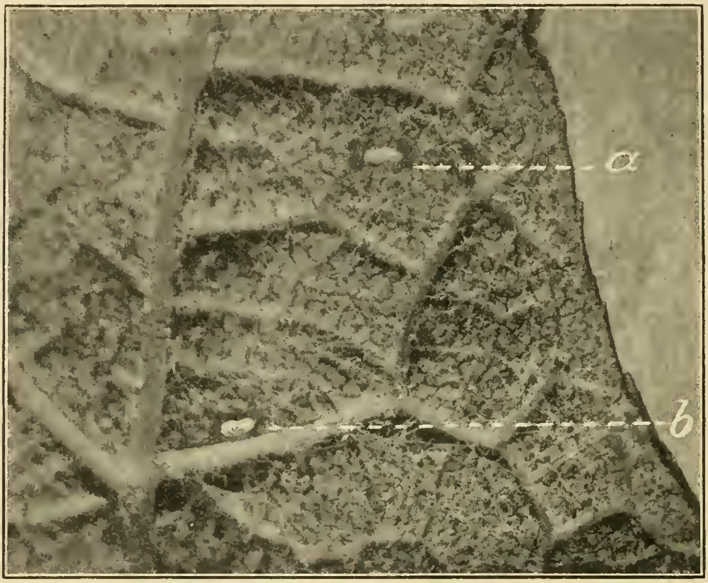


FIG. 9.—Outline of eggs, *a* and *b*, of grape leafhopper on underside of grape leaf with pubescence pushed aside. Greatly enlarged. (Original.)

the adult, but differing from the mature parent in that it does not possess wings. It attains its growth by casting its skin in a series of five molts. These five nymphal stages are represented in Plate I. The time required for the nymph to reach maturity varies greatly with the different individuals. During the season of 1912 rearings were made of a large number of nymphs.

First stage.—The newly hatched nymph has a white body and red eyes. It does not run very rapidly at first, but moves over the underside of the leaf with rather an uncertain, "wobbly" gait. The number of days required for this stage, from hatching to the first molt, may vary anywhere from 3 to 15. The majority of the nymphs, however, complete the stage in from 3 to 5 days.

Second stage.—In the second nymphal stage the insect becomes more active. The eyes lose some of their red color and the body assumes a yellowish tint, and at the base of the thorax there appear signs of the wing pads in the form of lateral buds. The length of this stage may vary from 1 to 7 days. The majority of nymphs complete the stage in 3 to 4 days.

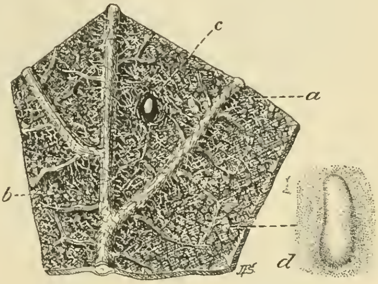


FIG. 10.—The grape leafhopper: *a* and *b*, Eggs, partially shown under pubescence; *c*, egg brought into view; *d*, greatly enlarged egg. All enlarged. (Original.)

Third stage.—The insect in the third stage moves about very actively when disturbed, running with a sidewise motion. Very rarely can one be made to hop for even the shortest distance. The red has disappeared from the eyes, and the yellow markings on the thorax have now become quite pronounced. The wing pads extend to about the caudal margin of the first abdominal segment. This stage may occupy from 1 to 11 days. In most cases from 4 to 6 days is required.

Fourth stage.—In the fourth stage the spines on the segments of the thorax and on the legs are more pronounced, and the wing pads now extend to the caudal margin of the second abdominal segment. This stage may occupy from 3 to 13 days, although the majority of nymphs complete it in 3 to 7 days.

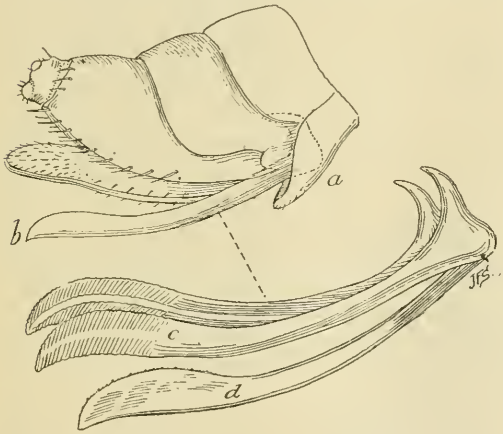


FIG. 11.—Anal segments of female grape leafhopper and details: *a*, Anal segments; *b*, ovipositor in oviposition; *c*, sheaths of ovipositor; *d*, sting. Greatly enlarged. (Original.)

Fifth stage.—In the fifth stage the wing pads are considerably lengthened, extending to about the middle of the fourth abdominal segment. The legs are much longer, and the insect runs very rapidly. This stage may cover from 4 to 20 days. The majority complete it in from 6 to 9 days.

The total length of time required to complete the nymphal stages, from hatching to the last molt, when the mature insect has fully developed wings, may vary from 19 to 37 days.

The number of days required to complete the stages of the nymph were arrived at as a result of rearing 114 nymphs through all of the five nymphal stages from hatching to adult during the season of 1912, and the data given above are based on these rearings. It was observed that variations in temperature greatly influenced the length of the different stages. It was also noted that although there might be a considerable variation in the number of days that were required by nymphs of the same age to complete any one of the stages, the total number of days covered would vary but slightly; since it frequently happened that when one stage was protracted beyond the average period, some other stage would be considerably shortened, and thus the total number of days for the entire nymphal period would be about the same for all nymphs of the same age. (See Table XI.)

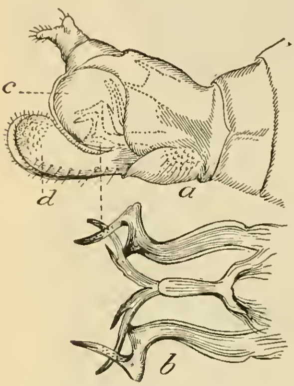
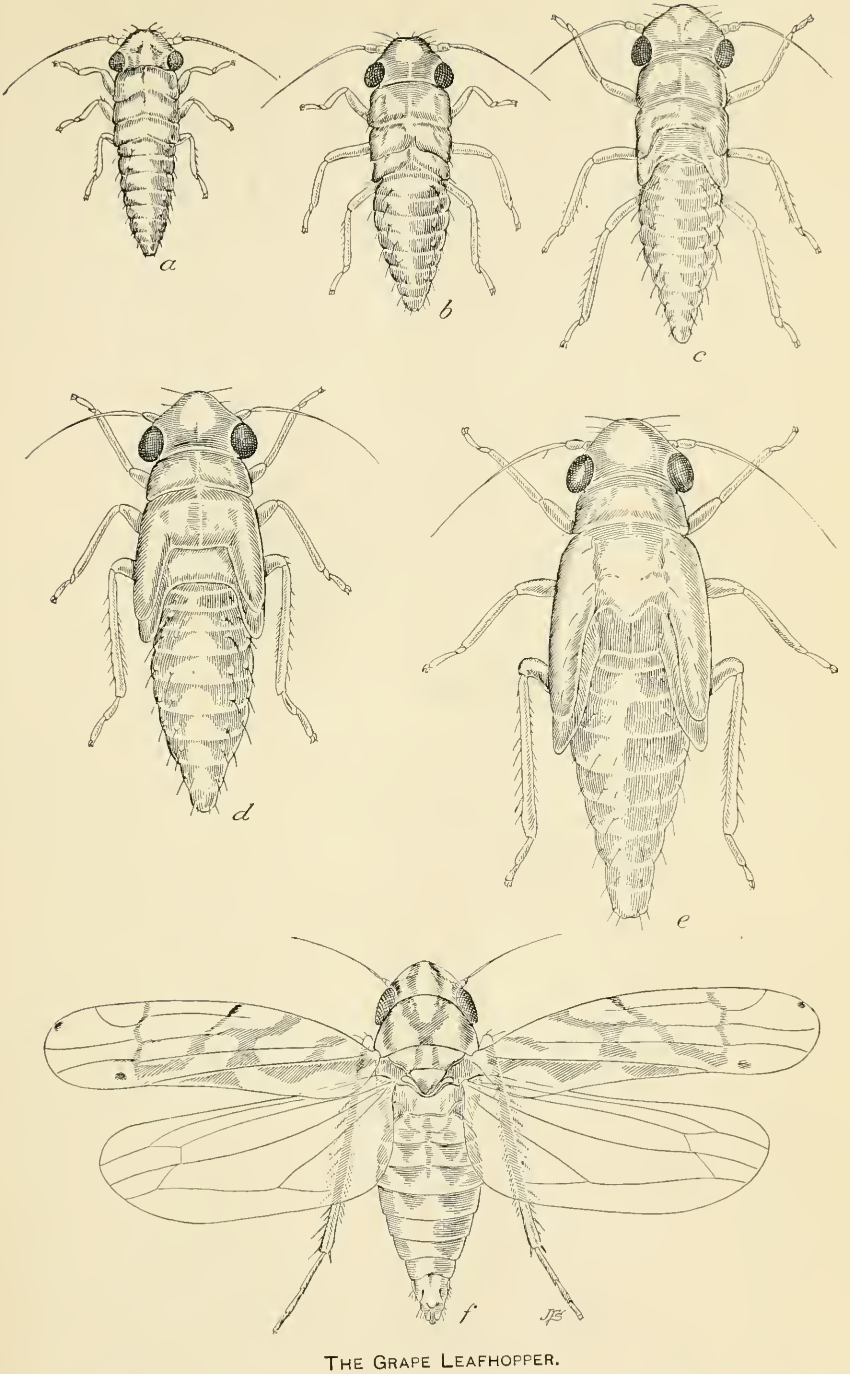


FIG. 12.—Anal segments of male grape leafhopper and details: *a*, Anal segments; *b*, genital hooks; *c*, superior clasper; *d*, inferior clasper. Greatly enlarged. (Original.)

SEASONAL HISTORY.

ACTIVITIES OF ADULTS IN EARLY SPRING.

The adult grape leafhoppers become active in their hibernating places beneath accumulations of leaves, trash, and dried grass during the warm days of late winter and early spring. During the warm sunny hours of such days they rise in swarms about one's feet when tramping through the leaves and dried grass of woodlands and swales which adjoin vineyards which were heavily infested during the preceding season. During these periods of activity they feed on the green parts of almost any plant that happens to be growing near these places of hibernation. At first the green blades of tufts of grass or the leaves of goldenrod or wild strawberry, and a little later the unfolding leaves of wild raspberry and blackberry, appear to form a favorite part of the menu offered by the woodland growth. As the days become warmer the adults extend their flight and feed upon the tender unfolding leaves of nearly all kinds of shrubs and undergrowth. When the new growth of the cultivated grapevine has attained a length of a few inches there is a general migration of the insect to the vineyards. This migration occurs about the middle of May in the vineyards of the Lake Erie Valley, and if the days are warm and bright the desertion of the woodland food plants for the foliage of the cultivated grapevine in the course of a few days is quite complete. In the spring of 1912 this migration from woodlands commenced about May 20. On May 24 the leafhoppers were extremely scarce in woodland places, where until four or five days previous they had been present in swarms since the time of first activity in spring.



THE GRAPE LEAFHOPPER.

The five nymphal stages and adult of the grape leafhopper (*Typhlocyba comes*): *a*, First stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, fifth stage; *f*, adult with wings spread. All greatly enlarged. (Original.)

From this date on, the adults confine their feeding and other activities to the foliage of the cultivated grapevine. About this time the red marking on the elytra disappears and is replaced by a light lemon-yellow. After the adults once settle down on the foliage of the vines in the vineyards there is very little evidence of further migration, and they seldom leave the shelter of the vines except when disturbed, in which case they fly but a short distance and return almost immediately to the underside of the grape foliage. On bright, warm days they become very active on the slightest disturbance of the vine, whereas on cold wet days it is with the greatest difficulty that they are dislodged from the underside of the leaves.

For several days after their appearance on the foliage of the grapevines the adults confine their activities to feeding on the underside of the foliage. This they do by inserting their threadlike mouth parts or proboscis into the tissue from the underside of the leaf and sucking out the juices.

TIME OF MATING.

It is exceedingly rare to find copulating pairs of adult grape leafhoppers before migration to the vineyards takes place. After migration to the vineyards mating is not common until a week or ten days of feeding has elapsed.

The first copulating pair seen during the spring of 1912 was on May 23 upon the foliage of a quince bush in the laboratory garden at North East, Pa. Occasional copulating pairs were seen in vineyards as early as May 25, 26, and 27, but mating did not appear to be general until about June 1. After June 5 mating of overwintering adults was rarely seen in the vineyards, although daily observations were made.

OVIPOSITION OF OVERWINTERING ADULTS.

No direct observation has been made of females in the act of oviposition. A number of experiments were made during the summer of 1912 to secure records of egg deposition and the number of eggs deposited by individual females, but without success. This failure was due to the fact that the leaves of all of the varieties of grapes grown in the Lake Erie Valley possess a heavy pubescence or hairy growth on the underside. This makes it extremely difficult to locate the eggs, since they are inserted within the tissue of the leaf beneath this hairy growth and can only be found after a thorough search. Even then many of them are doubtless overlooked, since it often happens that a large number of nymphs will hatch from grape leaves upon which it has been possible to locate only a small number of eggs after a prolonged and careful search. On June 10 the first eggs seen in 1912 were located on leaves of a Delaware grapevine.

LENGTH OF EGG STAGE.

Since we were unable to secure actual records of egg deposition from which to make a starting point in order to determine accurately the length of the egg stage, an approximation of this period was obtained in the following manner:

During the season of oviposition a number of adults were confined in an air-tight globe cage (Pl. II, fig. 1) upon the uninfested foliage of a small grapevine possessing not more than three or four healthy leaves. After 24 hours all the adults were removed. The vine was protected from further infestation and after seven days had elapsed was examined daily for the appearance of nymphs. A record was made of the date of the first nymphs to appear. These were removed from the cage and all other nymphs to hatch were removed at intervals of 24 hours. In the experiments recorded below the adults were placed on an inclosed grapevine, July 4, at 1 p. m. These adults were removed July 5, at 1 p. m. The newly hatched nymphs were removed on the dates recorded in Table I.

TABLE I. *Length of incubation period of eggs of the grape leafhopper.*

Date and hour of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.
50 adults placed on vine July 4, 1 p. m.; adults removed from vine July 5, 1 p. m.		
1912.		*Days.*
July 17, 1 p. m.	6	11 to 13
July 18, 1 p. m.	46	12 to 14
July 19, 1 p. m.	58	13 to 15
July 20, 1 p. m.	7	14 to 16
July 21, 1 p. m.	5	15 to 17
50 adults placed on vine June 25, 2 p. m.; adults removed from vine June 26, 2 p. m.		
1912.		*Days.*
July 9, 2.30 p. m.	15	11 to 13
July 10, 2.30 p. m.	45	12 to 14
July 11, 2.30 p. m.	13	13 to 15
July 12, 2.30 p. m.	0	....
July 13, 2.30 p. m.	1	15 to 17
100 adults placed on vine June 27, 2 p. m.; adults removed from vine June 28, 2 p. m.		
1912.		*Days.*
July 12, 2 p. m.	14	13 to 15
July 13, 2 p. m.	44	14 to 16
July 14, 2 p. m.	19	15 to 17
July 15, 2 p. m.	8	16 to 18
July 16, 2 p. m.	1	17 to 19
50 adults placed on vine July 27, 2 p. m.; adults removed from vine July 28, 2 p. m.		
1912.		*Days.*
Aug. 20, 2 p. m.	15	22 to 24
Aug. 21, 2 p. m.	4	23 to 25
Aug. 22, 2 p. m.	11	24 to 26
50 adults placed on vine August 10, 2 p. m.; adults removed from vine August 11, 2 p. m.		
1912.		*Days.*
Aug. 24, 2 p. m.	2	12 to 14
Aug. 25, 2 p. m.	1	13 to 15
Aug. 26, 2 p. m.	3	14 to 16
Aug. 27, 2 p. m.	0	....
Aug. 28, 2 p. m.	0	....
Aug. 29, 2 p. m.	2	17 to 19
Sept. 1, 2 p. m.	1	20 to 22

NUMBER OF EGGS DEPOSITED BY AN OVERWINTERING FEMALE GRAPE LEAFHOPPER.

On account of the great difficulty encountered in locating the eggs of the grape leafhopper, a record of the reproductive capacity of the females was secured by confining pairs of overwintering adults upon small grapevines in an arc-light globe cage similar to that shown in Plate II, figure 1, which had been protected from previous infestation, the object being to determine the number of nymphs that appeared on the vines. The pairs used for this purpose were among the first to be found copulating and at a period before any oviposition had taken place. Each pair of adults was allowed to remain on the vine until they died. To avoid the probability of the escape of the adults, only a few examinations were made until the nymphs were nearing the last molt. The parent adults were then removed and a careful count was made of the nymphs found upon the foliage; then the parent adults were returned to the cage until later examinations were made, and this process was continued until the death of the parent adults occurred. After the death of the adults a period equal to the length of incubation of the eggs was allowed to elapse before the final count for the last nymphs to appear was made. Four separate experiments were started May 27 with copulating pairs of adults. Removal of nymphs took place as shown in Table II.

TABLE II.—*Number of nymphs produced by a female grape leafhopper in confinement.*

1912.	Nymphs removed.
CAGE NO. I.	
July 11	34
July 17	33
July 25	36
Total	103
CAGE NO. II.	
July 11	49
July 17	49
July 25	33
Aug. 1	8
Total	139
CAGE NO. III.	
July 10	[1] 4
July 11	56
July 17	34
July 25	18
Aug. 1	1
Total	113
CAGE NO. IV.	
July 11	34
July 17	33
July 25	36
Aug. 1	9
Aug. 2	2
Total	114

[1] Four newly molted adults.

Several additional experiments were conducted in the same manner to determine the number of eggs per female. In each case several copulating pairs of leafhoppers were placed in each cage.

TABLE III.—*Experiment to determine extent of reproduction from four pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 19, 1912.*

1912.	Nymphs removed.
July 27	154
July 30	159
Aug. 22	8
Aug. 27	30
Aug. 29	159
Total	510
Average	127.5

TABLE IV.—*Experiment to determine extent of reproduction from nine pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 18, 1912.*

1912.	Nymphs removed.
July 24	230
July 31	423
Aug. 12	172
Aug. 22	131
Aug. 29	65
Sept. 4	14
Total	1,035
Average	115

TABLE V.—*Experiment to determine extent of reproduction from four pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 19, 1912.*

1912.	Nymphs removed.
July 24	185
Aug. 9	153
Aug. 23	58
Sept. 6	52
Total	448
Average	112

These experiments show that for 20 females the number of nymphs found ranged from 112 to 139 per female. This method of determining the egg-laying capacity of the females did not, of course, take into consideration the number of eggs that failed to hatch, or the number of fatalities which may have occurred among the nymphs after the hatching period, but the fact that the average number of nymphs reared from each of 15 females varied only from 112 to 115 would indicate that under favorable conditions a female may deposit over a hundred eggs, while the 139 nymphs obtained in cage 2 would indicate that under the most favorable conditions some females may deposit about 140 eggs.

Fig. 1.—Cages Used for Rearing the Grape Leafhopper, at Laboratory, North East, Pa., 1912. (Original.)

Fig. 2.—Steam-Engine Power Sprayer Used in Spraying Against the Grape Leafhopper, North East, Pa., 1912. (Original.)

THE GRAPE LEAFHOPPER.

HATCHING OF FIRST-BROOD NYMPHS.

After the finding of eggs in the tissue of the leaves on June 10, daily examinations of infested grape foliage were made both in badly infested vineyards and on vines at the laboratory. On June 18 three nymphs were found on the badly infested foliage of a Delaware grapevine. These nymphs were probably about a day or two old, since they were slightly larger than newly hatched nymphs. They had taken on a yellowish color, which indicated that some time had been spent in feeding, for the newly hatched nymphs before having taken any food are white.

On June 20 a number of newly hatched nymphs were found on Concord vines. After June 20 the hatching of the nymphs became general. By June 26 large numbers of them could be found in all badly infested vineyards in the vicinity of North East, Pa.

The process of hatching was observed in several instances and occupies a period varying from 10 to 25 minutes.

The hatching nymph appears as a small white object projecting through the pubescence on the underside of the leaf. At first its movement is almost imperceptible. Then, after three or four minutes, there is a swaying circular movement of the free end of this white object, each succeeding movement becoming more vigorous. After four or five minutes of this rapid motion the object commences to assume a definite form. The ends of the antennæ are freed, the eyes become prominent, and the stricture dividing the thorax from the abdomen may be distinguished. In a few minutes more the proboscis and the legs may be seen moving, then the circulation of the body fluids becomes visible through the transparent skin, and finally the feet clutch the hairy pubescence of the leaf and the tiny insect draws its abdomen free of the eggshell. By this time the body has dried, and the nymph runs with a rather unsteady gait over the underside of the leaf. Usually, however, its first excursion is a very short one, for it soon settles down, inserts its minute proboscis into the leaf tissue, and makes its first meal on the juices of its host plant.

APPEARANCE OF FIRST-BROOD ADULTS.

During the season of 1912 the first evidence of the appearance of a new brood of adults occurred on July 12, when examinations of nymphs in vineyards about North East, Pa., showed that at this date an occasional nymph was making the last nymphal molt and developing wings. However, winged adults of this new brood were not common in vineyards until from July 16 to 20, and even at the latter date they did not represent more than 25 per cent of the total number of the new brood upon the foliage. In order to secure some of these earliest transforming adults for the purpose of rearing a second summer brood, about 150 of the oldest nymphs that could be found were placed on the foliage of a young Concord grapevine on July 12. On July 13 several of these nymphs had transformed to adults. On July 16 about 75 per cent of them had developed wings.

MATING OF FIRST-BROOD ADULTS.

On July 22 numerous pairs of adults of the new brood were found copulating on the underside of grape leaves in the vineyards surrounding North East, Pa. From July 23 to 27 copulating pairs of new-brood adults were common, both in the vineyards and in cages at the laboratory. After the latter date only occasional mating pairs of adults were observed, either in the rearing cages at the laboratory or in the open vineyards, although observations along this line were continued during the remainder of the active season.

NUMBER OF EGGS DEPOSITED BY A FEMALE OF THE FIRST BROOD.

On July 26 three copulating pairs of the new-brood adults were placed in separate cages on a Concord grapevine inclosed in an arc-light globe cage similar to those in which pairs of overwintering adults had been confined, the object being to ascertain the number of nymphs that could be reared from them in order to see how it compared with the number produced by overwintering females. The number of nymphs reared from these first-brood females is shown in Table VI.

TABLE VI.—*Number of nymphs produced by a female leafhopper of the first brood.*

Date examined (1912).	Nymphs removed.
CAGE NO. I.	
Sept. 4	12
Sept. 7	5
Sept. 11	7
Sept. 14	9
Total	33
CAGE NO. II.	
Sept. 3	24
Sept. 5	16
Sept. 9	17
Sept. 11	9
Sept. 15	13
Total	79
CAGE NO. III.	
Sept. 4	37
Sept. 7	35
Sept. 11	9
Total	81

In the case of these three females of the first brood, the average number of nymphs produced by a single female was only a little more than half the number produced by the overwintering females under similar conditions.

TERMINATION OF OVIPOSITION OF ADULTS OF THE FIRST BROOD.

First-brood adults placed in cages with grapevines after August 10 gave no evidence of further reproduction, for nymphs failed to appear on the foliage. About 50 adults were placed in each of five separate cages on August 12, 15, 20, and 27, and September 9. No nymphs appeared in any of these cages, indicating that the season of egg deposition for them, at least, had closed.

Since there is a long period over which the nymphs of this first brood transform to adults, an endeavor was made to determine the date at which these later transforming adults would fail to reproduce during the same season. With this end in view, on July 24, 1912, 100 nymphs of each of the five nymphal stages were placed in five separate cages on the foliage of a small Concord grapevine in order to ascertain if the adults transforming from any or from all of the nymphs in these five cages would copulate and produce another brood of nymphs. Frequent examinations were made of all of these cages during the remainder of the season. All of the nymphs in the five cages transformed to adults, but no mating of the adults was observed nor did any nymphs of a new brood appear upon the foliage of the vines in the cages.

On the other hand, in another cage in which 50 adults were placed on July 22, to determine to what extent and how late in the season they continued to reproduce, nymphs continued to hatch as late as September 15. Below is given the daily hatching record of nymphs from these 50 adults:

TABLE VII.—*Hatching record of nymphs from 50 adult grape leafhoppers placed in confinement July 22, 1912.*

Date.	Number of nymphs removed.	Date.	Number of nymphs removed.	Date.	Number of nymphs removed.	Date.	Number of nymphs removed.
1912.		1912.		1912.		1912.	
Aug. 12	38	Aug. 22	143	Aug. 31	52	Sept. 9	25
Aug. 13	132	Aug. 23	76	Sept. 1	96	Sept. 10	13
Aug. 14	172	Aug. 24	83	Sept. 2	108	Sept. 11	8
Aug. 15	245	Aug. 25	50	Sept. 3	115	Sept. 12	6
Aug. 16	173	Aug. 26	137	Sept. 4	95	Sept. 13	4
Aug. 17	139	Aug. 27	108	Sept. 5	89	Sept. 14	2
Aug. 19	272	Aug. 28	5	Sept. 6	48	Sept. 15	6
Aug. 20	250	Aug. 29	73	Sept. 7	49		
Aug. 21	131	Aug. 30	47	Sept. 8	24		

LONGEVITY OF OVERWINTERING ADULTS.

An effort was made to determine the length of life of overwintering adults. Owing to the great activity of the adult leafhoppers it was found to be exceedingly difficult to keep a record of each individual. In order to secure some data on this point 100 overwintering adults were placed on a small Concord vine inclosed in an arc-light globe cage on May 31. A black cloth was stretched over the surface of the ground so that the dead adults falling from the foliage of the vine might be more easily seen. An examination for dead adults was made every few days by looking for them upon the black cloth. No dead adults were observed to July 12. On July 12 the adults were transferred to a new cage to avoid confusing them with newly transforming adults. During this operation 18 adults either escaped or were killed. In this new cage 82 adults were placed. Dead adults were found in the cage on the dates shown in Table VIII.

TABLE VIII.—*Longevity of overwintering adults of the grape leafhopper.*

Date of examination.	Number dead.	Date of examination.	Number dead.
1912.		1912.	
July 17	1	Aug. 12	3
July 28	3	Aug. 17	2
Aug. 2	2	Aug. 23	4
Aug. 3	[1] 5	Aug. 27	3
Aug. 5	[2] 2	Aug. 30	5
Aug. 7	[3] 3		

[1] Escaped. [2] Killed. [3] Killed by spider.

On August 30 these adults were again transferred to a new cage to avoid their being confused with newly transforming adults. During this transfer 10 adults were either killed or escaped. In the new cage there were 39 adults. The number of dead adults found in this cage is given in Table IX.

TABLE IX.—*Longevity of overwintering adults of the grape leafhopper.*

Date of examination.	Number dead.	Date of examination.	Number dead.
1912.		1912.	
Sept. 4	4	Sept. 20	3
Sept. 7	3	Sept. 26	7
Sept. 12	1	Oct. 2	6
Sept. 14	6		

The last examination was made on October 2, when there were four adults still living. Hence it is evident that some of the overwintering adults may remain on the vines during the entire growing season. Yet in vineyards that were the object of frequent visits during the seasons of 1911 and 1912 it was observed that there was a period, about the middle of the summer each season, when a decrease in the number of hibernating adults was quite noticeable. During the season of 1911 this period of apparent decrease of overwintering adults was about June 25. In 1912 it was about July 15. In both instances this decrease in number of adults occurred about two weeks before the transformation of the new brood in large numbers to adults.

EXPERIMENTS TO REAR A THIRD BROOD OF NYMPHS.

Rearing experiments were also conducted to determine if the adults which transformed from the earliest hatching nymphs of the season would produce a second summer brood of nymphs and also if the adults transforming from these second-brood nymphs would mate and produce a third brood of nymphs.

On July 2, 100 newly hatched nymphs, the product of overwintering adults, were placed on the foliage of a Delaware grapevine inclosed in an arc-light globe cage. By July 28 a few of these nymphs had transformed to adults. By August 14 all of these first-brood nymphs had transformed to adults. On August 26 several nymphs of the second summer brood in the first two nymphal stages were found upon the foliage of the vine. On August 29 all of the adults of the first brood were removed from this cage in order that there might be no confusion with adults transforming from the second-brood nymphs. On September 12 newly transformed adults of the second brood were found in this cage. On September 27 nearly all the nymphs had transformed to adults. The few remaining nymphs were in the last nymphal stage. By October 7 all nymphs had transformed to adults. Frequent observations were made after the appearance of the second brood of adults in this cage, but no mating was observed nor did any new nymphs appear on the foliage of the vine. Hence it would appear that reproduction did not occur among the adults of the second brood during the season of 1912. A similar rearing experiment was made on July 3 by taking 75 of the earliest nymphs to hatch and placing them on a grapevine inclosed in an arc-light globe cage. By July 16 nearly all of the nymphs had transformed to first-brood adults. On August 15 new nymphs of the second brood were present. On August 28 all first-brood adults were removed from the cage. All of the nymphs transformed to second-brood adults. Although frequent examinations were made of this cage for the remainder of the season, there was no evidence of reproduction by these adults of the second brood.

In another rearing experiment the date of transformation of adults of the second brood was secured. The rearings were made by taking nymphs of the first brood that were among the earliest of the season to hatch. They were nearing the last molt when they were placed on a Concord vine in a Riley cage on July 13. By July 16 nearly all of these nymphs had transformed to adults. On July 26 several pairs were observed mating. On August 17 a few nymphs of the second brood in the first and second stages were observed on the grape foliage. On August 28 all adults of the first brood were removed from this cage to avoid confusion with newly transforming adults of the second brood. A record of the dates of transformation of adults of the second brood is given in Table X.

TABLE X.—*Transformation to adults of second-brood grape leafhoppers.*

Date of examination.	Number of adults transformed.	Date of examination.	Number of adults transformed.
1912.		1912.	
Sept. 7	1	Sept. 14	85
Sept. 8	4	Sept. 15	63
Sept. 9	0	Sept. 17	16
Sept. 10	37	Sept. 19	26
Sept. 11	76	Sept. 20	5
Sept. 12	51	Sept. 21	11
Sept. 13	51	Sept. 24	3

The last of the nymphs transformed to adults on September 24. This rearing experiment indicates that the transformation of the second-brood adults which were the progeny of the earliest nymphs of the season to appear upon the vines was much too late in the season for the production of a third brood of nymphs.

REARING EXPERIMENTS TO DETERMINE LENGTH OF NYMPHAL STAGES.

A series of rearing experiments was made to determine the length of the nymphal stages. The newly hatched nymph was placed in a cage made as follows: A hole about an inch in diameter was punched out of the center of a piece of velvet about 2 inches square. The velvet was then placed, nap side against the leaf, on the underside of an uninfested leaf. A square of heavy manila paper of the same size was placed on the upper side of the leaf directly above the square of velvet, to hold the leaf rigid. The newly hatched nymph was then placed on the underside of the leaf in the circular space cut out of the square of velvet. A small watch glass, convex side up, was placed over the circular hole in the velvet so as to overlap about one-fourth of an inch onto the velvet. Then the watch glass, the velvet, the portion of grape leaf, and the square paper were all held tightly together by means of four paper clips, by slipping on one of the clips from each side of the square, making them clasp the paper and the velvet and overlap on to the watch glass and hold the latter firmly in place so that the nymph could not escape. In some instances squares of thin sheets of celluloid were used in place of the watch glasses, but it was found that the small nymphs would sometimes drown in the moisture collecting on the inside of the celluloid. Then, too, the concave of the watch glass made the space larger. Even with the watch glasses, drowning of the nymphs was likely to occur. In order to prevent this, two squares of velvet were glued together with the nap side out. This raised the watch glass a greater distance from the leaf, giving more space between the back of the nymph and the glass, and less drowning of nymphs resulted. Each cage was examined daily; thus the condition of the nymph was observed and record made of the date of each molt. During this operation the moisture was wiped from the inside of the watch glass.

The period covered by these rearing experiments was from June 22 to October 13. During this time 348 newly hatched nymphs were placed on grape leaves confined in cages similar to those just described. Many of the nymphs either died or escaped before they completed all of the nymphal stages. Nevertheless, complete records of the length of the five stages were secured for 114 nymphs. The greater number of fatalities occurred among the young nymphs during the early part of the rearing season before the leaf cage most suitable for the purpose was secured. After the double thickness of velvet was adopted fewer fatalities occurred.

The lengths of the several stages for the different individuals show a great variation, but it will be noted by an examination of Table XI that the variation of the total length of the five stages for a number of nymphs hatching on the same date is not very great. Changes in temperature appear to be the important factor in determining the length of time required to complete the entire nymphal period.

In the last column of Table XI the average daily temperature for the entire nymphal period of each of the 114 nymphs is given. These average temperatures are computed from the average daily temperatures given in Table XII. The average daily temperatures given in Table XII are derived from daily readings of a maximum and minimum thermometer, located in the garden of the laboratory at North East, Pa., only a few yards distant from the grapevines bearing the individual cages in which the nymphs were reared.

Table XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912.*

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
June 22	June 28	6	June 30	2	July 4	4	July 7	3	July 11	4	19	74.90
July 5	July 9	4	July 10	1	July 13	3	July 16	3	July 25	9	20	76.60
July 9	July 12	3	July 15	3	July 20	5	July 25	5	Aug. 8	14	30	69.97
Do...	July 15	6	July 18	3	...do.....	2	...do.....	5	Aug. 7	13	29	70.10
Do...	...do.....	6	July 17	2	July 21	4	July 28	7	Aug. 8	11	30	69.97
Do...	July 12	3	July 15	3	July 20	5	Aug. 2	13	Aug. 12	10	34	70.04
Do...	July 13	4	July 16	3	July 21	5	July 27	6	Aug. 9	13	31	70.03
Do...	...do.....	4	July 17	4	July 19	2	July 25	6	Aug. 7	13	29	70.01
Do...	...do.....	4	...do.....	4	July 21	4	July 28	7	Aug. 10	13	32	70.11
Do...	...do.....	4	...do.....	4	July 19	2	...do.....	9	Aug. 9	12	31	70.03
Do...	...do.....	4	...do.....	4	...do.....	2	...do.....	9	...do....	12	31	70.03
Do...	July 12	3	July 15	3	...do.....	4	July 25	6	Aug. 8	14	30	69.97
Do...	July 13	4	July 17	4	July 21	4	July 27	6	...do.....	12	30	69.97
Do...	July 14	5	July 18	4	July 23	5	July 29	6	Aug. 10	12	32	70.12
Do...	July 13	4	July 16	3	July 21	5	July 28	7	Aug. 9	12	31	70.03

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912*—Continued.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
July 10	July 14	4	July 18	4	July 23	5	July 30	7	Aug. 11	12	32	69.81
Do...	...do.....	4	July 17	3	July 19	2	July 25	6	Aug. 14	20	35	69.86
July 11	July 15	4	July 19	4	July 24	5	July 30	6	Aug. 12	13	32	69.58
Do...	...do.....	4	...do.....	4	...do.....	5	...do.....	6	...do.....	13	32	69.58
Do...	July 16	5	...do.....	3	July 25	6	Aug. 2	8	Aug. 13	11	33	69.69
Do...	July 15	4	...do.....	4	...do.....	6	Aug. 1	7	Aug. 12	11	32	69.58
Do...	...do.....	4	...do.....	4	...do.....	6	Aug. 3	9	Aug. 13	10	33	69.69
Do...	July 14	3	July 18	4	July 23	5	July 30	7	Aug. 10	11	30	69.62
July 12	July 17	5	July 20	3	July 26	6	Aug. 4	9	Aug. 13	9	32	69.75
Do...	July 16	4	July 21	5	...do.....	5	July 30	4	Aug. 15	16	34	69.32
Do...	July 17	5	...do.....	4	July 30	9	Aug. 7	8	Aug. 14	7	33	69.42
July 13	July 19	6	July 23	4	July 29	6	...do....	9	Aug. 15	8	33	67.14
Do...	July 17	4	July 21	4	July 26	5	Aug. 2	7	Aug. 12	10	30	69.08
Do...	July 19	6	July 23	4	July 29	6	Aug. 7	9	Aug. 15	8	33	69.10
July 14	...do.....	5	July 25	6	July 30	5	Aug. 9	10	Aug. 17	8	34	68.75
Do...	July 21	7	July 27	6	Aug. 4	8	Aug. 10	6	Aug. 19	9	36	68.63
Do...	July 19	5	July 25	6	Aug. 1	7	...do....	9	...do....	10	37	66.77
July 15	July 22	7	...do....	3	Aug. 5	11	Aug. 11	6	Aug. 21	10	37	68.36
Do...	July 21	6	...do....	4	Aug. 2	8	Aug. 10	8	Aug. 19	9	35	68.34
Do...	July 20	5	July 26	6	...do....	7	...do....	8	...do....	9	35	68.34
July 18	July 25	7	Aug. 2	8	Aug. 8	6	Aug. 14	6	Aug. 22	8	35	67.67
Do...	...do....	7	July 29	4	Aug. 6	8	Aug. 11	5	Aug. 20	9	33	67.79
Do...	Aug. 2	15	Aug. 7	5	Aug. 9	2	Aug. 15	6	Aug. 24	9	37	67.71
Do...	July 25	7	July 30	5	Aug. 8	9	Aug. 13	5	Aug. 22	9	35	67.84
July 19	July 29	10	Aug. 6	8	Aug. 11	5	Aug. 15	4	Aug. 25	10	37	67.92
Do...	July 24	5	July 27	3	Aug. 3	7	Aug. 9	6	Aug. 15	6	27	68.77
Do...	July 27	8	Aug. 3	7	Aug. 9	6	Aug. 15	6	Aug. 23	8	35	67.84
Do...	July 26	7	...do....	8	...do....	6	...do....	6	Aug. 24	9	36	67.71
Do...	July 25	6	...do....	9	...do....	6	Aug. 14	5	Aug. 23	9	35	67.84
Do...	July 28	9	Aug. 6	8	Aug. 12	6	Aug. 15	3	Aug. 25	10	36	69.81
July 20	July 27	7	July 29	2	Aug. 3	5	Aug. 9	6	Aug. 23	14	34	67.79
Do...	July 26	6	Aug. 3	8	Aug. 9	6	Aug. 14	5	Aug. 24	10	35	67.66
July 29	Aug. 8	10	Aug. 11	3	Aug. 15	4	Aug. 21	6	Aug. 31	10	33	67.53
Do...	Aug. 7	9	...do....	4	Aug. 17	6	Aug. 22	5	Sept. 1	10	34	67.73
Do...	Aug. 5	7	Aug. 10	5	Aug. 14	4	Aug. 21	7	Aug. 29	8	31	69.03
Do...	Aug. 7	9	Aug. 11	4	Aug. 15	4	...do....	6	Aug. 30	9	32	67.84
Do...	Aug. 8	10	Aug. 12	4	Aug. 16	4	Aug. 22	6	Sept. 1	10	34	67.73
Do...	Aug. 6	8	Aug. 11	5	...do....	5	...do....	6	...do....	10	34	67.73
July 30	Aug. 11	12	Aug. 14	3	Aug. 20	6	Aug. 25	5	Sept. 3	9	35	68.16
Do...	Aug. 7	8	Aug. 11	4	Aug. 15	4	Aug. 21	6	Aug. 30	9	31	67.68
Do...	Aug. 9	10	Aug. 14	5	Aug. 19	5	Aug. 25	6	Sept. 2	8	34	67.95
Do...	...do....	10	Aug. 12	3	Aug. 17	5	Aug. 22	5	Sept. 1	10	33	67.68
Aug. 5	Aug. 11	6	Aug. 15	4	Aug. 20	5	Aug. 25	5	Sept. 5	11	31	69.95
Do...	...do....	6	...do....	4	...do....	5	...do....	5	Sept. 3	9	29	68.55
Aug. 13	Aug. 19	6	Aug. 23	4	Aug. 27	4	Sept. 2	6	Sept. 8	6	26	71.52
Do...	Aug. 18	5	...do....	5	...do....	4	Aug. 29	2	Sept. 9	11	27	71.41
Do...	Aug. 21	8	...do....	2	Aug. 29	6	Sept. 3	5	Sept. 10	7	28	71.55
Do...	Aug. 18	5	Aug. 22	4	Aug. 26	4	Sept. 2	7	Sept. 8	6	26	71.52
Aug. 14	Aug. 20	6	Aug. 25	5	Aug. 31	6	Sept. 4	4	Sept. 11	7	28	71.75
Do...	Aug. 19	5	Aug. 24	5	Aug. 28	4	Sept. 3	6	Sept. 9	6	26	71.33
Do...	Aug. 20	6	...do....	4	Aug. 29	5	Sept. 5	7	Sept. 10	6	27	71.48
Do...	...do....	6	...do....	4	Aug. 28	4	Sept. 4	7	Sept. 11	7	28	71.75
Do...	...do....	6	...do....	4	...do....	4	Sept. 3	6	Sept. 9	5	26	71.33
Do...	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 2	6	Sept. 8	6	25	71.44
Do...	Aug. 20	6	Aug. 24	4	Aug. 29	5	Sept. 3	5	Sept. 9	6	26	71.33
Do...	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 2	6	...do....	7	26	71.33
Do...	Aug. 20	6	Aug. 25	5	Aug. 29	4	Sept. 3	5	...do....	6	26	71.33
Do...	...do....	6	Aug. 26	6	Sept. 2	7	Sept. 6	4	Sept. 14	8	31	71.24
Do...	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 3	7	Sept. 9	6	26	71.33
Do...	Aug. 24	10	Aug. 29	5	Sept. 2	4	...do....	1	Sept. 10	7	27	71.48

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912*—Continued.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
Do...	Aug. 20	6	Aug. 25	5	Sept. 1	7	Sept. 4	3	Sept. 10	6	27	71.48
Do...	...do....	6	Aug. 24	4	Aug. 29	5	Sept. 3	5	Sept. 9	6	26	71.33
Do...	...do....	6	Aug. 25	5	Sept. 1	7	...do....	2	Sept. 10	7	27	71.48
Do...	...do....	6	Aug. 24	4	Aug. 27	3	Sept. 2	6	Sept. 9	7	26	71.33
Aug. 15	Aug. 23	8	Aug. 26	3	Aug. 31	5	Sept. 4	4	Sept. 10	6	26	71.57
Do...	Aug. 21	6	...do....	5	...do....	5	...do....	4	...do....	6	26	71.57
Do...	...do....	6	...do....	5	Aug. 30	4	...do....	5	...do....	6	26	71.57
Do...	...do....	6	...do....	5	Aug. 31	5	...do....	4	...do....	6	26	71.57
Do...	...do....	6	Aug. 25	4	Aug. 30	5	...do....	5	Sept. 9	5	25	71.42
Do...	...do....	6	...do....	4	...do....	5	Sept. 2	3	Sept. 10	8	26	71.57
Aug. 16	...do....	5	...do....	4	...do....	5	Sept. 3	4	...do....	7	25	71.80
Do...	...do....	5	...do....	4	Aug. 31	6	Sept. 4	4	...do....	6	25	71.80
Aug. 17	...do....	4	Aug. 26	5	Sept. 1	6	...do....	3	Sept. 11	7	25	72.40
Do...	Aug. 22	5	...do....	4	Sept. 2	7	Sept. 5	3	...do....	6	25	72.40
Do...	...do....	5	...do....	4	Sept. 1	6	...do....	4	...do....	6	25	72.40
Do...	...do....	5	Aug. 27	5	...do....	5	...do....	4	...do....	6	25	72.40
Aug. 20	Aug. 25	5	Aug. 30	5	Sept. 3	4	Sept. 6	3	Sept. 13	7	24	76.58
Do...	Aug. 24	4	Aug. 27	3	Sept. 2	6	Sept. 5	3	Sept. 11	6	22	73.20
Aug. 21	Aug. 25	4	Aug. 30	5	Sept. 3	4	Sept. 6	3	Sept. 12	6	22	72.95
Do...	...do....	4	Aug. 29	4	Sept. 2	4	...do....	4	Sept. 13	7	23	72.65
Do...	Aug. 26	5	Sept. 1	6	Sept. 4	3	Sept. 7	3	Sept. 14	7	24	72.66
Do...	Aug. 25	4	Aug. 29	4	Sept. 2	4	Sept. 6	4	Sept. 12	6	22	73.18
Do...	Aug. 26	5	Sept. 1	6	Sept. 4	3	Sept. 7	3	Sept. 14	7	24	72.66
Do...	Aug. 25	4	Aug. 31	6	Sept. 3	3	Sept. 6	3	Sept. 13	7	23	72.65
Do...	Aug. 26	5	...do....	5	...do....	3	Sept. 7	4	Sept. 15	8	25	72.74
Aug. 22	Aug. 27	5	Sept. 2	6	Sept. 5	3	Sept. 8	3	...do....	7	24	72.83
Do...	Aug. 26	4	Aug. 31	5	Sept. 3	3	Sept. 7	4	Sept. 14	7	23	72.78
Do...	...do....	4	Sept. 1	6	Sept. 4	3	...do....	3	Sept. 15	8	24	72.83
Do...	...do....	4	...do....	5	...do....	3	...do....	3	Sept. 14	7	25	72.78
Aug. 30	Sept. 3	4	Sept. 7	4	Sept. 9	2	Sept. 13	4	Sept. 22	9	23	72.50
Sept. 4	Sept. 7	3	Sept. 14	7	Sept. 15	1	Sept. 22	7	Oct. 6	14	32	65.01
Do...	...do....	3	Sept. 12	5	...do....	3	Sept. 23	8	Oct. 8	15	34	64.41
Do...	...do....	3	Sept. 11	4	Sept. 14	3	Sept. 20	6	Oct. 6	16	32	65.01
Sept. 6	Sept. 10	4	Sept. 14	4	Sept. 19	5	Sept. 25	6	Oct. 12	17	36	63.64
Do...	...do....	4	...do....	4	Sept. 18	4	...do....	7	...do....	17	36	63.64
Do...	...do....	4	...do....	4	Sept. 19	5	...do....	6	...do....	17	36	63.64
Do...	...do....	4	...do....	4	...do....	5	Sept. 24	5	Oct. 10	16	34	63.53
Do...	...do....	4	Sept. 13	3	Sept. 18	5	Sept. 25	7	Oct. 13	18	37	63.32
Do...	...do....	4	Sept. 14	4	...do....	4	...do....	7	...do....	18	37	63.32

TABLE XII.—*Maximum, minimum, and average temperatures taken at the field laboratory, North East, Pa., from June 1 to October 31, inclusive.*

Day of the month.	June.			July.			August.			September.			October.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1	70	50	60.0	72	53	62.5	66	52	59.0	84	65	74.5	57	49	53.0
2	78	64	71.0	75	58	66.5	69	53	61.0	86	68	77.0	64	45	54.5
3	77	59	68.0	82	68	75.0	63	64	63.5	81	69	75.0	70	54	62.0
4	76	60	67.5	83	68	75.5	65	49	57.0	79	69	74.0	67	56	61.5
5	69	44	56.5	84	68	76.0	65	54	59.5	87	68	77.5	70	51	60.5
6	67	54	60.5	84	70	77.0	70	50	60.0	84	69	76.5	77	54	65.5
7	68	46	57.0	92	72	82.0	71	55	63.0	86	70	78.0	69	49	59.0
8	59	38	48.5	87	71	79.0	78	54	66.0	77	56	66.5	58	43	50.5
9	66	45	55.5	85	73	79.0	78	66	72.0	77	62	68.5	71	51	61.0
10	65	58	61.5	80	72	76.0	78	67	72.5	83	68	75.5	67	56	61.5
11	70	55	62.5	87	69	78.0	76	63	69.5	89	69	79.0	73	50	66.0
12	78	60	69.0	85	66	75.5	76	61	68.5	74	58	66.0	74	54	64.0
13	68	49	58.5	82	65	73.5	80	67	73.5	76	54	60.5	59	46	52.5
14	61	48	54.5	87	69	78.0	79	59	69.0	78	68	73.0	59	45	52.0
15	78	60	69.0	83	73	78.0	69	63	66.0	80	69	74.5	55	44	49.5
16	72	57	64.5	92	61	76.5	72	56	64.0	82	60	71.0	55	39	47.0
17	77	57	67.0	74	63	68.5	67	53	59.5	62	49	55.5	63	46	54.5
18	69	50	59.5	77	63	70.0	69	64	66.5	69	59	64.0	71	56	63.5
19	65	48	56.5	82	57	69.5	78	67	72.5	73	60	66.5	63	52	57.5
20	64	57	60.5	65	52	58.5	71	63	67.0	69	54	61.5	54	45	49.5
21	71	57	64.0	75	63	69.0	75	65	70.0	68	57	62.5	71	48	59.5
22	67	59	63.0	77	63	70.0	76	60	68.0	79	63	72.0	65	56	60.5
23	69	49	49.0	73	54	63.5	75	65	70.0	77	56	66.5	56	43	49.5
24	70	50	60.0	72	60	66.0	69	57	63.0	62	55	58.5	44	41	42.5
25	74	65	69.5	70	68	69.0	80	71	75.5	69	61	65.0	48	44	46.0
26	80	61	70.5	75	61	68.0	82	66	74.0	78	61	68.5	54	44	49.0
27	78	58	68.0	75	52	63.5	82	58	70.0	64	47	55.5	56	41	48.5
28	82	67	74.5	70	57	63.5	62	52	57.0	56	43	48.5	60	47	53.5
29	77	64	70.5	75	64	69.5	59	54	56.5	63	47	55.0	70	55	62.5
30	83	59	71.0	73	57	65.0	67	48	57.5	51	36	43.5	63	64	54.5
31	......	......	......	72	52	62.0	63	59	61.0	......	......	......	54	44	49.0

SUMMARY OF SEASONAL HISTORY OF THE GRAPE LEAFHOPPER.

The grape leafhopper (see fig. 1, p. 1) hibernates as an adult among accumulations of leaves and trash in vineyards, but mostly in adjoining woodlands, hedgerows, and pastures. It becomes active during the first warm days of spring and commences feeding on the new growth of almost any of the plants with which it comes in contact. With the unfolding of the grape leaves there is a general migration of the insect to the vineyards. In normal seasons this takes place about the middle of May in the vineyards of the Lake Erie Valley. After feeding for a few days the leafhoppers mate, and oviposition commences early in June. The eggs are deposited singly and are tucked under the epidermis beneath the pubescence of the underside of the grape leaf. The average length of the egg stage is from 11 to 15 days. The nymphs commence to appear on the underside of the leaves about the 20th of June, and by the end of the first week in July a large percentage of the first brood has hatched and is present in one of the several nymphal stages, of which there are five. (See Pl. I.) The average length of the nymphal period is about 28 days, but with many it varies from 20 to 35 days. At the last nymphal molt the adults have fully developed wings. A few newly transformed adults may be found in vineyards from about July 7 to July 12.

In normal seasons, however, the majority of the first-brood adults appear after the middle of July. Observations of the development of the insect indicate that if the nymphal period is lengthened by low temperatures during the month of July, the number of adults of the new brood that will mate and deposit eggs for a second brood is quite small; whereas, if high temperatures prevail during the early part of July, a large number of the nymphs are likely to develop rapidly and make their transformation about the middle of July. These early maturing adults mate and deposit eggs, and the resulting second brood of nymphs is quite large.

Mating of the first-brood adults appears to be common for only a few days. In 1912 few mating pairs were seen except during the period from July 23 to July 27.

Early in August the color markings on the elytra of the adults change from light yellow to a pale salmon color, which becomes more intense as the season advances. After the appearance of this change in coloration of the elytral markings little oviposition occurs.

By the early part of September most of the nymphs of both the first and second broods have transformed to adults, although a small number of nymphs may be found on the foliage until quite late in the fall. Toward the middle and latter part of September the adults commence to migrate from the vineyards and during warm, calm afternoons may be seen in swarms drifting through the air in an apparently aimless manner. They usually come to rest in adjoining woodlands or rough pasture lands. Here they remain more or less active during the warmer parts of the days of October and the late fall, seeking the shelter of leaves and trash at night and during the cooler days, and becoming less active as the cold weather of winter approaches.

REARING CAGES USED.

Since the adult grape leafhoppers are very agile creatures it was impossible to study their habits and life history in detail on the large fruiting vines in the open vineyard. Yet in order that the adults might oviposit and the eggs develop normally, it was necessary that the insects studied should be confined on healthy growing grape foliage. For this purpose a large number of young grapevines, including several varieties, were planted in the garden of the laboratory early in the spring of 1912. The vines were planted in rows about 3 feet apart. Those vines used for securing egg records, longevity of overwintering adults, number of eggs deposited per female, length of nymphal stages, etc., were covered with a cage early in the season so as to prevent the foliage from becoming infested by other adults.

Since it was impossible to secure enough Riley cages, or to have cages made that were sufficiently tight to prevent the escape of the adults, recourse was taken to the use of a number of second-hand arc-light globes, which were secured from the local lighting plant. These were about 15 inches high, with a small opening about 4 inches in diameter and a large opening about 8 inches in diameter. The globe was placed over the vine with the lower opening resting on the ground, and the larger opening was covered with a piece of muslin fastened to a stout wire ring. This cover was drawn tightly over the large opening by means of four cords fastened to the wire ring and connected to four pegs driven into the ground and tightened in the same manner as are the cords of a tent. In this way it was possible to draw the muslin perfectly tight all around the edge of the upper opening of the globe. The insects were examined during the cooler part of the day when they were least active. It was found that when the lower opening was set into the ground, the temperature inside of the cage was several degrees higher than that on the outside, owing to a lack of circulation of air inside the cage. This was overcome by taking a strip of fine wire screen about 4 inches wide and forming it into a collar a little larger than the smaller opening of the globe. This collar was then slipped over the young grapevine and pressed firmly into the soil. The globe was then placed over the vine and the small opening fitted into the wire screen collar, thus securing an air current into the bottom of the cage up through the muslin cover or vice versa. The muslin cover was then made large enough to shade the greater part of the globe. These modifications resulted in securing a cage that was light and tight, and that had a temperature about the same as that on the outside.

The cage that has just been described (see Pl. II, fig. 1) is spoken of as an "arc-light globe cage" in connection with the rearing experiments mentioned under seasonal history.

A smaller cage, employed for rearing single nymphs for the purpose of recording the length of the stages of individuals, is fully described on page 26 under another caption dealing with experiments to determine the length of the nymphal stages.

PARASITES AND PREDACEOUS ENEMIES.

Apparently the grape leafhopper suffers little from the attack of parasitic enemies. No records of parasites have been found in the literature dealing with this pest. During the investigations on grape insect pests conducted at North East, Pa., from 1907 to 1912, only one instance of parasitism was noted. In this instance, on July 31, 1907, Mr. P. R. Jones, of the Bureau of Entomology, observed the female of *Aphelopus* sp. in the act of thrusting her ovipositor into the body of a nymph. No attempt was made to determine if eggs were deposited in the body of this nymph, nor was any further evidence of parasitism of the nymphs or the adults of the grape leafhopper observed.[1]

On the other hand, the nymphs seem to be especially subject to the attack of many predaceous insects, mites, and spiders, while the adults become entangled in spider webs and are preyed upon by the occupants.

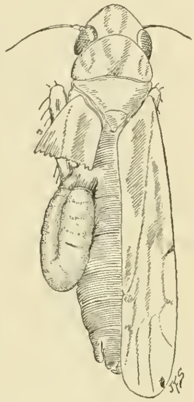


FIG. 13.—Adult grape leafhopper parasitized by a dryinid, and showing cocoon of parasite protruding from abdomen, at left. Greatly enlarged. (Original.)

The literature on the grape leafhopper contains the following records of attack by predaceous enemies on either the nymphs or the adults:

B. D. Walsh, in 1862, records *Hemerodromia superstitiosa* Say, one of the dance flies, as feeding on the "hoppers" in Illinois.

Townend Glover, in 1875, records *Hyaliodes vitripennis* Say, the glassy-winged soldier-bug, as feeding on the nymphs.

M. V. Slingerland, in 1902, records a mite, *Rhyncholophus parvulus* Banks, the larvæ of Chrysopa, and aphis lions as feeding on the nymphs.

J. H. Quayle, in 1908, records the destruction of the nymphs by the beetles and larvæ of ladybirds, aphis lions, and ants, but states that all of these predaceous enemies put together have little apparent influence in lessening the number of the pest.

During the investigation of this pest at North East, Pa., aphis lions, ants, mites, and spiders were frequently observed preying upon the nymphs, and in addition to them a very active orange-colored mite (*Anystis agilis* Banks) was often found feeding upon the nymphs and occasionally upon the adults, especially just after the latter had transformed and had not the full use of their wings. Both the nymph and the adult of a capsid of the genus Diaphnidia near *D. hamata* Van Duzee were frequently found with nymphs of *T. comes* impaled on their long probosces. Yet all of these predaceous enemies combined failed to have any appreciable influence in reducing the destructive numbers of the leafhopper.

[1] While Mr. J. F. Strauss, of this bureau, was making drawings of adults of *T. comes* for this paper he found an adult among some material in alcohol with the pupa of a dryinid (see fig. 13) attached to the body. These specimens were collected by the writer in vineyards near Euclid, Ohio, Aug. 9, 1911.

NATURAL CHECKS.

It would seem, however, that there are some as yet unknown natural checks which greatly reduce the numbers of this insect and occasionally almost entirely eliminate it over areas where only a short time previously it had been a serious pest.

In 1865 Trimble observed that once when the thermometer reached 100° F. thousands of the "hoppers" were killed.

There was a great diminution in numbers of the adults in the infested area of the Chautauqua County vineyards early in the season of 1903.

A condition similar to this was observed by Mr. E. W. Scott, of the Bureau of Entomology, during the season of 1912, when adults of *Typhlocyba tricincta* were so very abundant in the vineyards near Benton Harbor, Mich., that the vineyardists became greatly alarmed, many of them making preparations to spray the nymphs when they should appear. Yet this proved unnecessary, for when the time arrived for the nymphs to appear upon the foliage in large numbers most of the adults had disappeared and very few nymphs of the new brood had hatched. As yet nobody appears to be able to account for these sudden disappearances of the pest or to determine whether they are due to climatic or other causes.

In September, 1890, Thaxter observed that in Connecticut grape leafhoppers in large numbers were injuring a vineyard. He found that they were attacked by a fungous disease (*Empusa* sp.) which apparently destroyed all of them. This is the only case on record in which this insect was attacked by a fungous disease. Nothing of this nature has been observed in the vineyards of the Lake Erie Valley during the present investigation, and for the past four or five seasons the pest has steadily increased. Probably the time may not be far distant when large numbers of them will suddenly disappear, as happened at Westfield, N. Y., in the season of 1903. However, it is by no means safe for the vineyardist to count on these natural checks, for while one is waiting for relief from such a source the pest may work incalculable damage to his vineyard.

REMEDIES.

During the period that this insect has attracted the attention of economic entomologists much experimental work has been undertaken to determine the most effective means for its control. Early in the control work undertaken against this pest, tobacco, in some form or other, was employed as a killing agent. In 1828 Fessenden (see Bibliography) recommended the smoking of infested vines by burning tobacco stalks beneath them.

In 1843 J. F. Allen (see Bibliography) advised syringing or spraying infested vines and also smoking them by burning tobacco stalks. Since this date the use of tobacco in both of the forms mentioned has occupied a prominent place among substances recommended for the control of the grape leafhopper. The former method, that of fumigation, however, was impracticable for the open vineyard. In fact, it is quite probable that the process of fumigation with tobacco was originally intended for use against the insect when found infesting grapevines growing in hothouses which could be closed during the period of treatment. On the other hand, the use of a liquid tobacco decoction has withstood the test of numerous experiments in comparison with a large number of liquid spray materials and at the present time is the insecticide most generally recommended in making spray applications against the nymphs.

In the following paragraphs is presented a list of substances and mechanical methods either experimented with or recommended by various entomologists (see Bibliography) since this insect has been a pest of economic importance:

Liquid sprays.—Syringing with tobacco water or soapsuds (W. Saunders, 1870). Spraying with carbolic acid (W. L. Devereaux. Rural New Yorker, 1883). Spraying with kerosene and water, or sheep dip (O. Lugger, 1896). Spraying the adults with kerosene and water and the nymphs with whale-oil soap (M. V. Slingerland, 1904).

Dust sprays.—Dusting with lime and sulphur (C. J. S. Bethune, 1868). Dusting with hellebore (W. Saunders, 1870).

Other mechanical methods.—The use of sticky shields to trap the adults; torches to attract the adults (C. V. Riley, 1873). Destruction of leaves to destroy adults in hibernation (A. J. Cook, 1875). Sticky shields and cloth wet with kerosene to trap adults (J. A. Lintner, 1887). Sheets of cardboard smeared with tar to trap adults (F. M. Webster, 1893). Burning of leaves and rubbish in and surrounding vineyards to destroy adults in hibernation (O. Lugger, 1896). Sticky fans to catch adults as they fly from vines; collecting nets to catch adults (C. W. Woodworth, 1897). Box or cage having inside smeared with a sticky substance; the cage is placed over the infested vine and the "hoppers" are caught on the sticky sides and bottom of the cage (H. J. Quayle, 1908). Sticky shields held on both sides of the trellis (M. V. Slingerland, 1904).

Many of the methods of control mentioned in the foregoing paragraphs have been recommended by various other authors treating this subject. The foregoing simply indicate the date of their first mention in literature.

In his experimental work in vineyards in Chautauqua County, N. Y., Slingerland carried on quite extensive experiments with sticky shields for catching the adults before the commencement of egg deposition, the most practical shield for trellised vineyards being constructed and used as follows:

Make a light wooden frame about seven or eight feet long and four feet wide, having the bottom crosspiece about a foot from the ground and fasten to this stiff wires extending down nearly to the ground and bent inward something like hay-rake teeth. Tack over this a strip of table oilcloth 1¼ yards wide and let it extend down over the curved wire teeth, so that when the shield is held beside a vine, the oilcloth will come under the vine to catch the "hoppers" that try to drop to the ground. Cover the oilcloth with the "stick-em" and all is ready to operate. Two men, each carrying one of these light sticky shields on opposite sides of a trellis of vines, can reach over the shields, jar the vines to disturb the "hoppers" and thus go over an acre of vineyard in a little more than an hour.

In California, where the vines are not trained to a trellis, Mr. Quayle found that a screen cage having the inside smeared with crude oil, with one side open and a V-shaped opening cut in the bottom to admit the stem of the vine, could be used quite effectively in the vineyards to catch the adults before egg deposition commenced. In the course of his field experiments in California Mr. Quayle conducted experiments with suction apparatus for collecting the adults from the vines. He also attempted to destroy them with torches; by the application of dry powders, including lime, hellebore, and dry sulphur; and also by the fumigation of infested vines, both with cyanid and sulphur gas. None of these latter methods gave results of a practical nature, and the only mechanical method of control against the adults recommended by him is that of the screen cage previously mentioned.

Destruction of leaves and trash.—Many authors have urged the destruction of leaves and trash in and adjoining infested vineyards, while the insects are in hibernation, as a means of lessening their numbers. However, since the adults rise in the air and either fly or are carried considerable distances by the winds during the migrations which take place during the spring and fall, there are usually large areas of wood lots and pasture lands at considerable distances from vineyards where swarms of the adults may be found during the winter. Since in many cases these areas of rough land are not controlled by the owners of the vineyards there is slight possibility that this cleaning-up process will be undertaken on a large enough scale to be of any great value in lessening the numbers of overwintering adults. Furthermore, at the present time there is a strong tendency toward the growing of some form of cover crop, such as clover, vetch, turnips, rye, oats, etc., in vineyards as a means of furnishing soil protection and fertility; and this is very necessary and desirable in most of the vineyards of the Lake Erie Valley. This would have to be abandoned if the clean-culture method were followed. Observations along this line covering several seasons indicate that where cover crops are growing in badly infested vineyards the number of adult grape leafhoppers found among the shelter thus afforded is generally very small compared with the number that have migrated to adjacent wood lots and rough pasture lands. In fact, it would appear that there is a tendency for the larger percentage of adults to migrate from the vineyards in the fall, and this migration appears to be their chief mode of dispersal as much as a means for securing suitable hibernating quarters. Hence too much should not be expected of this destruction of leaves and trash on a limited scale, since in the following spring the adults are likely to swarm back into the vineyards from areas not included in the cleaning-up process.

SPRAY TREATMENT.

During recent years a great deal of attention has been given to combating this pest by means of liquid sprays. Owing to the agility of the winged adults, and also to the fact that their sloping wing covers protect their soft bodies from the killing action of spray liquids not sufficiently caustic to injure the foliage of the grapevines, it is a very difficult task to destroy many of them with liquid spray applications. This was demonstrated by Prof. Slingerland in his field experimental work in the vineyards of Chautauqua County, N. Y., during the outbreak of 1901–2. Since it frequently happens that during seasons of heavy infestation the hibernating adults appear on the new foliage in injurious numbers and cause considerable alarm among the vineyardists, he attempted to combat them by means of a kerosene and water spray. He found, however, that the margin between the percentage of oil necessary to kill the adults and the percentage that would seriously injure the grape foliage was so small that more injury to the vines was likely to occur than would offset the benefit derived from the number of flying adults that were killed by the process.

Much greater success, however, was secured by him in spray applications made against the nymphs by the use of whale-oil soap at a strength of 1 pound of the soap to 10 gallons of water. With this spray liquid he was able, by one thorough application when the majority of the nymphs were present on the foliage, to reduce their numbers to such an extent that those remaining caused no serious injury to the vines for the remainder of the season.

In experiments with liquid sprays consisting of 1 pound of whale-oil soap to 15 gallons of water Mr. Quayle was able to destroy a very large percentage of the nymphs infesting grapevines in California. He was also able to obtain good results by the use of a spray consisting of 1 pound of resin to 15 gallons of water, using enough lye or potash completely to dissolve the resin. This required 1 pound of lye to about 8 pounds of resin.

The chief objections to the use of whale-oil soap are the very offensive odor connected with its application and the fact that since the vines have to be thoroughly drenched with the spray in order to strike the underside of all of the leaves, the clusters of grapes are also necessarily drenched. This soapy liquid has a tendency to form in a drop on the lower part of each berry, and after the moisture has evaporated a white stain remains which makes an undesirable discoloration on the purple surface of the ripened grapes, rendering them unattractive for table use.

During the last few years commercial brands of tobacco extracts have come much into use as liquid spray substances for the control of soft-bodied sucking insects. Hence once more, after a period of over 80 years since it was first recommended, tobacco appears to be the most promising insecticide for the control of this pest.

During the seasons of 1910 and 1911 the grape leafhopper was present in very injurious numbers in many vineyards in the Lake Erie Valley. Vineyard experiments were undertaken by the Bureau of Entomology in the vicinity of North East, Pa., using the tobacco extracts as liquid sprays against the nymphs. The results of these experiments were very gratifying, since with one thorough application of the tobacco extract the numbers of these insects in the treated vineyards were so greatly reduced and the injury was so slight that the foliage retained its dark green color throughout the season, the cane growth was strong and well matured, the berries were large, the fruit sweet, and the size of the crop considerably increased; whereas, on the untreated portion of the vineyards the foliage turned brown and dropped prematurely, the cane growth was stunted, the berries were undersized and lacking in sugar content, and the tonnage per acre was much less than on the sprayed portions of the vineyards.

Detailed reports of these vineyard experiments against this pest are given in Part I of Bulletin No. 97 and Part I of Bulletin No. 116 of this bureau.

SPRAY MATERIAL.

The forms of tobacco extract used in these experiments in 1910 and 1911 were the blackleaf tobacco extract containing 2.70 per cent nicotine sulphate and the blackleaf tobacco extract containing 40 per cent of nicotine sulphate. The blackleaf tobacco extract containing 2.70 per cent of nicotine was effective in killing all of the nymphs which were thoroughly wetted by the spray, when applied at a dilution of 1 part of tobacco extract to 150 parts of water or Bordeaux mixture. The blackleaf tobacco extract containing 40 per cent nicotine sulphate was found to be effective at a dilution of 1 part of tobacco extract to 1,500 parts of water or Bordeaux mixture. Both of these forms of tobacco extract appear to be equally effective in destroying the nymphs at the dilutions mentioned. The one containing the smaller percentage of nicotine (2.70 per cent), however, necessarily contains more sticky inert matter. When this is applied as a spray to the vines late in the season, i. e., toward the middle of August, and when little rainfall occurs before the harvesting season, some of this sticky substance may adhere to the ripe grapes, giving the skins a slight flavor of tobacco.

It was noted that this condition obtained during the dry fall of 1910. The "blackleaf 40" tobacco extract does not appear to carry so much of this sticky substance, and owing to the greater dilution that is possible in its use the dilute spray liquid is almost clear; hence there is not the likelihood that it will leave the undesirable stain on the ripened fruit. It should be stated, however, that neither of these extracts is likely to leave the unpleasant stain or odor on the fruit if applied in the early part or middle of July, which is usually the period at which the maximum benefit is to be derived from them in the destruction of the nymphs.

SPRAYING APPARATUS.

Various types of spraying machinery are used by the vineyardists of the Lake Erie Valley. It was on account of the depredations of the grape rootworm, requiring a spray application to the upper surface of the foliage, that the use of spraying machinery in vineyards became general. The sprayer in general use for this work is of the tractor type (Pl. III, fig. 1), the power being generated either by a chain or an eccentric gearing connecting the wheel and the pump. Thus in order to maintain a uniform high pressure with this type of machine it is necessary to keep it in motion. Although most of these machines are supplied with a large air chamber so that the pressure is held quite steady and does not vary with every stroke of the plunger, yet as soon as the wheels of the machine stop turning the pressure drops quite rapidly.

Other types of sprayers in use for vineyard work are compressed-air power outfits, gasoline-engine power outfits, and steam power outfits. With all of these latter types the pressure is independent of the rate of movement of the machine through the vineyard rows.

In making spray applications against the nymphs of the grape leafhopper it is necessary to apply large quantities of spray liquid to the underside of the infested grape leaves. Where the foliage is quite dense the amount of spray required for thorough work may amount to from 200 to 300 gallons per acre, whereas in making applications to the upper surface of the foliage against the beetles of the grape rootworm thorough work can be done on quite dense foliage with about 100 to 125 gallons of liquid per acre, and this may be accomplished while the team is being driven slowly.

During the seasons of 1911 and 1912 all of the types of spray machinery previously mentioned were observed in use in spraying against the grape leafhopper, and in the hands of careful operators effective work was accomplished with all of them.

It should be stated that in all cases observed, with the exception of the steam-engine power outfit, all of the spray applications were made by the trailer method. That is, the operator directed the spray to the underside of the grape leaves by holding a short rod, one end connected to the spray hose and the free end carrying a large nozzle of the cyclone type directed upward at right angles to the rod. (See Pl. III, fig. 1.) Effective results in killing the nymphs by this method appeared to depend more upon the person manipulating this rod than upon the type of sprayer used or the number of pounds of pressure applied, providing the pressure was not allowed to drop below 75 pounds. Of course with the higher pressure larger areas can be covered in a given time than with the low pressure. Yet the most effective work done in the control of this pest coming under observation of the writer was accomplished with a tractor machine, with a pressure fluctuating between 70 and 125 pounds, in the hands of a very thorough vineyardist. This feature is emphasized here because the small vineyardist, being under the impression that an expensive high-pressure spray outfit is necessary, is frequently deterred in attempting to control this pest, whereas the most important thing is care in the direction of the spray so that the greatest number of nymphs will be drenched, and this can be done with the same tractor machine that is used for applications against the grape rootworm. On the other hand, it is doubtless much more economical for the vineyardist with large areas to cover to have larger high-pressure outfits, since with them two or even more leads of hose may be used (Pl. III, fig. 2), making it possible to cover large areas in a very short time. This is highly desirable, since there are only about 8 to 12 days during which the maximum number of nymphs is present upon the foliage.

In order to lessen the time required to make the application and to reduce the cost, many attempts have been made to apply the spray to the underside of the grape foliage by means of a fixed nozzle arrangement instead of making the application by the trailer method described above. The chief difficulty arising in the use of a fixed-nozzle arrangement is that such a device applies no more liquid to a vine carrying a large amount of dense foliage than to one carrying a moderate amount of more widely spaced foliage; hence it frequently happens that much more spray than is necessary is applied to the vine carrying light foliage and not enough is applied to the one carrying dense foliage.

The types of fixed-nozzle arrangement are being tried out in the vineyards of the Lake Erie Valley. One of these was for a tractor or a gasoline-engine power sprayer, and was devised and used by Mr. F. Z. Hartzell.[1] The other arrangement was used for a steam-engine power sprayer. (Pl. II, fig. 2.) Both of these arrangements are reported to have given fairly satisfactory results in killing nymphs where the foliage was not very dense. In most cases, however, suc-

[1] Bul. 344, N. Y. (Geneva) Exp. Sta., Pls. I-IV.

FIG. 1.—ROD AND SINGLE CYCLONE NOZZLE USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY TRACTOR SPRAYER. VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA. (ORIGINAL.)

FIG. 2.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF MR. J. E. BEATTY, NORTH EAST, PA. (AUTHOR'S ILLUSTRATION.)

THE GRAPE LEAFHOPPER.

cess with any type of spray apparatus in present use in work against this pest appears to depend more on the care and ingenuity of the individual operator than upon the great superiority of any given type of machine over another.

RECOMMENDATIONS.

Efforts to control the depredations of the grape leafhopper by the destruction of the winged adults, by burning over or cleaning up their hibernating places adjacent to vineyards, by trapping them on sticky shields, or by endeavoring to treat them with contact sprays when they appear on the new growth of the grapevines in spring before oviposition takes place, have proven far from satisfactory. Although these methods may furnish a certain measure of relief over very limited areas, they are of very slight practical value as control measures when serious infestations occur in large vineyards.

Observations indicate that except in seasons of extremely heavy infestation, or over limited areas, the injury wrought by the over-wintering adults in spring to the new growth is not likely to reduce greatly the entire seasonal growth of the infested grapevine provided a large percentage of their offspring in the form of nymphs can be destroyed before they reach the adult stage. In other words, it is the steady drain made on the infested grapevines from the time the overwintering adults attack them in spring, combined with the unchecked attack of the nymphs and adults of the new brood until late September, that results in serious injury by curtailing the size of the crop and the growth of the vine.

That the nymphs can be controlled by the spray method has been thoroughly demonstrated. Successful control of the nymphs by this method depends on thoroughly wetting all parts of the underside of the infested leaves with the spray liquid.

Tobacco extracts have given excellent results, used according to the following formulas:

I. Tobacco extract containing 2.70 per cent nicotine sulphate, diluted at the ratio of 1 part to 150 parts of water.

II. Tobacco extract containing 40 per cent nicotine sulphate, diluted at the ratio of 1 part to 1,500 parts of water.

The killing quality of the tobacco extract is apparently just as effective when added at the same dilution to the Bordeaux mixture and arsenate of lead spray liquids, which are used to control fungous diseases and chewing insect enemies of the grapevine, as when used with clear water. No injury results from combining these spray mixtures, namely, tobacco extract, Bordeaux mixture, and arsenate of lead. However, the tobacco extract should not be mixed with spray mixtures containing arsenicals in the form of Paris green or arsenite of lime, for serious injury to the foliage is likely to occur as a result of the combination.

The most effective time to make the tobacco spray application against the nymphs is just before those that hatched earliest in the season have reached the fourth molt. This can be determined by the length of the wing pads (Pl. I) which, in the fourth stage, extend about one-third the length of the abdomen. At this time a larger number of nymphs are likely to be present on the vines than at any other time during the season. In the vineyards of the Lake Erie Valley this condition occurs toward the end of the first week in July, and the most effective work with the tobacco-spray liquid may be done during the two weeks following this date. After this period, or toward the end of July, a large percentage of the nymphs of the first brood will have transformed to winged adults, and these latter can not be successfully treated with the diluted tobacco spray.

In vineyards where black-rot, mildew, the grape rootworm, and the grape-berry moth occur, it is suggested that arsenate of lead and Bordeaux mixture be used with the tobacco extract to take the place of the second spray application in the schedule of treatment recommended against these diseases and insect pests.

When it is deemed expedient to use sticky shields to capture the winged adults before oviposition takes place, the best sticky substance for this purpose, according to Slingerland, is a mixture of melted resin, 1 quart, in 1 pint of castor oil, smeared liberally over the face of the shield.

CONCLUSIONS.

Typhlocyba comes, the species of grape leafhopper discussed in this paper, is at the present time a very destructive enemy of the grapevine throughout the vineyards of the Lake Erie Valley. For several seasons it has caused great losses to the vineyardists of this region by reducing the yield and quality of the grape crop and by curtailing the growth and lowering the vigor of the vines. The vineyardist who desires to maintain his vines in full vigor and produce high-quality fruit can not afford to allow this pest to develop in destructive numbers in his vineyards, for if not controlled sooner or later it is almost sure to occasion serious loss. Field experiments prove conclusively that this pest can be controlled by spraying against the nymphs with a tobacco-extract solution.

The life-history studies recorded in the preceding pages show that there is only one full brood of nymphs a year in the region of the Great Lakes.

The spraying experiments recorded in Part I of Bulletin 97 and Part I of Bulletin 116 of the Bureau of Entomology indicate that a single thorough spray application, made when the greater percentage of the nymphs of this brood is present on the underside of the grape leaves, will so reduce their numbers that injury to the crop and the vines for the remainder of the season by those that escape the spray action will be very slight.

In the vineyards of Ohio, west of Cleveland, and in the vineyards of Michigan another species of grape leafhopper, *Typhlocyba tricincta* (figs. 6 and 7, pp. 10, 11), is the predominant and destructive species. The life history and habits of this species, however, are so nearly identical with those of *Typhlocyba comes* that the remedial treatment recommended for the latter can also be used with success against the former, namely, the application of the tobacco-extract spray to the nymphs at the time they appear in maximum numbers upon the underside of the grape leaves, which for these States is during the last few days in June or very early in July.

BIBLIOGRAPHY.

1825. Say, Thomas. Descriptions of new hemipterous insects collected in the expedition to the Rocky Mountains. Journ. Acad. Nat. Sci. Phila., vol. 4, pp. 307–345.

Description of *T. comes*, p. 343.

1828. Fessenden, T. G. New American Gardener, pp. 299–300. Boston.

Brief description of the grape leafhopper and its injury to the grapevine. Remedy: Smoking vines with tobacco stalks.

1841. Harris, T. W. Report on the insects of Massachusetts injurious to vegetation, pp. 182–185. Cambridge.

"The leaf-hoppers (Tettigoniadæ)." Description, life history, habits, injury to grapevines.

1843. Allen, J. F. Practical treatise on the grape vine, p. 154.

Brief mention. Remedies: Syringing with tobacco water, or smoking with tobacco stalks.

1848. Horticulturist [Downing], vol. 3, pp. 28–29.

Brief mention. Remedy: Tobacco water.

1855. Glover, Townend. Report of the [U. S.] Commissioner of patents for 1854. Agriculture, pp. 77–78.

"The vine-hopper." Habits of insect, injury to grapevines. Remedy: Fumigation with tobacco.

1856. Fitch, Asa. Third report on * * * the insects of * * * New York, pp. 391–393.

"Vine leaf hoppers." Brief descriptions of Typhlocyba, Erythroneura, and Empoa. Discussion of injury to grapevines.

1864. Walsh, B. D. Proc. Bost. Soc. Nat. Hist., vol. 9, pp. 317–318.

"Erythroneura." Description of three species and mention that *E. vitis* Harris, *E. vulnerata* Fitch, *E. vitifex* Fitch, and *E. tricincta* Fitch belong to this genus.

1867. Walsh, B. D. Pract. Ent., vol. 2, pp. 49–52.

"The true thrips and the bogus thrips." Explaining difference in appearance and habits of true thrips and the grapevine leafhopper.

1868. Bethune, C. J. S. Canadian Farmer, vol. 5, p. 7.

"Grape-vine tree-hopper (*Tettigonia vitis* Harris)." Description, habits, injury. Remedies: Dusting with sulphur and lime; fumigating with tobacco.

1869. Walsh, B. D., and Riley, C. V., eds. Amer. Ent., vol. 1, p. 227.

"Grapevine leaf-hopper." Brief note recommending syringing with strong tobacco water.

1870. Saunders, William. Report of the Fruit Growers Assn., Ont., for 1870, pp. 111–113.

"The thrips (so-called) (*Tettigonia vitis*, Harris)." Life history, habits, injury. Remedies: Syringing with tobacco water, soapsuds, dusting with hellebore, fumigating with tobacco.

1871. Glover, Townend. Report of the [U. S.] Commissioner of Agriculture for 1871, pp. 85-86.

"The grape-vine hopper (*Erythroneura* (*Tettigonia*) *vitis*)." Life history and habits, injury to grapevines. Remedies: Spraying with tobacco water, soapsuds, trap lights, etc.

1874. Riley, C. V. Trans. Ill. State Hort. Soc., new ser., vol. 7, p. 138.

Brief mention; suggests use of sticky substance on stalk of vine in spring, sticky shields, torches.

1875. Cook, A. J. Thirteenth Annual Report of the State Board of Agriculture, Michigan, for 1874, p. 146.

"Grape-vine leaf-hopper (*Erythroneura vitis*)." Brief account of habits and injury. Remedy: Destruction of leaves.

1877. Glover, Townend. Report of the U. S. Commissioner of Agriculture for 1876, pp. 32–33.

"*Erythroneura* (*Tettigonia*) *vitis*." Brief discussion of habits and remedies.

1878. Perkins, G. H. Fifth Report of the Vermont Board of Agriculture, pp. 285–286.

"*Erythroneura vitis* Harris." Life history, injury. Remedies: Washes—lye, soapsuds, tobacco water; fumigating vines with tobacco.

1880. Riley, C. V. Amer. Ent., vol. 3 (ser. 2, vol. 1), p. 182.

"Terrestrial insects in stomach of shad." Mention of a Typhlocyba, probably *vitis*.

1883. Devereaux, W. L. Rural New Yorker, vol. 42, p. 474.

"The grape-vine hopper." Brief mention of habits and injury to grapevines. Remedies: Fumigation with tobacco, spraying with carbolic acid.

1883. Saunders, William. Insects Injurious to Fruits, pp. 286–288.

"The grape-vine leaf-hopper (*Erythroneura vitis*)." Life history, habits, injury, remedies.

1884. Uhler, P. R. Standard Natural History [ed. J. R. Kingsley], vol. 2, p. 246.

Brief description and note on habits and distribution.

1886. Lintner, J. A. Thirty-third Annual Report Massachusetts Board of Agriculture for 1885, pp. 191–195.

"The grapevine 'Thrips.'" Discussion of habits, injury, and remedial measures.

1887. Lintner, J. A. Cultivator and Country Gentleman, vol. 52, p. 493.

"Grapevine leaf-hoppers." Brief description, habits, injury to grapevines. Remedies: Spraying with tobacco infusions, soapsuds, sticky shields.

1888. Fernald, C. H. Mass. Hatch Exp. Sta., Bul. 2, pp. 3–5.

"The grape-vine leaf-hoppers." Life history, nature of injury to vines, remedial measures.

1888. Marvin, D. S. Rural New Yorker, vol. 47, p. 576, September 1.

"Thrips, *Tettigonia vitis*." Brief description. Mentions as remedies tobacco water, pyrethrum-kerosene emulsion, and strong carbolic soapsuds.

1889. Bethune, C. J. S. Ninth Annual Report of the Entomological Society of Ontario, 1888, pp. 63–66.

"The grape-vine leaf-hopper (*Erythroneura vitis* Harris)." Detailed discussion of injury, life history, habits, and remedies.

1889. Woodworth, C. W. Psyche, vol. 5, pp. 211–214.

"North American Typhlocybini."

1889. Fernald, C. H. Orange Judd Farmer, vol. 5, no. 20, p. 315, May 18.

"The grape-leaf hopper." Habits, injury. Remedies: Smoking vines in graperies, syringing with soapsuds, tobacco water, torches.

1889. Fernald, C. H. Annual Report of the Massachusetts Hatch Experiment Station, pp. 21–23.

"The grape-vine leaf-hoppers." Brief statement of life history and injury.

1890. Provancher, Abbé L. A. Petite Faune Entomologique du Canada, vol. 3, pp. 298–299.

Descriptions of *Erythroneura vitis*, *E. vitifex*, and *E. vulnerata*.

1890. Cassidy, James. Colo. Agr. Exp. Sta., Bul. 6, p. 20.

Brief mention of two undetermined species of Erythroneura occurring on apple and grape.

1890. Felton, W. B. Annual Report of the Colorado State Horticultural and Forestry Association, vol. 5, 1889, pp. 573–576.

"Codling moth and leafhopper." Remedies: Burning leaves, torches, spraying with tobacco decoction, sticky shields.

1890. Thaxter, Roland. Annual Report Connecticut Agricultural Experiment Station for 1890, p. 97.

Brief mention of infestation by fungous disease.

1891. Blount, A. E. New Mex. Agr. Exp. Sta., Bul. 2, p. [6].

"The vinehopper (*Tettigonia vitis*.)" Brief mention of injury to vines. Remedies: Tobacco fumigation and kerosene sprays.

1891. Gillette, C. P. Colo. Agr. Exp. Sta., Bul. 15, pp. 18–22.

"The grape-vine leaf-hopper." Gives Harris's description of *Tettigonia vitis* and a brief list of remedies which may be effective.

1891. Fletcher, James. Can. Centr. Exp. Farm, Bul. 11, p. 21, May.

"Grape-vine leaf-hopper (*Erythroneura vitis* Harris)." Brief mention. Recommends clean culture and spraying with kerosene emulsion.

1891. Townsend, C. H. T. New Mex. Agr. Exp. Sta., Bul. 3, pp. 3–6.

"Insects injurious to the vine." Life history; mentions possibility of third brood. Remedies: Kerosene emulsion, "I.X.L." compound, tobacco water, and "shield method."

1891. Lintner, J. A. Cultivator & Country Gentleman, vol. 56, p. 815, October 8.

"Grapevine leaf-hopper." Brief discussion of habits and injury. Remedies: Sticky shields, cloth wet with kerosene.

1891. Weed, C. M. Insects and Insecticides, pp. 123–124. Hanover, N. H.

"The grape-vine leaf-hopper (*Typhlocyba vitis*)." Life history. Remedies: Pyrethrum, tobacco dust, sticky screens.

1892. Townsend, C. H. T. New Mex. Agr. Exp. Sta., Bul. 5, pp. 3–5.

"The vine leaf-hopper (*Typhlocyba vitis*)." A résumé of paper in Bulletin 3 of the New Mexico Station.

1892. Gillette, C. P. Annual Reports Colorado State Bureau of Horticulture for 1891–2, vol. 6, pp. 233–235.

"The western grapevine leaf-hopper (*Typhlocyba vitifex* Harris, var. *coloradoensis* Gill.)." Description. Life history, two brooded. Remedies: Spraying with kerosene emulsion, sticky shields.

1893. Fitch, Asa. Catalogue of the insects collected and arranged for the State Cabinet of Natural History. Reprint in Lintner, 9th Rept. Inj. Ins. N. Y. f. 1892, pp. 383–409.

"Erythroneura," pp. 402–403. Brief descriptions of *E. vulnerata*, *E. vitis*, and *E. tricincta*.

1893. Webster, F. M. Twenty-sixth Annual Report Ohio State Horticultural Society for 1892–93, pp. 63–70.

"Insects of the year." Brief statement of use of tar-smeared cardboard in destroying adults in vineyards of New Jersey, p. 67.

1894. Osborn, H. Report of the Iowa State Horticultural Society for 1893, vol. 28, pp. 262–264.

"Insects affecting grapes." General discussion of life history, injury to vines, and remedial measures against *Typhlocyba vitis*, p. 263.

1894. Fletcher, James. Reports Experimental Farms, Canada, for 1893, p. 181.

"The grape-vine leaf-hopper." Brief mention of habits and injury; remedies.

1894. Van Duzee, E. P. Catalogue of the described Jassoidea of North America. Trans. Amer. Ent. Soc., vol. 21, pp. 245–317.

"*Typhlocyba comes*," p. 312.

1894. Gravestock, J. Semi-annual Reports Colorado State Board of Horticulture for 1893–94, vol. 7, pp. 229–233.

Brief mention of remedies: Kerosene emulsion, hot water, pp. 229–230.

1895. GILLETTE, C. P., and BAKER, C. F. Colo. Agr. Exp. Sta., Bul. 31, p. 113.
"*Typhlocyba vitifex* Harr. var. *coloradensis* Gill." Brief mention of date collected.

1895. COMSTOCK, J. H. Manual for the Study of Insects, p. 154. Ithaca.
"The grape-vine leafhopper (*Erythroneura vitis*)." Brief mention of appearance, habits, and remedies.

1896. LUGGER, OTTO. Minn. Agr. Exp. Sta., Bul. 48, pp. 61–65.
"Grape-vine leaf-hoppers (*Typhlocyba* sp.)." Discussion of applications: Kerosene and water, sheep dips. Recommends burning leaves and rubbish to destroy hibernating adults.

1896. MARLATT, C. L. U. S. Dept. Agr., Yearbook, 1895, pp. 400–402.
"The grape leaf-hopper (*Typhlocyba vitifex* Fitch)." Injury, life history, habits. Remedies: Kerosene emulsion, sticky shields.

1896. MARLATT, C. L. Amer. Nat., vol. 30, p. 759, September.
"Grape insects." Review of U. S. Dept. Agr. Yearbook article, 1895.

1896. SLINGERLAND, M. V. Rural New Yorker, vol. 55, p. 689, October 17.
"The grapevine leaf-hopper." Brief discussion of life history, injury to grapevines. Remedies: Spraying with kerosene emulsion, tobacco dust, sticky shields.

1896. SMITH, J. B. Economic Entomology, ed. 2 rev., pp. 148-149. Philadelphia.
"The grape leaf-hopper (*Erythroneura vitis*)." Brief mention.

1897. WOODWORTH, C. W. Cal. Agr. Exp. Sta., Bul. 116.
"California vine hopper." Detailed description of life history and habits, extent of injury, remedial measures. Recommends use of sticky fans and nets for catching adults.

1897. WOODWORTH, C. W. Univ. Cal. Agr. Exp. Sta., App. to Viticultural Rept., 1896, p. 219.
Brief mention, use of sticky fans for vine hopper.

1900. GILLETTE, C. P. Annual Report Colorado Agricultural Experiment Station, p. 126.
"Important insects of the year, Leafhoppers (*Typhlocyba* sp.)." Brief statement of spring food plants and breeding habits on grapevines and Virginia creeper.

1901. FELT, E. P. N. Y. State Mus., Bul. 53, pp. 737–738, 838.
"Grapevine leaf-hopper." Brief mention.

1902. FELT, E. P. U. S. Dept. Agr., Div. Ent., Bul. 37, p. 103.
Brief note.

1903. Twelfth Report Oklahoma Agricultural Experiment Station, 1902–1903, p. 49.
"Grapevine leaf-hopper." Brief mention. Recommends dusting with equal parts of sulphur and fresh lime or pyrethrum.

1904. SLINGERLAND, M. V. Cornell Univ. Exp. Sta., Bul. 215.
"The grape leaf-hopper (*Typhlocyba comes* Say)." Full discussion of distribution, injury, life history, habits, and remedial measures; many illustrations.

1904. SMITH, J. B. Report of the New Jersey Agricultural College Experiment Station, pp. 651–659.
"Rose-leaf tobacco extract." Describes experiment against grape leafhopper on a few vines with this spray, applying it to underside of grape leaves.

1907. QUAINTANCE, A. L. U. S. Dept. Agr., Farmers' Bul. 284, pp. 19–22.
"Grape leaf-hopper." Distribution, life history, description, injury, remedies.

1907. QUAYLE, H. J. Cal. Agr. Exp. Sta., Bul. 192, pp. 111–116.
"The vine hopper (*Typhlocyba comes* Say)." Injury to grapevines, life history. Remedies: Hopper cage, spraying.

1908. QUAYLE, H. J. Journ. Econ. Ent., vol. 1, pp. 182–183.
"The California life history of the grape leaf-hopper (*Typhlocyba comes* Say)."

1908. QUAYLE, H. J. Cal. Agr. Exp. Sta., Bul. 198.
"The grape leaf-hopper (*Typhlocyba comes* Say)." Full discussion of destruction, distribution, life history, habits, and remedial measures. Many illustrations.

1910. HARTZELL, F. Z. N. Y. Agr. Exp. Sta., Geneva, Bul. 331, pp. 568–579.
"The grape leaf-hopper (*Typhlocyba comes* Say)." Economic importance, injury to grapevines. Brief description, seasonal history. Remedy: Black-leaf tobacco extract. Records of vineyard experiments.

1911. JOHNSON, FRED. U. S. Dept. Agr., Bur. Ent., Bul. 97, Pt. I.
"Spraying experiments against the grape leaf-hopper in the Lake Erie Valley." Brief discussion of life history, habits, and injury to grapevines. Remedies: Tobacco extracts. Record of spraying experiments in vineyards.

1912. HARTZELL, F. Z. N. Y. Agr. Exp. Sta., Geneva, Bul. 344.
"The grape leaf-hopper and its control." Life history, injury to grapevines, species and varieties found in Chautauqua County, food plants, control experiments, automatic spraying attachment, spraying recommendations.

1912. SANDERSON, E. D. Insect Pests of Farm, Garden and Orchard, pp. 520–523. New York.
"The grape leaf-hopper (*Typhlocyba comes* Say)." Life history, injury, remedies.

1912. O'KANE, W. C. Injurious Insects, pp. 311–313.
"The grape leaf-hopper (*Typhlocyba comes* Say)." Life history, habits, injury to grapevines, remedies.

1912. JOHNSON, FRED. U. S. Dept. Agr., Bur. Ent., Bul. 116, Pt. I.
"Spraying experiments against the grape leafhopper in the Lake Erie Valley in 1911." Results of vineyard experiments with tobacco extracts, giving method and cost of application and results in crop yield.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 45

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
November 22, 1913.

EXPERIMENTS IN THE USE OF SHEEP IN THE ERADICATION OF THE ROCKY MOUNTAIN SPOTTED FEVER TICK.

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PLAN OF EXPERIMENTS.

In order to test the destructive power of sheep against the spotted fever tick and to ascertain what importance sheep might play in the practical eradication of the tick, some experiments were performed by the Bureau of Entomology in the Bitter Root Valley in Montana in June and July, 1913. This work followed the announcement to the Montana State Board of Entomology, by Dr. L. D. Fricks of the Public Health Service, of observations on the death of ticks on sheep which have been published in the Public Health Reports of August 8, 1913.

Two experiments were performed, one with 20 sheep and the other with 2 sheep. The first experiment, with 20 sheep, which included 1 ram, 11 other adult sheep, and 8 lambs, was performed in country known to be well infested with ticks. The country over which the sheep ranged is adjacent to the foothills and is well supplied with bushes of various sorts, a growth of small pines, a few fairly large trees, and several streams of water. There was an abundance of grass along the streams, but under the pines next to the foothills there was little grass. In the ravine between two hills there was a thick growth of brush. It is next to the foothills, where brush abounds, that the ticks were found most abundantly. Very few ticks were observed along the streams and where the grass was growing in abundance.

Previous to the time the sheep were driven onto a school section which was used as an experimental pasture, they had been ranging away from the foothills and were probably quite free of ticks. No ticks were seen on cattle and horses running in the range from which the sheep were taken during the whole tick season, and the animals were under close observation by the owner. It is fair, then, to suppose that there could have been few, if any, ticks on the sheep at the time they were driven into " ticky " country.

In the evening of June 3 the sheep were driven onto the school section into a small corral previously prepared for them. On the morning of June 4, and thereafter until the evening of June 14, the sheep were herded twice a day for about two hours at each feeding. For the remainder of the time they were kept in the corral. About three-fourths of the time the sheep were herded, they were allowed to run at will, and the other one-fourth they were driven and made to feed in places known to be well infested with ticks. During all this time the development of the ticks was watched on some of the sheep, and when it was found that some of the ticks were nearly engorged the sheep were driven to the camp laboratory, about a mile from the sheep corral. At the camp the sheep were examined, usually twice a day, so that the development of the attached ticks might be followed, and any females that were engorged, or nearly so, were removed. Here the sheep were allowed their freedom the greater part of the day, but at night were confined in a shed. It is probable that they picked up a tick or two about camp, but probably only a very few.

Two thorough examinations were made of each sheep, to locate the living ticks and to remove the dead ones. The first examination began on June 10 and was finished on June 15; the second was started on June 23 and ended on June 27. Besides these examinations numerous less thorough examinations were made, any dead ticks found being removed and the living ones noted.

Near the completion of this experiment two sheep were selected from the adult sheep with heavy wool, and after thorough examinations were utilized in another experiment. Ticks were collected by dragging cloths over the ground and placed on these sheep. They were first put on one sheep June 20 and on the other June 25. Until June 28 these sheep were allowed to run with the others, but after that time the other sheep were driven back to the owner and the two were taken out to feed. They were examined twice a day.

OBSERVATIONS AND RESULTS.

In order to show as exactly as possible the results obtained, the 20 sheep have been divided into three groups, namely, unsheared lambs, unsheared sheep, and sheared sheep. In the first group were 8 spring lambs, Nos. 2–9, inclusive; in the second group were 7 adult sheep with heavy wool, Nos. 10–16, inclusive, and in the third group were the ram and 4 sheared adult sheep, Nos. 1 and 17–20, inclusive.

The results have been summarized in Table I. The heading, "total dead unfed ticks" includes all males and females which were thought to have been killed before having fed to any extent. It may also include, besides males which had not fed to any extent, males which had fed considerably, for it is usually impossible to distinguish fed males from unfed males when they are dead. The headings under "location of dead ticks on host's body" are self-explanatory. The ticks taken from the head were usually in the wool on the top of the head. The same statement also applies to the neck. The heading, "total ticks found attached at first examination," is also self-explanatory. Only a few ticks were on the sheep at this examination. It is likely that there were only a few ticks which had attached themselves and become detached before this examination, except those which were found dead in the wool. The headings under "location of living attached ticks" need some explanation. The "other place" referred to in the case of No. 1 was near the base of the right fore leg, and in the case of No. 7 the tick was attached on the breast. Ticks attached on the head were in all cases found attached in the wool. No preference was shown by the ticks on sheep with heavy wool for places where the wool was short. They attached both in short wool and in long wool which was somewhat open. On the ram the ticks attached in a bunch in the cavity where the horn ordinarily is located (this ram was hornless).

All the ticks attached on sheared sheep, except one, were in front of the ears where the wool was thin; the exception was in the case of one tick which was attached on the shoulders.

TABLE I.—*Number of ticks, living and dead, found on sheep.*

	Sheared ram.	Unsheared lambs.							Unsheared sheep.							Sheared sheep.					Grand total.
No. of host	1	2	4	5	6	7	9	Total.	10	12	13	14	15	16	Total.	17	18	19	20	Total.	
Total dead unfed ticks:																					
Male	1	0	0	1	1	2	1	5	4	8	8	8	7	1	36	0	1	3	0	4	46
Female	1	3	0	3	0	2	1	9	8	13	6	10	15	2	54	1	4	0	0	5	69
Location of dead ticks on host's body:																					
Head—																					
Male	0	0	0	0	1	0	0	1	0	1	3	5	1	1	11	0	0	0	0	0	12
Female	0	1	0	1	0	0	0	2	3	4	0	5	1	2	15	0	2	0	0	2	19
Neck—																					
Male	1	0	0	0	0	0	0	0	1	0	3	1	3	0	8	0	1	2	0	3	12
Female	0	1	0	1	0	1	1	4	3	1	2	1	3	0	10	0	2	0	0	2	16
Back—																					
Male	0	0	0	1	0	2	0	3	1	5	2	1	2	0	11	0	0	0	0	0	14
Female	1	1	0	0	0	0	0	1	1	3	2	2	6	0	14	0	0	0	0	0	16
Sides of body—																					
Male	0	0	0	0	0	0	1	1	2	2	0	1	1	0	6	0	0	1	0	1	8
Female	0	0	0	1	0	0	0	1	0	4	2	2	5	0	13	1	0	0	0	1	15
Underparts of body—																					
Male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Female	0	0	0	0	0	1	0	1	1	1	0	0	0	0	2	0	0	0	0	0	3
Total ticks found attached at first examination:																					
Male	4	2	2	3	0	1	7	15	4	3	0	0	0	0	7	0	1	0	0	1	27
Female	11	0	2	4	0	7	7	20	13	2	0	0	1	1	17	0	3	4	0	7	55
Location of living attached ticks:																					
Head—																					
Male	3	0	1	1	0	1	3	6	0	2	0	0	0	0	2	0	1	0	0	1	12
Female	10	0	0	0	0	6	5	11	3	1	0	0	1	1	6	0	3	3	0	6	33
Neck—																					
Male	0	2	1	2	0	0	4	9	4	1	0	0	0	0	5	0	0	0	0	0	14
Female	0	0	1	2	0	0	1	4	10	1	0	0	0	0	11	0	0	0	0	0	15
Shoulders—																					
Male	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Female	0	0	1	2	0	0	1	4	0	0	0	0	0	0	0	0	0	1	0	1	5
Other places—																					
Male	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Female	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Total ticks found crawling at first examination:																					
Male	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3	0	0	0	0	0	4
Female	0	0	0	0	0	0	1	1	1	1	1	0	2	0	5	0	0	0	0	0	6
Total females known to have engorged one-half or more	3	0	2	4	0	7	4	17	1	0	0	0	0	1	2	0	3	4	0	7	29
Total females found with males beneath	3	0	1	2	0	5	4	12	2	0	0	0	0	0	2	0	1	0	0	1	18
Engorged females recovered from sheep	2	0	1	4	0	6	4	15	1	0	0	0	0	1	2	0	0	2	0	2	21
Engorged females dropped	(?)	....	....	....	....	....	....	(?)	....	....	....	....	....	....	(?)	....	....	....	....	(?)	1

On the lambs, ticks were found attached in several different places: Some were in front of the ears, some in the wool on top of the neck, others in the wool on the top and sides of the shoulders, and one was attached, as stated before, on the chest. In no case were the ticks on lambs found attached on the hind quarters or beneath the body.

The ticks referred to as crawling were no doubt those males and females which had recently gotten on the sheep, or perhaps they were males seeking females. Besides the females referred to in Table I as "engorged one-half or more," there were some other females which had fed slightly but had never become as much as one-half engorged. This division at one-half engorged is made because females less than about that size seldom lay eggs. Should ticks less than one-half full get rubbed off, it is extremely doubtful if they would ever deposit eggs. Just how many ticks were rubbed off or killed before complete engorgement it is impossible to say, but a few cases of this kind were observed. In all cases in which females are referred to "with males beneath," such pairs were in the correct position to effect fertilization. The "engorged females recovered from sheep," except one, were picked from the host when they had reached full or nearly full engorgement.

It seems probable that the dead unfed ticks found in the wool were for the most part killed by the lanolin, although the heat of the wool may have been a factor. It was found in a number of cases that ticks died after attaching. This factor was indicated by a reddish spot on the skin near the place where the tick was found dead. The ticks, however, were usually found loose in the wool. Both living (attached) and dead ticks were found at times in the same fold.

To show the location of the ticks recovered and the relation between shearing and the development of the ticks, certain data in Table I have been rearranged in Tables II and III.

TABLE II.—*Location of ticks recovered from sheep.*

	Dead.	Alive.
Head	31	45
Neck	28	29
Upper parts	30	[1] 5
Sides	23	0
Underneath	3	[2] 3

[1] On the shoulder. [2] Two on leg.

TABLE III.—*Relation between shearing and attachment of ticks.*

	Dead females.	Engorged females.
Lambs not sheared	9	15
Sheep not sheared	54	2
Sheep sheared (including ram)	6	4

The data appertaining to sheep numbered 3, 8, and 11 have been omitted from the tables because these individuals were dipped on June 13.

Special observations were made on sheep No. 10. On June 20, 9 females and 3 males, collected by dragging, were scattered on the back, neck, and head of this sheep. Most of the ticks went beneath the wool immediately near where they were dropped. On the forenoon of June 21 a male and a female were found dead in the wool, the female on the head and the male on the side. A female, nearly dead, was also found in the wool on top of the head. The live ticks attached were a male and a female on top of the head at a place where the wool was very short. Six males and 12 females, collected by dragging, were now scattered on the head, neck, and back. In addition 1 female (one-twelfth engorged) which was picked from a saddle horse was placed on the back of the sheep at the edge of a spot where the wool had been worn short. In the afternoon 3 males were found dead in the wool on the back. These had never attached. The one-twelfth engorged female was found dead and shriveled about 8 inches from where it was placed, in heavy wool. Eight males and 5 females, collected by dragging, were scattered on back, neck, and head. On the morning of June 22, 3 males and 1 female were found dead in the wool. Two males were taken on the shoulder and the other 2 ticks were taken from the head. None had attached. The live ticks found attached at this time were 4 females and 3 males, between the folds of heavy wool. Two of the dead ticks that were removed were taken from a fold where 2 females and 1 male had attached. The attached ticks were scattered as follows: 2 females and 1 male in a fold near each other; 1 male and 1 female near each other in another place; and 1 male and 1 female, each alone, at still other places. All were in long wool. A male, barely alive, was crawling at the edge of the short wool spot mentioned before. On the forenoon of June 23, 2 females and 1 male previously found attached were dead. These ticks were still attached when found. Two dead males and 3 dead females were also found. These had never attached. They were picked, 2 from the back, 2 from the head, and 1 from the neck. One of those on the back was a tick spoken of before as barely alive. At this time 1 female was found slightly engorged. A male was seen to be attached on the neck. A female loose in the wool appeared entangled. In the afternoon of this day 4 females and 1 male, collected by dragging, were put on the head, neck, and back of the sheep, as was also a male which had fed. All ticks went quickly under the surface of the wool. On the morning of June 24 the female that appeared entangled in the wool was dead. Three males and a female were picked from the wool, dead. These had never attached. Two females and 1 male were attached. The

2 females were ticks put on the day before. The male was attached before. Two females, 1 on the head and 1 on the back, were barely alive. On June 25, 2 dead females were picked from the wool on the head. They had never attached. One dead female was picked from the wool on the back. This tick was spoken of as barely alive. There were 3 females attached in long wool, 1 of which was engorged a little.

The following notes show the progress of the experiment:

June 27, a. m.: The 3 females are engorging to some extent. A male is under the largest of the three.

June 28: One of females on the head, which had begun to engorge, is now dead. This female was probably killed by the host. There are 3 females attached and feeding on the head. The largest is one-twentieth engorged.

June 29, a. m.: One dead male was taken from the neck and a dead female from the shoulder. The female had been attached. The one-twentieth engorged female is now missing.

June 30, a. m.: Two males and 2 females are attached on the head. Both females are feeding.

June 30, m.: One female, collected by dragging, was put on head.

July 1, a. m.: One female was picked from shoulder, which had never attached. The 2 males and 2 females are still attached as before. One female, collected by dragging, was put on the head. This female attached near one of the other females.

July 2: The female put on yesterday is attached as well as the other females. Two females are now one-twelfth engorged. The two males are attached as before.

July 3, a. m.: Three females and 2 males are now attached. The female put on sheep July 1 has moved one-half inch from its former place. Two females are about one-tenth engorged.

July 3, p. m.: One of the females that had become one-tenth full is now missing. The other is one-seventh engorged. Only 1 male was noticed attached.

July 5, a. m.: The female that was spoken of as one-seventh full is now full or nearly so and has a male beneath. This is the first time that a male has been seen near this female. The engorged female was picked.

July 6: One dead unfed female was picked from back. One male and 1 female are now attached.

July 7, a. m.: The male that was seen under the engorged female is now dead. It is crushed as though by the host. The female put on July 1 is now one-fifteenth engorged.

July 7, p. m.: A thorough examination was made at this time. Two dead females (unfed) and a dead male were picked from the back and sides of the sheep. The attached female is one-twelfth full.

July 8: The attached female is about one-sixth full. No males are near.

July 9: The attached female is about one-fifth full. No males are near.

July 10: The attached female is about one-fourth full. No males are near.

July 11: The attached female is about one-fourth full. No males are near.

July 12: The female is not attached, but is loose in the wool near its former place of attachment. It has begun to shrivel.

July 13: The female is dead in the wool at same place. It is shriveled and discolored.

The following notes record the observations on sheep No. 11:

June 23. The sheep thoroughly examined and no ticks found.

June 25, a m.: Four males and 11 females, collected by dragging, were put on the head, neck, and shoulders of the sheep. A male and a female of the foregoing were put in a fold close to the skin. The ticks put on the surface were out of sight in a few minutes.

June 25, p. m.: A dead male and a dead female were picked from the wool. The male had his head near the skin but had apparently never attached. Two females and one male were alive loose in the wool. The female that was placed in wool next to the skin is attached. The male is not where it was placed.

June 26, a. m.: A male and a female were picked from the head, both dead. These ticks had been attached. The female that attached in the fold where it was put is no longer there. No ticks are now attached.

June 27: Two females, collected by dragging, were put on the base of the sheep's ear; also 1 female (one-fourth engorged), picked from saddle horse, was put on the sheep's back. One dead unfed female was picked from the side. The tick had never attached.

June 28, p. m.: Two partly fed males were put on the head of the sheep. One of the 2 females put on the ear was found dead at the base of the ear. It had never attached. One female was loose on the head, crawling. The one-fourth engorged female was still alive, but has not attached.

June 29: Two males and an unfed female found dead in wool on the head. The partly fed female is now dead.

June 30, a. m.: One dead male was picked from wool on the head.

July 1: One female about one-twelfth engorged was picked from a saddle horse and placed in wool on the sheep's head next to the skin.

July 2: The partly engorged female is now dead.

July 9: No ticks were found after a thorough examination.

Table IV gives a summary of the experiments with sheep Nos. 10 and 11.

TABLE IV.—*Summary of experiments with individual sheep.*

Details.	Sheep No. 10.		Sheep No. 11.	
	Male ticks.	Female ticks.	Male ticks.	Female. ticks.
Total number ticks put on sheep	19	33	4	13
Total dead unfed ticks which never attached	15	13	5	4
Total ticks which attached but died quickly	1	5	0	2
Total ticks which fed some but died or were killed before attaining any size	1	2	0	0
Partly engorged females which died quickly when put on sheep	0	1	0	2
Total dead ticks recovered	17	21	5	8
Dead unfed ticks:				
From head	3	8	5	5
From neck	2	10	0	0
From back	8	9	0	0
From side	0	0	0	1
Total ticks known to have attached	4	7	0	1
Total female seen with males beneath	0	2	0	0
Total engorged females recovered	0	1	0	0

It is a fact generally recognized that animals in confinement will fight ticks more than animals running free. This fact will probably account for the small number of ticks which were successful in engorging. The last female on sheep No. 10 would probably have become engorged had it been fertilized, for fertilized females engorge rapidly, whereas with infertile females engorgement is slow.

THE APPLICATION OF THE INFORMATION OBTAINED TO PRACTICAL ERADICATION.

The main point to be considered in the last experiment is the fact that of 33 females put on sheep No. 10, only 1 fed sufficiently to lay eggs. There were in all, however, 6 females which stood a fair chance of engorging, so that it is difficult to say what percentage of females that get on a sheep in nature will engorge to repletion. If we assume that 6 females would have fed to repletion in nature, we find that 5.5 per cent of those females which got on the sheep became engorged. In the experiment with 2 sheep, at the end of 6 days these animals had picked up at least 19 females, of which 13 females attached. At the same rate in 30 days sheep No. 10 would have had attached 80 females and would have picked up 94 females. If we take 5.5 per cent of 94 we have 5.17 females which would engorge to repletion in a month. We would have to assume this many to be the maximum for the sheep with heavy wool in the experiment. The minimum would be 0, since there were 2 sheep which had no females attached at the examination. It would be impossible to strike an average, but let us assume that each sheep would breed, on an average, 2 ticks per month. We would then have, for a herd of 1,000 sheep, 2,000 ticks per month during the tick season. Each female means about 4,000 larvæ. This would make 8,000,000 larvæ, which is a rather large number, though it is of course impossible to estimate what percentage of these would ever reach maturity. It might, however, be possible to eliminate the sheep which are likely to breed the majority of the ticks. Could this be done, it would be possible to use sheep in the destruction of ticks without dipping them. Until that fact is demonstrated, however, it would seem necessary to dip sheep along with other live stock in case they were allowed to run in "ticky" country. Even if it were not necessary to dip sheep with heavy wool, it would certainly be necessary to dip lambs or sheared sheep. A mere glance at the table will show that lambs or sheared sheep will breed a considerable number of ticks and kill but few. The only possibility, therefore, of employing sheep in the work of tick eradication would be the using of wethers of other sheep with heavy wool. It does not appear practicable to attempt to use wethers alone, under any circumstances, as a means of ridding the Bitter Root Valley of spotted fever ticks. Nevertheless it would appear to be possible to use sheep as one means of reducing the numbers of the ticks, although in this connection several considerations must be mentioned.

There would be some very serious objections to using sheep exclusively in the destruction of ticks, even though they should be found to kill practically all the ticks which get on them. In the first place, it would be necessary to eliminate all live stock except this on which the ticks could be destroyed at weekly intervals by dipping or otherwise. Secondly, it is impracticable to stock heavily a given area with sheep and attempt to carry the usual number of other live stock on the same pastures. It would thus be necessary to reduce greatly the number of live stock other than sheep in order to graze a sufficient number of sheep to have any appreciable value as collectors of ticks. Moreover, it would be necessary to cut down all vegetation higher than a sheep's back, for there are many ticks that await a host higher than 2 feet from the ground. It would also be necessary to drive the sheep where the ticks were known to be located, for the sheep naturally go where the feed is best. In the locality where the experiment with 20 sheep was carried on it was found that there were few ticks where the feed was abundant, but many next to the foothills and in the ravines where the feed was scarce. The character of the country on the western side of the valley in many places is also such that it would not admit of herding sheep. Should sheep run continuously in the wooded and brushy country on the western side of the valley they would wear off the wool, which would make them increasingly more susceptible to tick attack and less profitable to the owners.

The tendency of the tick to attach in bunches would indicate that in case ticks obtained a start on any animal they would breed on that animal with increasing facility; for it would be more easy, as the females enlarged, for the males to find them. Since most of the engorged females picked from the sheep in the experiment had males beneath them, and all of the females which were removed when well engorged deposited eggs which hatched normally, there appears to be little likelihood that there would be many females to drop which would not be fertile.

The possibility that sheep may serve as a reservoir for the virus of spotted fever is a point that should be tested before sheep are used at all in the destruction of ticks.

It appears, however, that sheep are very good collectors of ticks. Six sheep with heavy wool picked up in 11 days about 72 females and 47 males. Although no comparative experiment has been performed, it is the writer's opinion that 6 horses or 6 cattle under the same conditions would not have picked up and retained nearly that number. Therefore in "ticky" country which is favorable to the herding of sheep it would be advantageous to use sheep as collectors of ticks. By dipping the sheep once in 7 days it would seem that much good could be accomplished. To bring about the greatest good it would be necessary to herd the sheep with a knowledge of the location of the ticks. It is extremely doubtful if sheep would be of much importance as collectors of ticks if they were allowed to run free.

The several limitations to the practicability of using sheep in the eradication of the spotted fever ticks that have been mentioned emphasize the great importance of following the plan of dipping domestic animals which is successfully under way. Sheep may be used under some conditions in the work, but the main reliance must be upon the dipping of horses and cattle. The extent to which sheep may be used will depend upon future experiments and observations.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1913

BULLETIN OF THE
U. S. DEPARTMENT OF AGRICULTURE
No. 59

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 19, 1914.

(PROFESSIONAL PAPER.)

IV. INSECT.

THE TOBACCO SPLITWORM.

By A. C. Morgan and S. E. Crumb,
Of Southern Field Crop Insect Investigations.

INTRODUCTION.

The following account of the tobacco splitworm (*Phthorimaea operculella* Zeller), although not complete, contains data not heretofore published. The life history notes, description of stages, etc., were made by the junior writer. Credit is due the senior writer for the observations made in Florida and for the recommendations under the heading: "Remedial measures."

In California this insect is a serious potato pest, and Dr. F. H. Chittenden[1] reports that in 1912 two growers at El Monte, Cal., lost $90,000 and $70,000, respectively, on the crop of that year. Although quite generally distributed over the Southern States, this insect has caused serious loss to tobacco growers in only one locality, viz., Dade City, Fla. The injury at that place was severe in 1906, more severe in 1907, and culminated in 1908 in a conservatively estimated loss of $150 per acre—a loss totaling $12,000 for the 80 acres of shade-grown tobacco. The injury since 1908 has been very light, due in part to the early planting and in part to the very careful and very thorough remedial measures employed.

The variation in food habits, which is noted later, had created the suspicion that the form working upon potatoes might be specifically distinct from the one attacking tobacco. During the summer of 1913 experiments were conducted to determine this point.

EXPERIMENTS ON THE SPECIFIC STATUS OF THE TWO FORMS.

The potato-tuber moths used in these experiments were of the habitual potato-feeding type from Whittier, Cal., kindly furnished by Mr. J. E. Graf. The splitworm moths were of the habitual tobacco-feeding type from Florida, North Carolina, and Virginia.

[1] Chittenden, F. H., 1912. The potato-tuber moth. A preliminary account. (*Phthorimaea operculella* Zell.). U. S. Dept. Agr., Bur. Ent., Circ. 162, p. 2. Chittenden, F. H., 1913. The potato-tuber moth. U. S. Dept. Agr., Farmers' Bul. 557, p. 2.

Larvæ of the potato-tuber moth were reared on potato tubers and on the foliage of *Solanum carolinense*, eggplant, *Physalis* sp., *Datura stramonium* ("jimsonweed"), and tobacco; they also mined the leaves of *Solanum nigrum* until the plant died. Larvæ of the tobacco splitworm moth were reared on potato tubers and on the foliage of *Solanum carolinense*, eggplant, *Physalis* sp., *Physalodes physalodes*, *Datura stramonium*, and tobacco. There was no perceptible difference in the period of development, in habits, or in behavior of the two forms on a given food plant that could be ascribed to the different origins of the individuals. A male potato-tuber moth of the habitual potato-feeding type and a female splitworm moth of the habitual tobacco-feeding type, reared from isolated pupæ and caged together, produced larvæ that reached maturity upon tobacco.

The earliest stages of the two types show no appreciable differences except in the case of the larva, and here the differences, excepting size, are entirely colorational. The larva on potato is larger, grayish, and has the mesothorax and metathorax pinkish, while the habitual tobacco feeder is green and has the mesothorax and metathorax deep maroon. By reversing the two food plants the larvæ can be made to approach each other in coloration, but even after two generations on tobacco the habitual potato feeder is less green and has the thorax distinctly paler than the habitual tobacco feeder; also, the coloration of the latter type persists when reared upon potato tubers. The larvæ of the crossed moths were intermediate in coloration between the two types just discussed.

The rather persistent color variation noted in the two larval types under discussion, while probably of sufficient constancy to warrant a varietal separation, is not, the writers believe, of sufficient importance to justify a specific separation.

Potato-tuber moths reared from potato are usually somewhat larger than splitworm moths reared from tobacco. This difference disappears when the potato-tuber moth is reared on other plants. Potato-tuber moths reared from potato tubers, *Physalis* sp., *Solanum carolinense*, tobacco, and *Datura stramonium*, and splitworm moths reared from tobacco, potato tubers, and *Physalis* sp., were submitted to Mr. August Busck, who reported that he could find no specific differences.

DISTRIBUTION.

In the United States the species occurs in California and southward from a line connecting the District of Columbia and Colorado. The definite localities include Tennessee, Virginia, North Carolina, South Carolina, Florida, and Texas. Reports of more northern occurrence are probably due to the shipment of infested potatoes into these localities. The known range also includes Cuba, Costa Rica, Peru, Hawaii, Australia, Tasmania, New Zealand, Sumatra, Transvaal, Algeria, and southern Europe.

COMMON NAMES.

Phthorimaea operculella when working upon tobacco is known as the tobacco splitworm and the tobacco leaf-miner; when working upon potatoes it is known as the potato-tuber moth and the potato moth.

FOOD PLANTS.

The known food plants of *Phthorimaea operculella* include *Solanum torvum, S. verbascifolium, S. carolinense, S. nigrum*(?), eggplant, potato, tomato, *Physalis peruviana, Physalis* sp., *Physalodes physalodes, Datura stramonium*, and tobacco.

FOOD HABITS.

The larva occurs as a borer and also as a leaf-miner. The former is probably the original habit, examples of which have been observed by Quaintance in the fruit of eggplant, by Kotinsky in tomatoes, and by C. W. Howard and Oliff in the stems of tobacco. Dr. L. R. De Bussy considers this the more common form of injury to tobacco in Sumatra, where the larva forms a gall in the stem. C. W. Howard reports a similar habit of the larva in the Transvaal.[1]

In Cuba and the United States the insect is known on tobacco as a leaf-miner only. A boring tendency is still apparent, however, as noted by Houser, in that the larva usually tunnels the midrib or a vein in addition to mining the membrane of the leaf. In about 50 mines examined by us the larva had also tunneled the midrib or a vein in almost every case.

Only the older tobacco leaves are affected, unless the infestation is very severe; and in these, the lower leaves, grayish, irregular blotches are produced, which later turn brown and become fragile, so that the tobacco is unfit for wrappers. At Clarksville, Tenn., where the infestation is very slight, the larva in most cases begins work in the "ruffles" along the midrib and may afterward migrate and form mines in various parts of the leaf.

In forming its mine the larva begins by spinning a tent of silk between the midrib, or between the vein and the surface of the leaf. Under this protection it soon forms a shelter between the leaf surfaces by consuming the parenchyma. The mined leaf becomes more or less distorted, and this is especially noticeable on leaves,

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[1] *Gnorimoschema heliopa* Low causes similar injury to tobacco in India, Ceylon, and Java.

such as those of *Solanum carolinense*, which the larva is more capable of manipulating, but there is no tendency to form a firm, cylindrical, silk-lined tube, as is the case with the blue or bluish-green larva of *Phthorimaea glochinella* Zell., which feeds upon some of the same plants as does *Phthorimaea operculella*.

DESCRIPTION OF STAGES.

THE EGG.

The egg is pale, translucent, yellowish gray, and strongly iridescent; it is oval, 0.45 mm. long, 0.35 mm. broad at the middle, membranous, and without apparent sculpture. The side upon which it is deposited is slightly flattened.

THE LARVA.

The full-grown larva is 7 to 14 mm. long. The head shield is 0.80 to 0.86 mm. broad and fuscous brown. The cervical shield is darker brownish fuscous, with a pale mid-dorsal line, shining, the posterior margin medially straight. The anal shield is brown. The mesothorax and metathorax are deep maroon. The body varies in color through green and gray and is overlaid dorsally with purplish as the larva nears pupation. It is slender, tapering from the mesothorax posteriorly and set closely and uniformly with minute granules each bearing a minute point, the granules of the thorax and the last abdominal segment being the larger. The tubercles and their setæ are inconspicuous, brownish; tubercle II is slightly larger than I. The legs are deep fuscous; the prolegs, green.

The larva which has just emerged is light grayish, with strongly contrasting dark head and cervical shield.

Larvæ which have been reared habitually upon potatoes are of a larger average size than those reared upon tobacco, and the maximums of the foregoing measurements are from potato-feeding larvæ. The larva on potato is more grayish on the body than the tobacco miner and has the mesothorax and metathorax pinkish instead of deep maroon.

THE PUPA.

The pupa is yellowish brown, 5.5 to 7 mm. long and 1.5 to 2 mm. broad; it is broadest through the metathorax, tapering both anteriorly and posteriorly. The head is rather distinct and slightly nodding. The abdomen, excepting the last three segments, is set with very minute spinules; it bears at the tip mid-dorsally a short, curved, erect, pointed horn flanked by about four pairs of long hooked spinules, and ventrally a pair of blunt, rounded lobes beneath which are about four pairs of long hooked spinules. Each abdominal segment is set with a transverse row of spinules near the anterior margin.

As in the case of the larvæ, the pupæ of the habitual potato feeder are larger than those from the habitual tobacco feeder and the maximum measurements in the foregoing description are from potato-reared pupæ.

The adult is a slender, inconspicuous moth with dark grayish wings bearing indefinite yellowish streaks and having an expanse of about 20 mm.

LIFE HISTORY.

At Clarksville, Tenn., the splitworm requires 25 to 30 days in summer for completing its development from egg to adult. Of this time 4 days are spent in the egg stage, 15 to 17 days in the larval stage, and 6 to 9 days in the pupal stage. The length of these stages is considerably affected by temperature, as is indicated in detail in the accompanying tables. By reference to Table III we see that at an average mean temperature of about 81° to 82° F. the minimum pupal period is obtained, and that when the average mean temperature falls below about 68° to 70° F. the pupal period is very greatly lengthened.

Eggs are deposited singly upon the foliage of the host plant. Moths begin to oviposit two or three days after emergence and continue ovipositing for several nights. The largest number of eggs obtained from a single moth was 46, but this probably does not represent the maximum oviposition under normal conditions.

The larva is very active, is capable of prolonged exertion immediately after hatching, and clings very tenaciously to the foliage. The frass is either stored in a particular part of the mine or is cast outside where, in the case of those working upon potato tubers, it forms masses held together by silk. The larva pupates in a slight but somewhat tough cocoon of silk and débris among clods or rubbish at or near the surface of the soil.

TABLE I.—*Length of egg stage of tobacco splitworm.*

Eggs deposited night of—	Eggs hatched night of—	Egg stage.	Average mean temperature.
		Days.	° *F.*
June 15, 1910	June 19, 1910	4	77.3
June 17, 1910	June 21, 1910	4	79.5
June 22, 1910	June 27, 1910	5	80.5
July 3, 1913	July 7, 1913	4	82
July 3, 1913	July 7, 1913	4	82
July 4, 1913	July 8, 1913	4	80.9
July 5, 1913	July 9, 1913	4	79.7
Aug. 5, 1913	Aug. 8, 1913	3	88.6
Aug. 6, 1913	[1]Aug. 10, 1913	3½	88
Aug. 21, 1913	Aug. 25, 1913	4	72.6
Sept. 11, 1913	Sept. 15, 1913	4	81.9
Sept. 12, 1913	Sept. 16, 1913	4	82.4

[1] Forenoon.

TABLE II.—*Length of larval stage of tobacco splitworm.*

Egg hatched night of—	Larva pupated night of—	Larval stage.	Average mean temperature.	Food plant.
		Days.	° *F.*	
June 21, 1910	July 6, 1910	15	78.7	Tobacco.
July 9, 1913	July 25, 1913	16	81.1	Do.
Aug. 25, 1913	Sept. 10, 1913	16	81.2	Do.
Aug. 25, 1913	Sept. 11, 1913	17	81.1	Do.
Sept. 27, 1911	Nov. 3, 1913	37	64.4	Do.

The lengths of the larval stage given above are corroborated by about 25 records giving the combined length of the larval and pupal stages.

TABLE III.—*Length of pupal stage of the tobacco splitworm.*

Number of individuals.	Larva pupated night of —	Moth emerged night of —	Pupal stage.	Average mean temperature.	Food plant of larva.
			Days.	° *F.*	
2	Apr. 21, 1909	May 14, 1909	23	65.1	Tobacco.
4	May 22, 1910	June 5, 1910	14	67—	Do.
1	July 6, 1910	July 14, 1910	8	83.3	Do.
1	July 25, 1913	Aug. 1, 1913	7	85.1	
[1] 3	Aug. 19, 1913	Aug. 28, 1913	9	77.1	Potato.
1	.....do........	.....do........	9	77.1	"Jimsonweed."
1	.....do........	Aug. 29, 1913	10	77.5	Potato.
[1] 1	Aug. 21, 1913	Aug. 30, 1913 [3]	8.5	76.4	Tobacco.
1	Aug. 27, 1911	Sept. 8, 1911	12	76.8	Do.
1	Aug. 31, 1913	Sept. 6, 1913	6	83.7	Do.
2	.....do........	.....do [3]......	5.5	83.7	Do.
1	.....do........	.....do [4]......	6—	83.7	Do.
3	Sept. 1, 1913	Sept. 7, 1913	6	83.7	Do.
1	.....do........	Sept. 8, 1913	7	83.2	Do.
1	Sept. 2, 1913	Sept. 9, 1913	7	81.8	Do.
1	Sept. 3, 1913	.....do........	6	81.4	Do.
1	.....do [2]......	.....do........	7	81.4	Do.
3	.....do........	Sept. 10, 1913	7	81	Do.
2	Sept. 10, 1913	Sept. 23, 1913	13	69	Potato.
1	.....do........	Sept. 24, 1913	14	69.1	Do.
1	Sept. 11, 1913	Sept. 27, 1913	16	68—	Tobacco.
2	Sept. 13, 1913	Sept. 29, 1913	16	67.6	Do.
1	Sept. 27, 1913	Oct. 9, 1913	12	70.4	Do.
1	Sept. 30, 1913	Oct. 15, 1913 [4]	15	68.3	Physalis.
1	Oct. 1, 1913	.....do [4]......	14	68.3	Do.

[1] Reared from moths of the habitual potato-feeding type. [2] Forenoon. [3] 2 p. m. [4] Afternoon.

SEASONAL HISTORY.

Full-grown larvæ have been received from Florida in late April, indicating that oviposition may begin in that region as early as March. Larvæ have not been found at Clarksville, Tenn., earlier than June 3, and moths have emerged in numbers as late as the middle of November. It seems probable that at least six generations are produced in Florida and that about three or four are produced at Clarksville, Tenn. Moths emerged in five cages at Clarksville November 14, 1913, and were still active December 15, 1913, upon which date about an equal number of cages still contained pupæ. These records seem to indicate that the winter is passed in both the pupal and adult stages. No larvæ, so far as known, have entered hibernation successfully.

PARASITES.

Kotinsky[1] records two larval parasites, *Chelonus blackburni* Cam. and *Limnerium polymesiale* Cam. About 25 per cent of the full-grown larvæ of a large shipment of splitworms, sent by Mr. G. A. Runner late in August, 1913, from Kinston, N. C., were parasitized. Several parasitic larvæ emerged from each splitworm which was killed at or just before the emergence of the parasite, and while still in the mine. The parasites spun their cocoons in the mine and sometimes within the larval skin. A single splitworm from which this parasite was reared was included in another large shipment of material sent by Mr. Runner from Appomattox, Va. Larvæ of this parasite which emerged from the host September 1, 1913, pupated September 3, and the adults emerged September 10, giving a pupal stage of seven days.

REMEDIAL MEASURES.

Quaintance[2] recommends the destruction of the larvæ in the mines by pinching, and the destruction of all trash in and around tobacco fields and tobacco barns. Both of these recommendations should be followed. However, in severe infestations it may be necessary to prime off and destroy the leaves infested by the earlier generations. A heavy infestation would ruin the leaves for wrappers, in which case the priming and destruction of the leaves will be a cheaper and more thorough method of destruction, for it will cause the death not only of the larvæ but also of a large number of eggs. This plan was pursued at Dade City, Fla., following the severe infestation of 1908, and with excellent results. Since that year, also, the crop has been transplanted much earlier than was the custom previously, and was matured before the appearance of the most destructive generation of the splitworm. Loss has been very light since 1908.

To summarize the remedial recommendations: (1) Transplant the crop as early as possible, in order to mature it before the appearance of the most destructive generation of the splitworm; (2) when the early infestation is very severe, prime off and destroy the infested leaves; (3) destroy all tobacco stubble as soon as the crop is harvested to prevent the breeding of a hibernating generation; (4) clean up and destroy all trash in and around tobacco fields and tobacco barns; (5) do not follow potatoes by tobacco, for the infestation of tobacco has been more severe in such cases than where a different rotation was followed; (6) grow potatoes as far as possible from tobacco fields.

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[1] Kotinsky, Jacob, 1906. Hawaii. Forester and Agr., v. 3, no. 7, p. 200–201.

[2] Quaintance, A. L., 1898. The tobacco leaf-miner (*Gelechia picipellis* Zett.). Fla. Agr. Exp. Sta., Bul 48, p. 178–181.

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DIV. INSECTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 78

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
May 18, 1914.

(PROFESSIONAL PAPER.)

THE SO-CALLED TOBACCO WIREWORM IN VIRGINIA.[1]

By G. A. Runner,
Entomological Assistant, Southern Field Crop Insect Investigations.

INTRODUCTION.

For the study of insects injurious to tobacco the Bureau of Entomology during the last four summers has maintained a temporary field station at Appomattox, Va. Work of this station has been under the direction of Mr. W. D. Hunter, in Charge of Southern Field Crop Insect Investigations, and more immediately under the supervision of Mr. A. C. Morgan. Laboratory quarters were furnished by the Tenth Congressional District Agricultural School. The results of investigations of the tobacco Crambus (*Crambus caliginosellus* Clem.) are given in this bulletin.

The work in Virginia was in cooperation with the State experiment station and the Bureau of Plant Industry of the U. S. Department of Agriculture. Through an agreement with the cooperators, the Bureau of Entomology was furnished all data pertaining to the rotation of crops grown in connection with tobacco, and the plats of the several tobacco stations in the State were placed at the disposal of the agent in charge, for inspection and experiment. The records of these stations, extending over a series of years, are of great value in determining the crop rotations and cultural methods of control best adapted to the special conditions to be dealt with in different tobacco sections.

The experimental work with tobacco in Appomattox County, Va., was begun by the Bureau of Soils in 1904. The work has since been conducted cooperatively by the Bureau of Plant Industry and the Virginia experiment station. Since the first, owing to the work of

[1] Throughout the tobacco-growing sections of Maryland, North Carolina, and Virginia the larvæ of the tobacco Crambus are generally known as "wireworms." They are also known in other sections as "tobacco wireworms," "budworms," "corn worms," "stalk worms," "heart worms," "cutworms," "stem worms," "root webworms," and "screw worms." In parts of Tennessee and Kentucky the larvæ are commonly called "screw worms." The term "wireworm" is also applied, as in other sections, to the true wireworms (larvæ of Elateridæ), which the Crambus larvæ in no way resemble.

Note.—This bulletin is descriptive of an insect enemy of tobacco and corn. Of especial interest in the eastern tobacco and corn districts.

the tobacco Crambus, great difficulty has been encountered, in many of the experiments, in getting the perfect stand of plants so essential for comparative tests. This led to a study of the life history of the insect and of the somewhat extensive cultural experiments by the Bureau of Entomology aimed at its control. The effect of certain crop rotations in reducing injury from the tobacco Crambus was noticed during the early progress of the cultural investigations by Mr. E. H. Mathewson, Crop Technologist of the Bureau of Plant Industry, to whom the writer is indebted for suggestions concerning the cultural methods of control undertaken by the Bureau of Entomology.

GENERAL HABITS AND ECONOMIC IMPORTANCE OF THE GROUP TO WHICH THE TOBACCO CRAMBUS BELONGS.

The larvæ of insects included in the family Crambidæ, to which the tobacco Crambus belongs, feed mainly on the grasses (Gramineæ), although some of them subsist on plants of other families. Many construct tubular, web-lined galleries near the roots of the plants on which they feed, and some bore or tunnel into the roots or stems; for this reason they have been named "root webworms." The moths, or adults, are medium or rather small in size, with brown, yellow, or white colors prevailing. Many species have metallic markings on the forewings, which are comparatively long and usually narrow. When at rest the forewings are rolled around the body and conceal the hind wings, which are folded beneath. This gives the body the appearance of a tiny cylinder, and accounts for the term "close-wings." The species are widely distributed over the globe, but are apparently most numerous in temperate climates. In North America comparatively few are known, and the majority of these belong to the genus Crambus, in which Dr. H. G. Dyar[1] catalogues 60 species.

Moths of the genus Crambus fly mostly on dark afternoons and during the early part of the night. They are more common in open fields. When disturbed they make short erratic flights, rarely flying more than a few rods at a time. They usually alight head downward on the stems of plants, and their color often harmonizes so perfectly with their surroundings that they can with difficulty be seen. Most of the species are single-brooded; but as the moths of different species emerge successively throughout the season, one or more of the latter are present in most localities from spring until late fall. Though various species of Crambus are common in most localities, they seldom attract much attention unless some important crop is attacked. This is due (1) to the fact that the moths are small and inconspicuous, (2) to the underground feeding habits of the arvæ, land (3) to the fact that damage from different species is distributed throughout the growing season.

[1] Dyar, Harrison G. A List of North American Lepidoptera * * *. U. S. Nat. Mus. Bul. 52, pp. 404-410, 1902.

The principal species of the genus of economic importance in this country are: *Crambus caliginosellus* Clemens, which attacks tobacco and corn; *C. vulgivagellus* Clemens, an enemy of corn, wheat, rye, and grasses; *C. trisectus* Walker, an enemy of grasses, oats, and corn; *C. laqueatellus* Clemens, which attacks corn and oats; *C. zeellus* Fernald, *C. luteolellus* Clemens, and *C. mutabilis* Clemens, enemies of corn; and *C. hortuellus* Hübner, which is injurious to the cranberry. The wide distribution of several of these and their great capacity for injury give them rank as species of considerable economic importance. Damage by them to cultivated crops is, in most cases, the result of unusual conditions. Their range of food plants is not large, and the larvæ are inclined to remain in or near one place. The moths frequent the weedy fields, pastures, or meadows which contain the natural food plants of the larvæ, and the greater number of eggs are deposited in such localities. When such land is plowed up the larvæ are forced to live on other than their natural food plants. With crops such as corn and tobacco this means a concentration of larvæ from many of the wild or natural food plants to the comparatively few cultivated plants.

ECONOMIC IMPORTANCE OF THE TOBACCO CRAMBUS.

The tobacco Crambus (*Crambus caliginosellus* Clem.) occurs in most, if not all, of the tobacco-growing districts of the Eastern States, but it seems to be most destructive in certain sections of Maryland and Virginia. It is especially destructive in the famous "dark-tobacco district" of the Piedmont section of middle Virginia, although found in all sections of the State in which tobacco is grown. In Virginia the damage to the tobacco crop alone from the insect is estimated to average at least $800,000 annually.

At the Virginia tobacco experiment stations, at Appomattox, Bowling Green, and Chatham, injury has been recorded for a number of years. The reduction in value of the crop has been great, amounting to about 14 per cent annually, through failure to secure an early stand of plants. At the Appomattox Station, in one of the experimental fields, there was a loss in 1910 amounting to about 27 per cent. In 1911 there was still greater loss in some of the plats. In many fields in the county fully one-half of the plants were attacked, making several replantings necessary. At the Chatham Station in 1909 there was an estimated decrease in the value of the crop amounting to about $15 per acre.

In 1912 considerable damage occurred to tobacco in Montgomery County, Tenn., and in Christian and Todd Counties, on the southern border of Kentucky, growers in a number of instances reporting fully 40 per cent of the plants destroyed.

The insect has for many years been a serious pest to tobacco and corn in Maryland. W. G. Johnson, formerly State entomologist, recorded the species as extremely abundant and destructive in Prince Georges, Cecil, Kent, Queen Anne, and Dorchester Counties in 1897, and reported damage in various parts of the State in 1898, 1899, and 1900, many fields of young corn being almost completely destroyed.

M. H. Beckwith mentions it as injurious to corn in Delaware, and John B. Smith has recorded injury to corn in New Jersey.

ORIGIN AND DISTRIBUTION.

Crambus caliginosellus has been recorded only from North America. Its preference for the naturalized buckhorn plantain and oxeye daisy as food plants, however, points to the possibility that it has been introduced from Europe.

In literature the recorded distribution of the species is as follows: Ontario (Saunders, Felt, and Fernald); New York (Grote, Felt, and Fernald); Delaware (Beckwith); New Jersey (Smith); Maryland (Johnson and Howard); Massachusetts, Pennsylvania, District of Columbia, North Carolina, Illinois, and Texas (Fernald); Virginia (Mathewson, Anderson, and Runner); Ohio (Gossard).

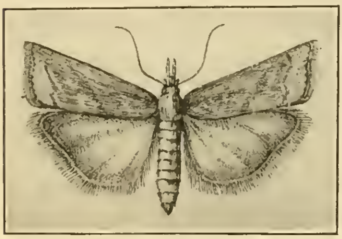

Fig. 1.—Adult, or moth, stage of the tobacco Crambus, or "wireworm" (*Crambus caliginosellus*). Enlarged. (Original.)

In collections in the National Museum are specimens from the following localities: Washington, D. C. (August Busck); Plummers Island, Md. (H. S. Barber); Plainfield, N. J. (F. O. Herring); Pittsburgh, Pa. (H. Engel); Clarksville, Tenn. (A. C. Morgan); Chapel Hill, Tenn. (G. G. Ainslie); Vienna, Va. (R. A. Cushman).

Records of the Bureau of Entomology show the insect to be present in Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Ohio, Tennessee, and Kentucky.

These records indicate a wide distribution, but as most reports of injury to cultivated crops come from certain portions of the Eastern States it is probable that severe injury occurs only in localities where natural food plants are exceedingly abundant, and where crops subject to injury are planted at the time the larvæ are completing their growth and are in their most active feeding stage.

SEASONAL HISTORY.

The moths (fig. 1) emerge during summer, the heaviest emergence occurring at Appomattox, in central Virginia, during the first and second weeks in August. The earliest emergence takes place during the latter part of June, but moths are not abundant until about the third week in July. From this time their numbers gradually increase until about the second week in August, when they are exceedingly numerous, at times appearing almost in swarms in weedy fields when disturbed. From the middle of August there is a rapid decrease and after the 1st of September only an occasional one can be found. Table I gives dates of emergence of moths from some of the field cages at Appomattox in 1910.

TABLE I.—*Emergence of moths of the tobacco Crambus in outdoor rearing cages at Appomattox, Va., 1910.*

Larvæ collected—	Food plant on which found.	Moth emerged—	Larvæ collected—	Food plant on which found.	Moth emerged—
1910.		1910.	1910.		1910.
June 4	Tobacco	July 2.	June 26	Tobacco	July 18.
Do	do	July 21.	Do	Wild carrot	Aug. 13.
Do	do	July 22.	Do	Tobacco	Aug. 6.
Do	do	Aug. 3.	Do	do	Aug. 15.
June 5	do	July 3.	June 28	Plantain	July 14.
Do	Corn	July 14.	Do	Daisy	Aug. 15.
Do	Senecio	July 22.	Do	Aster (stickweed)	Aug. 7.
Do	Plantain	July 23.	July 1	Plantain	July 29.
June 6	Corn	July 26.	Do	Tobacco	Aug. 14.
Do	Daisy	Aug. 1.	Do	Corn	July 27.
Do	Aster spp	July 29.			

The females die soon after egg laying is finished. There is apparently only one generation a year, the eggs hatching in summer and the larvæ completing their growth during the following year. The greater number of larvæ are in the pupal stage during the first half of July.

DESCRIPTION.

THE EGG.

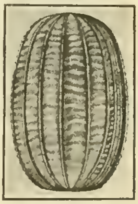

FIG. 2.—The tobacco Crambus: Egg. Greatly enlarged. (Original.)

The egg (fig. 2) is creamy white when first deposited, but gradually assumes a pinkish shade, which deepens to orange rufous before hatching. The average length is 4 mm. and the diameter 0.32 mm. It is regularly oval, with the ends slightly truncate, and has a polished appearance. There are about 18 longitudinal carinæ and numerous transverse striæ.

THE LARVA.

FIRST INSTAR.

When first hatched, the body of the larva is semitransparent, and the alimentary canal can be plainly seen. The outline of the body, when seen from above, is almost triangular. The larva is white, or pale yellowish white, and about 1 mm. long, with a few scattered, light-colored hairs on the head and body. The head shield measures 0.15 mm. in width, is yellowish brown, and moderately bilobed, with the clypeus attaining the apical third. The cervical shield is tinged slightly with brownish. Five pairs of prolegs occur on the 7th to 10th segments, inclusive, and on the 13th segment.

LAST INSTAR.

The full-grown larva (figs. 3, 4) is about 15 mm. long, and yellowish white, with a tinge of pink dorsally. The hairs of the body are slender, brownish, and set on large fuscous tubercles. The head shield measures 1.2 mm. in width, and is pale yellowish brown, flecked with darker brown. The cervical shield is distinct, shining, yellowish brown, tinged with fuscous, and bears 12 hairs in two transverse equal rows. The anal shield is pale fuscous. About the middle of abdominal segments 3, 4, 5, and 6, and slightly above the spiracles, is a series of distinct, dark fuscous, chitinous areas about the size and shape of spiracles, one to each segment.

The arrangement of the tubercles is as follows: Beneath the anterior margin of the cervical shield is a tubercle bearing two hairs. The mesothorax above bears eight setigerous tubercles on the anterior margin, each, except the lateral tubercle, with two hairs. Posteriorly it is provided with three bare tubercles, of which the median is narrow and transverse. The metathorax is armed, as is the mesothorax. Each abdominal segment above the spiracles bears two transverse rows of four tubercles each. The anterior dorsal pair are subquadrate, with the posterior lateral angles strongly rounded. The posterior dorsal pair are oblong, transverse, about half as long as the anterior, with the posterior lateral angles strongly rounded. The anterior lateral tubercles are supraspiracular, irregularly quadrate, with the lower margin produced diagonally behind the spiracle, emarginate at the spiracle and before the impressed area on segments 3, 4, 5, and 6. The corresponding tubercle on segment 8 has the produced portion isolated and is placed anterior to the spiracle. The posterior lateral tubercles are transverse, elongate, and somewhat oblique.

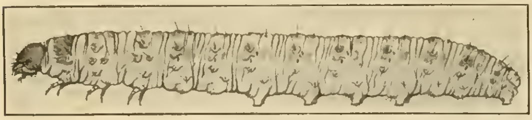

FIG. 3.—The tobacco Crambus: Full-grown larva, or "wireworm." Much enlarged. (Original.)

Abdominal segments 1 to 7 each bear a minute spinule anterior to and nearly equidistant from the spiracle and the supraspiracular hair.

The legs are pale brown, the maxillary palpi brown, and the mandibles brownish fuscous at apices.

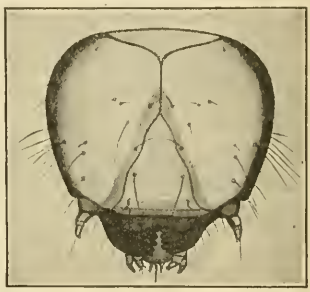

FIG. 4.—The tobacco Crambus: Head of larva. Greatly enlarged. (Original.)

The color of larvæ collected from different food plants varies considerably, this being merely an effect of the color, whether light or dark, of the food in the alimentary canal. Larvæ collected from corn are considerably lighter than those collected from tobacco.

THE PUPA.

The pupa (fig. 5) measures about 8 mm. in length and 2 mm. in greatest width. The general color is dark brown, or pale yellowish brown when newly transformed, with the appendages and segments marked with dark brown. The head is blunt, with a median apical emargination. The tips of the wings are rounding on abdominal segment 5; the margin of the inner wing is visible over segments 2, 3, and 4. The spiracles are not prominent, the first three pairs being set on blunt tubercles. The cremaster is transversely rounded oblong, with a lateral bristle near the apex.

THE ADULT, OR MOTH.

Expanse of wing, 13–25 mm. Head, palpi, and thorax dark fuscous, sprinkled with gray scales. Fore wing dark fuscous, sprinkled with brown or yellowish, and frequently with a few gray scales; median line dark brown, often edged with white, arising a little beyond the middle of the costa, extending outward, forming a very acute angle, thence backward across the end of the cell to the hind margin, a little beyond the middle, and giving off an outward angle on the fold. Subterminal line dark brown, edged outwardly with dark lead-colored scales, and frequently dentate along the first part of its course. It arises from the costa about half way between the median line and the apex, extending down to a point beyond the end of the cell, where it forms an outward angle, thence to the hind margin, a little within the anal angle, giving off an inward angle on the fold. This angle is frequently connected along the fold with the outward angle of the median line; terminal line dark brown, rather indistinct. The lines are often obliterated more or less, especially the median. Fringes dark leaden gray. Hind wings dark fuscous; fringes a little lighter. [Fernald, 1896.] (See fig. 1.)

The moths vary somewhat in color and distinctness of markings, some specimens being much darker than others when first transformed. In the hind wing the frenulum is a single short spine in the male. In the female the frenulum is more slender and is very finely divided at the tip. In the female of a number of other species of this genus the frenulum consists of two distinct spines.

FIG. 5.—The tobacco Crambus: Pupa. Much enlarged. (Original.)

LIFE HISTORY.

HABITS OF THE MOTHS.

The moths fly during late afternoon, on dark days, and during the early part of the night. They are attracted to light, but in comparatively small numbers considering their great abundance at certain times. The majority of the females collected at trap lights are those which have deposited their eggs. During the day, when disturbed, they make short, erratic flights, usually alighting head downward on the stems of weeds and grasses, their tightly closed wings and grayish color making them very inconspicuous. As with other members of the genus Crambus, their long palpi, extending parallel to the stem of the plant on which they are at rest, help to make the outlines of the body conform to the appearance of that part of the plant.

OVIPOSITION.

When the moths were confined in cages, the eggs were deposited at random over the surface of the ground. They seemed dry when deposited, rolled about easily, and did not adhere to papers placed over the soil in the rearing cages, or to glass when females were confined in large test tubes. Normally the eggs are doubtless placed in the same manner, for on two occasions eggs were found on the upper surface of leaves of sweetbrier lying flat on the ground. Egg laying commences shortly after the moths emerge. Fertile eggs were not obtained from moths reared in the cages.

Records obtained from a large number of females, collected in the fields and placed in separate cages for egg deposition, show the average number of eggs laid to be 177. Among the records obtained at Appomattox, Va., during 1910, are those in Table II.

TABLE II.—*Number of eggs laid by the tobacco Crambus, Appomattox, Va., 1910.*

No. of female.	Moth collected.	Period of oviposition.	Number eggs laid.	No. of female.	Moth collected.	Period of oviposition.	Number eggs laid.
	1910.	1910.			1910.	1910.	
1	July 8	July 9–13	218	10	Aug. 11	Aug. 12–15	83
2	do	do	68	11	do	Aug. 12–16	203
3	do	July 9–14	271	12	Aug. 14	Aug. 15–20	218
4	July 10	July 11–14	156	13	do	Aug. 15–18	194
5	July 12	July 13–18	211	14	Aug. 15	Aug. 16–20	222
6	July 17	July 18–22	316	15	do	Aug. 16–19	91
7	do	July 18–23	287	16	do	Aug. 16–21	238
8	July 25	July 26–30	77	17	do	Aug. 16–18	63
9	Aug. 11	Aug. 12–16	301				

Several individual females laid over 300 eggs, and over 300 were obtained in several instances by dissection. It is probable that the average number of eggs deposited normally is above rather than below the average obtained in the cages, as some of the moths may have laid eggs before capture, although records were not included from moths which deposited eggs within 12 hours after capture.[1]

The period of oviposition lasts from 3 to 5 days, the females dying shortly after egg laying is finished. The records of two females collected in the field on August 10, 1910, are given in Table III.

TABLE III.—*Rate of oviposition of the tobacco Crambus, Appomattox, Va., 1910.*

Female No. 1.		Female No. 2.	
Date.	Number of eggs deposited.	Date.	Number of eggs deposited.
1910.		1910.	
Aug. 11	7	Aug. 10	93
Aug. 12	89	Aug. 11	87
Aug. 13	70	Aug. 12	23
Aug. 14	36	Aug. 13	5
Aug. 15	19		
Total	221	Total	208

DURATION OF THE EGG STAGE.

The period of incubation was found to be from 5 to 9 days, the greater number of eggs hatching about the sixth day at ordinary summer temperatures.

[1] The dissection of 17 females of *Crambus caliginosellus* collected in the field during the third week in July, 1912, showed that 8 of the 17 collected contained more than 100 eggs. The number of eggs (mature or nearly mature) found in the 8 moths containing more than 100 eggs was as follows: 143, 322, 127, 290, 307, 124, 342, 208.

FIG. 1.—INJURY OF THE TOBACCO CRAMBUS, OR "WIREWORM," TO TOBACCO.

FIG. 2.—INJURY OF THE TOBACCO CRAMBUS, OR "WIREWORM," TO CORN.

WORK OF THE TOBACCO CRAMBUS.

FIG. 1.—POOR STAND OF TOBACCO RESULTING FROM PLANTING ON WEEDY LAND.

Note heavy growth of oxeye daisy in part of field not in tobacco.

FIG. 2.—WILD CARROT AND OTHER WEEDS IN FIELD OF RED CLOVER.

Injury from the "wireworm" occurs when land of this kind is planted in tobacco or corn.

RELATION OF WEEDY LAND TO INJURY BY TOBACCO CRAMBUS.

TABLE IV.—*Duration of egg stage of the tobacco Crambus, Appomattox, Va., 1910.*

Lot No.	Eggs laid—	Eggs hatching—	Incubation period.	Lot No.	Eggs laid—	Eggs hatching—	Incubation period.
	1910.	1910.	*Days.*		1910.	1910.	*Days.*
1	July 7	July 12	5	8	Aug. 12	Aug. 17–18	5–6
2	July 11	July 19–20	8–9	9	Aug. 13	do	4–5
3	July 12	July 19	7	10	Aug. 14	Aug. 19–20	5–6
4	July 13	July 19–20	6–7	11	Aug. 15	Aug. 20	5
5	July 25	July 31	6	12	Aug. 16	Aug. 21–22	5–6
6	July 26	Aug. 1–2	6–7	13	Aug. 17	Aug. 23–24	6–7
7	Aug. 11	Aug. 16–17	5–6				

HABITS OF THE LARVÆ.

NATURAL FOOD PLANTS.

Larvæ of the tobacco Crambus have been found feeding on the following wild plants:

Buckhorn plantain (*Plantago lanceolata*).
Oxeye daisy (*Chrysanthemum leucanthemum*).
Wild aster or "stickweed" (*Aster ericoides* and other species).
Wild carrot (*Daucus carota*).
Sheep sorrel (*Rumex acetosella*).
Senecio (*Senecio jacobæa*).
White-top (*Erigeron annuus* and other species).

The first two plants named, the buckhorn plantain and the oxeye daisy (Pl. II, fig. *a*), were found to be the main food plants of the larvæ in the localities studied. The eradication or control of these weed pests, therefore, will result in comparative immunity from loss by this insect. Both species of plants have been found heavily infested in many localities in widely separated sections. During early spring the plantain seems to be the preferred food plant; later a heavy infestation occurs on both plantain and daisy.

On July 8, 1910, 23 out of 25 oxeye daisy plants examined in a weedy field were infested, there being a total of 69 larvæ about the roots. As many as 20 larvæ have been collected from one plant of the oxeye daisy.

In tobacco-growing sections of Tennessee and Kentucky white-top is a frequent food plant.

When meadows are plowed up and planted to tobacco there is frequently serious injury from the "wireworms." (See Pl. II.) Where such injury has occurred the weeds mentioned above have invariably been found abundant in the sod, which explains the presence of the "worms." Injury has not been observed where there had been previously a clean growth of grass or clover. Attempts to rear adults from larvæ confined in field cages containing only timothy and clover resulted in failure, although the larvæ lived for a considerable time without other food.

INJURY TO TOBACCO.

The tobacco is attacked soon after planting, and feeding by the larvæ continues until the first or second week of July. The larvæ usually commence operations just below the surface of the ground, although newly set plants are frequently attacked at the "bud" or whorl of terminal leaves. As feeding continues the larvæ, especially the smaller ones, frequently enter the stalk and tunnel upward, the burrows often extending to the base of the first leaves and some distance above the surface of the ground. (See Pl. I, fig. *a*.) When not feeding the "worms" are found about the base of the plant, usually in cylindrical, web-lined galleries, which extend from the plant, often for several inches, beneath the surface of the soil.

Injured plants may usually be detected by their stunted or wilted appearance, which is more noticeable during hot, dry weather. The stems are in some cases entirely cut off, although this form of injury is rather unusual.

Although plants often partially recover they do not obtain full growth, and it is evident that the presence of many dwarfed or stunted plants must result in very materially lessening the yield. The value of the crop is greatly decreased also, owing to the large proportion of late plants resulting from replanting. Early planted tobacco is usually better in quality than the late planted, it being finer and more elastic, curing better, and consequently bringing higher prices. The attacks of the larvæ often make it necessary to reset the crop several times, and a good stand of plants is not secured, if at all, until too late to make the crop as profitable as it should be.

INJURY TO CORN.

Owing to its wide distribution in the Eastern States the tobacco Crambus is a serious pest to the corn crop. Injury has been noted in many localities where little tobacco is grown, and it is probable that damage to corn amounts to even more than that to tobacco. As with tobacco, injury is most severe when corn is planted on land which has been in weedy pasture or meadow previously, or when planted on land which has not been under cultivation for a number of years and on which there has been a rank growth of weeds. On such land it is usually difficult to secure a satisfactory stand of corn, and the yield is greatly reduced. (See Pl. I, fig. *b*.) In central Virginia many fields under observation were replanted several times, and owing to the lateness of the season when a stand was secured the value of the crop was decreased fully one-third. Corn or tobacco planted on newly-cleared land seldom suffers injury from the Crambus. Since the species of weeds which are the natural food plants of the insect do not thrive in woodland, the larvæ are not present when the crop is planted.

The larvæ attack the young corn near the surface of the ground and burrow into the base of the stalks, the outer portion of the stalk being frequently girdled. If the stalks are small when attacked, they are either killed or so stunted or dwarfed that they never fully outgrow the injury, and produce little or no grain. Much of the corn is attacked just after the seed has sprouted. The larvæ frequently burrow into the folded leaves as the corn is coming through the ground. As the leaves unfold they show transverse rows of holes. When the stalks reach a height of a foot or more comparatively little damage is done. Several larvæ are frequently found about the roots of a single stalk, and as many as 22 have been collected from a single hill of corn. In wet weather injury is not apt to be so severe, as the plants are then more vigorous and the weeds, which furnish suitable food for the worms, more plentiful. As with tobacco, corn is attacked when the natural food supply of the "worms" is cut off.

GENERAL FEEDING HABITS.

The feeding habits of the "wireworm" on plants other than corn and tobacco are, in a general way, the same. There is a tendency to girdle soft-rooted plants, such as plantain and the wild carrot (Pl. II, fig. *b*), and the larvæ are often found embedded in cavities where they have fed. The buckhorn plantain (*Plantago lanceolata*) is frequently killed where the infestation is heavy. A marked preference is shown for the natural food plants, and farmers, when the larvæ are especially troublesome, frequently take advantage of this fact by cultivating at first only one round to the row, allowing the weeds to grow in the center of the row until the corn or tobacco has become better established. In a plowed field the larvæ, if they have not finished feeding, concentrate about plantain, daisy, and stickweed (*Aster* spp.) which have not been killed by plowing.

The larvæ do not seem to travel far in search of food, as was ascertained by plowing badly infested land adjoining fields of corn and tobacco. When disturbed they crawl actively in either direction, and they will often spin a slender silken thread by which they may be suspended. They feed most actively at night.

THE PUPÆ.

The larvæ pupate in the soil near the plants on which they feed. Before pupation there often seems to be a rather long period during which the larvæ remain inactive in their cells. The pupal cells are usually found at a distance of from 1 inch to 6 inches from the base of the food plant and at a depth varying from one-half inch to 4 inches.

Table V shows the depths at which pupæ were found about various food plants in soils varying from hard stiff clays to loose sandy loams.

TABLE V.—*Depth at which pupation of the tobacco Crambus takes place, Appomattox, Va., 1910.*

Date.	Character of soil.	Food plant.	Depth.	Date.	Character of soil.	Food plant.	Depth.
1910.			*Inches.*	1910.			*Inches.*
July 9	Red clay	Tobacco	2.5	July 11	Red clay	Tobacco	1
Do	Sandy loam	do	3.5	Do	do	Corn	2.5
Do	do	Plantain	1	Do	Sandy loam	Daisy	.5
Do	Red clay	do	.5	Do	Red clay	Plantain	1
Do	Black loam	Daisy	4	Do	do	Daisy	1.5
July 11	Gray sandy loam	Tobacco	3.5				

Numerous measurements made at different times gave results very similar to those shown above. The average depth at which pupation takes place was found to be about 1.5 inches.

The cells averaged about 9.5 mm. in length and 4.5 mm. in width (inside measurements). The lower portion of the cell is usually somewhat larger than the upper portion, the pupa lying in the larger end of the cell in convenient position for its egress. The cells are extremely fragile and are easily broken when removed from the soil. They are constructed of fine particles of earth and grains of sand interwoven with a silky weblike material. The walls are thin and the interior surface quite smooth.

The pupal period, as shown in Table VI, lasts from 10 to 15 days.

TABLE VI.—*Pupal period of the tobacco Crambus, Appomattox, Va., 1911.*

Larvæ collected—	Pupated—	Moth emerged—	Number of days.	Larvæ collected—	Pupated—	Moth emerged—	Number of days.
1911.	1911.	1911.		1911.	1911.	1911.	
June 18	July 7–10	July 21	11–14	July 1	July 8	July 22	14
Do	July 10–11	do	10–11	July 12	Aug. 1–3	Aug. 15	12–15
June 20	July 7–9	July 22	15–17	Do	July 15	Aug. 1	15
Do	July 12	do	10	Do	July 28–31	Aug. 10	10–13
Do	July 15	July 26	11	Do	Aug. 1–2	Aug. 15	13–15
July 1	July 28–31	Aug. 10	10–13	Do	Aug. 1	Aug. 12	12

Table VII shows the duration of the period during which the insect is in the pupal cell before and after pupation.

TABLE VII.—*Duration of prepupal and pupal periods of the tobacco Crambus at Appomattox, Va., 1911.*

Number of record.	Larvæ ceased feeding—	Moth emerged—	Days.	Number of record.	Larvæ ceased feeding—	Moth emerged—	Days.
	1911.	1911.			1911.	1911.	
1	June 18	July 10	22	7	July 9	Aug. 1	23
2	do	July 15	27	8	July 11	July 24	13
3	do	July 16	28	9	July 13	July 29	16
4	July 3	July 18	15	10	July 14	Aug. 3	20
5	do	July 20	17	11	do	July 29	15
6	do	July 19	16				

NATURAL ENEMIES.

In spite of its long larval period the tobacco Crambus does not seem to be largely parasitized, at least during the later stages, this being due presumably to the subterranean habits of the larvæ and the protection afforded by the loose web in which they usually lie when not feeding. Nevertheless parasitic and predaceous enemies are doubtless factors in keeping the insect in check. The vast number of newly hatched larvæ as contrasted with the number found later in the season shows that comparatively few survive the earlier larval stages. This reduction is due in part to various natural enemies the exact or relative importance of which it is hard to estimate.

Various carabid beetles have been observed to feed on the larvæ. Among them were *Calosoma calidum* Fab. and *Chlænius tomentosus* Say. Adults and larvæ of Harpalus (*Harpalus pennsylvanicus* De G. and *H. faunus* Say) were observed to be very abundant about roots of oxeye daisy and plantain which were heavily infested with Crambus larvæ. As the species of Harpalus are known to be general feeders, they were thought to feed on the larvæ of the Crambus. The adults, when confined in tubes with larvæ, occasionally fed on them.

Spiders of several species were observed to feed on the larvæ, and large numbers of the moths are captured in spider webs in weedy fields.

Ants also occasionally attack the larvæ. An ant found carrying a partly grown larva at Chatham, Va., was examined by Mr. Theodore Pergande and found to be a species of Solenopsis.

W. G. Johnson, in Maryland, reported the rearing of an undetermined hymenopterous parasite from the larvæ. No parasitic Hymenoptera were secured from the rearing cages at Appomattox, although large numbers of larvæ were confined.

Several Diptera were observed in cages containing larvæ on various occasions, but actual proof of parasitism was not obtained, although a species of Phoridæ was secured from tubes containing larvæ under circumstances pointing strongly to parasitism.

In the National Museum are specimens of a hymenopterous parasite, *Perisemus prolongatus* Prov., labeled as reared from larvæ of *Crambus caliginosellus* from La Fayette, Ind. The record is doubtful, however, as the notes concerning the specimens in the files of the Bureau of Entomology clearly refer to a different species of Crambus as the host.

Birds are a factor in keeping the tobacco Crambus in check. Two species, the quail (*Colinus virginianus*) and the kingbird (*Tyrannus tyrannus*) were observed by the writer to capture the moths, and others are known to feed freely on moths of this genus. F. M. Webster states that the wood pewee (*Myiochanes virens*) was observed to destroy large numbers of *Crambus laqueatellus* at Haw Patch, Ind., and C. H. Fernald observed barn swallows feeding on different species of Crambus in Maine. Meadowlarks frequent weedy fields which harbor the larvæ of Crambus, and as these birds are known to feed on various species of cutworms, they doubtless feed also on the larvæ of the tobacco Crambus.

REPRESSION.

CULTURAL METHODS OF CONTROL.

Injury from the tobacco Crambus occurs where crops susceptible to injury are grown on weedy land. Tobacco or corn planted on land which has been under clean cultivation the previous year and kept free from weeds which live throughout the winter does not suffer serious injury. *The larvæ can not live over winter in the soil from the previous summer unless plants on which they are able to feed are present.* All field experiments and observations so far have shown that the most effective means of control consist of freeing the land from the weeds, such as buckhorn plantain, daisy, stickweed, etc., which have been found to be the natural food plants of the larvæ.

There are many methods by which weeds may be eradicated or controlled, but the most practical and effective is the systematic rotation of crops. Sowing clean seed, preventing weeds from ripening seed, fall or winter plowing, the use of lime or of certain fertilizers, and doing away with wide fence rows are important preventive measures. Mowing and burning over weedy fields destroys many weed seeds and weeds which live over winter, and also destroys many injurious insects. Burning during August or September has been found to destroy the eggs and young larvæ of the tobacco Crambus, but as this method destroys humus, which is so badly needed in most tobacco soils, it is in most instances not advisable.

Many weeds are "soil indicators," their presence showing that the soil is lacking in fertility and in some instances pointing to a deficiency of lime.

CLEAN SEED.

One of the main factors in the control of weeds is clean seed, and the importance of procuring such seed can hardly be overestimated. Many weed pests are introduced and disseminated in the seed of various crops, such as grass and clover. As tobacco or corn must frequently be grown on land which has previously been in these crops, and as injury from the tobacco Crambus is apt to occur if the meadows have been weedy, it is desirable, for this and other reasons, to have the meadows as free from weeds as possible.[1] Owing to

[1] An analysis made by the Massachusetts Experiment Station shows that 1 ton of oxeye daisy (cured) withdraws from the soil approximately 25 pounds of potash, 8.7 pounds of phosphoric acid, 22 pounds of nitrogen, and 26 pounds of lime. To restore the stated amounts of the first three constituents to the soil it would be necessary to apply about 50 pounds of muriate of potash, 65 pounds of superphosphate, and 140 pounds of nitrate of soda. (Farmers' Bul. 103, U. S. Dept. Agr.)

careful cultivation of previous crops, the land is frequently fairly free from weeds when seeded to meadow; so that if the clover and grass seed has been sown pure there will be few weeds in the tobacco field or cornfield.

An examination of samples of clover and grass seed procured from farmers and seedsmen in various sections of Virginia shows that seeds of buckhorn plantain and oxeye daisy—both natural food plants of the tobacco Crambus—are common. Of 30 samples examined by the seed expert of the Virginia State department of agriculture during 1910, 28 contained seeds of oxeye daisy, and of these, 5 contained plantain and daisy. Of 70 samples of clover, redtop, and timothy seed examined at the Virginia Experiment Station in 1909, seeds of buckhorn plantain were found in 16.[1]

The United States Department of Agriculture and those in charge of similar work in many of the States have provided means by which samples of seed may be examined for purity by experts. Some of the States, also, have laws compelling dealers to furnish a stated guaranty as to the purity of the seeds sold.

WEEDS TO BE ELIMINATED.

The buckhorn plantain (*Plantago lanceolata*) is one of the numerous naturalized weed pests from Europe. It ranks among the worst weeds, particularly upon the lighter soils and on clay uplands. "Ray-bud," "rib-grass," "ribwort," "buck plantain," "English plantain," "ripple," "ripple grass," and "narrow plantain" are names applied to the plant in different sections. It is perennial or biennial and is common in meadows. The seeds are widely distributed with clover seed, from which it is difficult to separate them. Rotation of crops, thorough cultivation, and the use of clean farm seed are the usual methods for its control.

The oxeye daisy (*Chrysanthemum leucanthemum*) (Pl. II, fig. *a*) is also a naturalized species from Europe. It is often abundant on old or poor soil. It spreads from the seeds, which are distributed in various farm seeds, in hay, and in manure; also, by shoots from the perennial root stocks, which must be entirely killed before the plant can be wholly eradicated. It is best controlled by rotation of crops, by smothering out by means of cowpeas or other suitable soiling crops, and by thorough cultivation. It is a bad weed pest in meadowland. The seed can be prevented from ripening by mowing the hay early.

White top or fleabane (*Erigeron annuus* and other species) is a common pest in meadows. In some localities it has been found to be a food plant of the tobacco Crambus. Early mowing of infested meadows before the seeds ripen and pasturing with sheep, which

[1] Bul. 184, Va. Agr. Exp. Sta.

readily eat the weed, are control methods commonly practiced. Chemical sprays are fairly effective, but can not be used in meadows where clover is grown, as clovers are killed by the solution. Sprays have been found most effective while the plant is in bloom.

The stickweed or aster (*Aster ericoides*), known also as frostweed, steelweed, white heath, etc., and related species, are common and abundant weeds in old fields in tobacco-growing sections of the Atlantic States. They are perennial and thrive on poor soil. It is useless to try to eradicate them completely, but they can be readily controlled by growing cultivated crops and by putting the land in a higher state of fertility by the use of lime and clover. Aster is not a usual food plant of the tobacco Crambus, but as the weed is so frequently associated with daisy and plantain, which thrive best under similar soil conditions, its control is essential in the preparation of land for tobacco.

CROP ROTATION.

One of the main reasons for a rotation of crops is that the accumulation of weeds in meadowland and pastures may be destroyed during the cultivation of the crop that follows. A rotation found very satisfactory by the Virginia experiment station has been devised by Mr. E. H. Mathewson, Crop Technologist of the Bureau of Plant Industry. This plan is slightly modified to meet conditions in different tobacco-growing sections. It calls for a seven-year rotation of crops, as follows: *First year*, tobacco, fertilized heavily; *second year*, wheat without fertilizing; *third and fourth years*, mixed grasses and clover, seeded alone early in the fall and top dressed early in the spring with 200 to 300 pounds of nitrate of soda; *fifth year*, corn, with barnyard manure and a small amount of fertilizer; *sixth year*, cowpeas, fertilized with a little acid phosphate and sulphate of potash; *seventh year*, tobacco.

Crops such as cowpeas, soy beans, and crimson clover, which aid so greatly in fitting land for increased and more profitable yields of tobacco and corn, not only add humus to the soil and increase the fertility, but help to eradicate certain weeds by smothering them out. The weeds are also destroyed or prevented from maturing seed when crops are plowed under. Although eggs of the Crambus may have been deposited in such a field, the larvæ can not survive until the tobacco is planted unless there are weeds which remain alive over winter to supply them with food.

The following rotation experiments have been under observation during the present investigation:

A test with tobacco following crimson clover was conducted as a cooperative experiment on the J. R. Horsley farm in Appomattox County, Va., in the season of 1910–11. The field selected contained

4 acres. It was in corn during the season of 1910. Previous to plowing for corn the field was in weedy sod. The corn was badly injured by the Crambus and was replanted twice. At the last cultivation of corn in July, crimson clover was sown. Rains were frequent during the latter part of the summer, and a fairly good stand of clover was secured. There were some weeds, in spots, which cultivation at the time clover was sown had not destroyed. The field was planted to tobacco during the season of 1911. Damage by the Crambus was estimated to be about 6 per cent.

A test with tobacco following cowpeas was conducted as a cooperative experiment on the S. L. Ferguson farm, Appomattox County, Va., in the seasons of 1911 and 1912. A field containing about 6 acres was used in the experiment. The land previous to plowing for cowpeas was in weedy pasture, and numerous Crambus larvæ had been observed. A good growth of the cowpeas was secured. The land was deeply plowed during winter and was prepared for planting to tobacco during the third week in May, 1912. Scarcely any injury from the Crambus to the first planting was observed. After the first planting damage from the Crambus and from other causes was estimated to be less than 4 per cent. In the check field, where conditions were similar to those in the experimental field, except that a crop of cowpeas had not been grown, there was an estimated damage from the Crambus of about 9 per cent. The sod in the check had been winter-plowed.

In the plats of the Virginia Tobacco Experiment Station, at Appomattox, nine experiments were under observation, as detailed below.

The first experiment was with tobacco planted on sod in an old weedy pasture. A large part of the first planting was destroyed. The plat was replanted three times. About 9 per cent of a stand was secured by the second week in July. Owing to injury from "wireworms" and the large percentage of late plants the value of the crop was decreased 25 per cent as compared with plats in which an early stand of plants had been secured.

The second experiment was with tobacco following cowpeas on land that had been uncultivated for several years and was very weedy. Almost a perfect stand of plants was secured at the first planting, which was made the last week in May. The injury (decrease in the value of the crop) was less than 1 per cent.

The third experiment was on a plat used for fertilizer tests. The condition of the land was similar to that used in the second plat, except that cowpeas had not been grown during the preceding season. The tobacco was replanted three times. The decrease in the value of the crop was 7 per cent.

The fourth experiment was again with tobacco planted on sod. There were few weeds in the sod. Nearly a perfect stand of plants was secured at the first planting, which was made during the last week in May. The plat was replanted once. The loss was estimated at less than 1 per cent.

The fifth experiment was again with tobacco following cowpeas. A perfect stand of plants was secured at the first planting, made during the last week in May. Injury from the tobacco Crambus was estimated at less than 1 per cent.

The sixth experiment was with tobacco planted on red-clover sod. The stand of clover had been good and there were few weeds. Tobacco was planted during the last week in May. A good stand was secured at the first planting. Loss from the Crambus was estimated at less than 1 per cent.

The seventh experiment was on spring-plowed land where stickweed, daisy, and plantain had been abundant. The tobacco was planted during the second and third weeks in May. The loss was estimated to be about 20 per cent, owing to late plants, the tobacco having been replanted three times. Injury from the Crambus was worst in the portion of the field where weeds had been most abundant.

The eighth experiment was with tobacco following rye. The stand of rye had been poor and the stubble was weedy. The first planting was made on June 8, and was almost completely destroyed. Tobacco was replanted three times. A stand of 90 per cent was secured by the second week in July. The estimated decrease in the value of the crop was about 30 per cent.

The ninth experiment was with tobacco following cowpeas. The first planting was made on June 2. About 20 per cent of plants were injured by "wireworms." The plat was replanted once, there being only slight damage after the second planting. The estimated loss in value of the crop was about 10 per cent. Most of the injured plants were in the end of the plat where the stand of peas had been poor.

Three experiments were under observation at the Virginia Tobacco Experiment Station at Chatham in 1910 by Mr. R. P. Cocke, superintendent of the station.

In experiment No. 1 tobacco was preceded by corn in which crimson clover was sown at the last cultivation. This clover was fallowed May 2. The corn was kept clean of weeds and grass. Tobacco was set June 6. The first replanting was made June 14 with 5 per cent of the plants injured; the second replanting was made June 23, with 3 per cent injury; and the third replanting, June 28, with 2 per cent injury. About 97 per cent of a stand was finally secured after the third replanting.

In experiment No. 2 tobacco followed corn, in a plat used for fertilizer tests. Tobacco was set June 6. The first replanting was made June 14, with 5 per cent injury; the second replanting, June 23, with 3 per cent injury; and the third replanting, June 28, with 2 per cent injury. About 98 per cent of a stand was secured after the third replanting.

In experiment No. 3 tobacco was planted after a cover crop of wheat, in variety test plats. The wheat was fallowed May 1. Tobacco was set June 7. The first replanting was made June 17, with 20 per cent injury, and the second replanting, June 28, with 6 per cent injury. About 95 per cent of a stand was secured. In these plats it was estimated that about 5 per cent of the entire loss was due to cutworms and to true wireworms (larvæ of Elateridæ).

SUMMER PLOWING.

The moths are local in habits and do not fly far from the weedy fields, which furnish protection for them and which are suitable places for them in which to deposit eggs. On emerging from plowed or bare land, or from fields in which the vegetation is not suitable for protection or for egg deposition, they fly to surrounding fields where conditions are more favorable. The land from which emergence took place will then be left free from worms which, if present would attack the crop the following year.

The preparation of weedy land for tobacco or corn must, therefore, be commenced the season before the crop is planted. Best results have been obtained by summer plowing, as the land was thus rendered bare of vegetation, and conditions were not suitable for egg laying when the moths emerged. By this means infestation of the land is prevented in the first place. It has been found that it is difficult to prevent injury, or to eradicate the worms, if they have once become established. Summer treatment of land makes conditions unfavorable for the moths to deposit eggs, destroys weeds which furnish food for the young larvæ, and kills many of the insects while in the pupal stage.

The results of an experiment made in 1910 to ascertain the effect of plowing on pupæ is given in Table VIII. Larvæ were placed in large field cages. When the greater number had pupated, one of the cages was removed temporarily and the land plowed.

TABLE VIII.—*Effect of plowing on pupal stage of the tobacco Crambus.*

Cage No.	Number of larvæ.	Collected.	Moths emerged.	Number.	Per cent.
1	200	June: Second and third week	July: Third and fourth week	84	42
2 (check)	200	do	do	118	59

Pupation takes place at an average depth of 1½ inches. The pupal cells are fragile and easily broken up by plowing or disking. Many of the pupæ are deeply buried by plowing and the moths are unable to reach the surface.

The satisfactory results following summer treatment of land, whether or not cowpeas or other similar crops are grown, are mainly due to the fact that conditions are made unfavorable for the deposition of eggs by the moths and for the growth of newly hatched larvæ.

FALL AND WINTER TREATMENT OF LAND.

During September, 1909, two cultural experiments were begun in Appomattox, Va., to ascertain the effect of fall and winter treatment of land already infested with Crambus larvæ.

The field selected on the J. F. Purdum farm contained five plats of one-half acre each. In this experiment (experiment A) fall and winter preparation of the tobacco land gave decidedly beneficial results. The field had been in pasture previous to plowing, but the growth of weeds was not so rank as on the land used in experiment B. The following were the results obtained in each of the plats:

Plat No. 1.—Ground plowed during second week in December, 1909. Thoroughly disked during first week in January, 1910. Tobacco planted during last week in May. Number of plants, 2,200. Number replanted, 89. Per cent injured, 4+.

Plat No. 2.—Land plowed during first week in January, 1910. Disked during second week in February. Tobacco planted during last week in May. Number of plants, 2,350. Number of plants reset, 165. Per cent injured, 7+.

Plat No. 3.—Land plowed during last week in February, 1910. Disked during third week in March. Tobacco planted during last week in May. Number of plants, 2,280. Number of plants reset, 138. Per cent injured, 6+.

Plat No. 4.—Land plowed during third week in March, 1910. Disked during third week in April. Tobacco planted during last week in May. Number of plants, 2,214. Number of plants reset, 251. Per cent injured, 11+.

Plat No. 5 (check plat).—Land plowed during third week in April. Prepared for planting during last week in May. Tobacco planted during last week in May. Number of plants, 2,225. Number reset, 375. Per cent injured, 17+.

Tobacco in all plats was replanted twice. A good stand of plants (about 98 per cent) was secured by July 4. After July 4 there was but slight injury from the worms. The land had been heavily fertilized, and the tobacco made a fine growth.

The second tobacco cultural experiment was conducted on the farm of Mr. J. R. Horsley (experiment B), in Appomattox County, Va. Four plats, each containing 1 acre, were included in the experiment. Two check plats, one at each end of the experimental plats, were used. Each of these contained 1 acre. The growth of weeds was heavy, stickweed, daisy, and buckhorn plantain being abundant.

In this test beneficial results from fall and winter plowing were not so conclusive as in the experiment on the Purdum farm (experiment

A). On plat No. 1 the effect of mowing and burning the weeds after the eggs had hatched was noted.

Plat No. 1.—Weeds mowed and burned during third week in September, 1909. The land was not disturbed until the ground was prepared for planting, during the third week in May. Number of plants in plat, 4,400. Number of plants reset, 610. Per cent injured, 13.8+. Tobacco replanted twice

Plat No. 2.—Ground plowed during last week in September, 1909. In March, April, and May it was disked and harrowed at frequent intervals, no vegetation being allowed to grow before the tobacco was planted, in order, if possible, to starve out the hibernating larvæ. Number of plants, 4,400. Number replanted, 415. Per cent injured, 9.4+.

Plat No. 3.—Land plowed during second week in March and not disturbed until just before planting. Number of plants, 4,400. Number of plants reset, 410. Per cent injured, 9.3+.

Plat No. 4.—Land plowed during third week in December, 1909. Nothing further done to it until prepared for planting during last week in May, 1910. Number of plants, 4,400. Number replanted, 540. Per cent injured, 12.2+.

The results of these experiments are shown also in Table IX.

All plats were replanted twice. A good stand of 98 per cent was secured by July 5.

TABLE IX.—*Effects of fall and winter treatment on injury by the tobacco Crambus in 1909 and 1910.*

Experiment No.	Preliminary treatment.	Time of treatment.	Later treatment.	Time.
A1	Plowed	Second week of December, 1909	Thoroughly disked.	First week of January, 1910.
A2	....do	First week of January, 1910	Disked	Second week of February.
A3	....do	Last week of February	....do	Third week of March.
A4	....do	Third week of March	....do	Third week of April.
A5	....do	Third week of April		
B1	Weeds mowed and burned.	Third week of September, 1909	Disked and harrowed at frequent intervals.	March, April, May.
B2	Plowed	Last week of September		
B3	....do	Second week of March		
B4	....do	Third week of December		
B5	....do	First week of April	Disked	First week of May.

Experiment No.	Planted tobacco.	Number of plants.	Number reset.	Per cent injury.
A1	Last week of May	2,200	89	4
A2	....do	2,350	165	7
A3	....do	2,280	138	6
A4	....do	2,214	251	11
A5	....do	2,225	375	17
B1	Third week of May	4,400	610	13.8
B2	....do	4,400	415	9.4
B3	....do	4,400	410	9.3
B4	....do	4,400	540	12.2
B5	....do	8,800	1,218	13.9

In the season of 1910–11 another series of cultural experiments was conducted on the J. F. Purdum farm, in Appomattox County, Va The land previous to preparation for tobacco was in meadow (timothy, herd's grass, and clover) which had been quite weedy. Natural food plants of the tobacco Crambus were abundant. This series was made for the purpose of ascertaining the effect on the tobacco Crambus of preparation of weedy land at different times during the fall and winter as compared with spring preparation of land. The field was divided into 6 plats containing one-half acre each. Tobacco was planted in all plats on the same date. The amount of fertilizer applied to each plat was the same.

In plat No. 1 the land was plowed September 6, 1910, and fallowed February 25, 1911. It was harrowed and disked on April 3, April 10, April 20, and May 3. The stand of tobacco was nearly perfect after the first planting except along one end of the plat. The percentage of a stand secured was 95.4. In the preparation of this plat it will be noticed that the land was plowed during the first part of September, a time just after the larvæ had hatched.

Plat No. 2 was plowed December 8, 1910, and fallowed February 28, 1911. It was harrowed and disked on April 3, April 10, April 20, and May 3. Tobacco was replanted once. About 85 per cent of a stand was secured at the first planting.

Plat No. 3 was plowed January 8, 1911, and fallowed or replowed February 28, 1911. It was harrowed and disked on April 3, 10, and 20 and May 3. Tobacco was replanted once. About 85 per cent of a stand was secured at the first planting.

In plat No. 4 the land was plowed on April 11. No further treatment was given until the third week in May, when the land was prepared and bedded for planting. The tobacco was replanted three times. About 51 per cent of a stand was secured at the first planting.

In plat No. 5 the land was plowed on January 18, 1911, and disked May 15. Tobacco was replanted three times. About 70 per cent of a stand was secured at the first planting.

Plat No. 6 served as a check plat. The land was plowed during the third week in April, and was prepared for planting on May 15. Tobacco was replanted three times. About 55 per cent of a stand was secured after the first planting.

Further cultural experiments were conducted on the S. L. Ferguson farm, in Appomattox County, Va., in the season of 1911–12. This series was made to ascertain the effect of deep winter plowing and subsoiling of pasture land infested by the Crambus. The field of which the experimental plats were a part had been in sod for a number of years and was used as pasture land. The general conditions for the experiment were ideal. The oxeye daisy, buckhorn plantain, and stickweed were abundant. There was not a rank growth of weeds, however, as the field had been quite closely pastured. The field was deeply plowed in February, a subsoil plow following the turning plow, and the clay subsoil was broken up to a depth of several inches. The tobacco in all plats was planted at the same time. The kind and amount of fertilizer applied was the same in all plats, and after the first cultivation all plats received the same treatment. The land was divided into 3 plats of 2 acres each and 1 plat containing one-half acre. Below are given the details of each experiment and the results obtained.

Plat No. 1 contained 2 acres. It was deeply plowed and subsoiled in February, 1911. The land was thoroughly disked and harrowed at frequent intervals during March, April, and May and kept almost entirely free from weed growth until tobacco was planted. The stand of tobacco was practically perfect. Only an occasional plat could be found which showed damage from Crambus larvæ.

Plat No. 2 contained 2 acres. The land was deeply plowed and subsoiled in February, 1911, and was not disturbed until prepared for planting in May, when it was deeply disked, harrowed, and bedded just before planting. Ninety-four per cent of a stand was secured at the first planting. The plat was reset once.

Plat No. 3 contained one-half acre. The land was plowed and subsoiled in February, 1911, as in plats Nos. 1 and 2. The land was not disturbed until prepared for planting as in plat No. 2. Weeds and grass were allowed to grow after planting. The middle of the row was not disturbed until after the first cultivation, in order to provide natural food for the Crambus larvæ, so that they would not be forced to attack the tobacco plants. The infestation of this plat was not heavy enough, so that the effect of this treatment, which is said to be practicable under certain conditions, could be accurately determined. The stand of tobacco secured at the first planting was 96 per cent. A few larvæ were found in the weeds left in the middle of the row.

Plat No. 4 was used as a check. The land was plowed and prepared for planting just before the tobacco was set out. The weed growth and general conditions were similar to those in plats Nos. 1, 2, and 3. The stand secured at first planting was 86 per cent. The tobacco was replanted twice. In land adjoining this tract which had been under clean cultivation during the previous summer and where there was no weed growth, about 98 per cent of a stand of tobacco was secured at the first planting. This land had been prepared for planting in practically the same manner as in the check plat, No. 4.

CHEMICAL SPRAYS FOR WEED DESTRUCTION.

Certain chemical sprays, such as iron-sulphate (copperas) solution, copper-sulphate (bluestone) solution, and common-salt solution, are frequently used for eradicating weeds and under certain conditions have been found very effective. The success of this method of eradicating such weeds as oxeye daisy and wild mustard from grain and pasture fields without injury to the grains or grasses depends largely on the fact that cereals and grasses are narrow-leaved plants with a single seed leaf, whereas the weeds injured are broad-leaved plants with two seed leaves. Spraying with a solution of iron sulphate at a strength of 1 pound to one-half gallon of water was found to be fairly effective on the oxeye daisy in a test made at Appomattox, Va. While spraying may be practical where certain weeds in grain fields are to be eradicated, it is hardly a suitable remedy under most conditions in tobacco-growing sections, except possibly where small patches of weeds are to be destroyed. Chemical sprays have been found to be more effective when applied on warm bright days when the plants are dry. Immediately after weeds have been cut off close to the ground an application of salt, kerosene, crude oil, or acid solutions will often be found effective. In eradicating weeds from pastures the salt solution is preferable, as copper-sulphate solution is poisonous to stock.

LIMING.

Aside from improving the mechanical and chemical condition of many soils, liming will be found to aid greatly in the control of several of the weed pests which have been found to be the natural or favorite food plants of the tobacco Crambus. Control of weed pests may be accomplished by making soil conditions less favorable for the weeds, or by making conditions more favorable to the cultivated crop. Many weed pests, like other plants, require for their best development certain soil conditions; and they are excessively abundant in certain localities because soil conditions are peculiarly favorable to their growth, or because conditions are less suited to more desirable plants which under favorable soil conditions would crowd them out. A change in the condition of the soil, brought about by the use of lime, will often bring about a marked effect in checking or preventing the growth of a weed pest, and at the same time make the soil better adapted to the growth of certain cultivated crops such as clover.

The sheep sorrel[1] (*Rumex acetosella*), on which newly hatched Crambus larvæ frequently feed, thrives in acid soil. Where lime had been applied to certain fields, and to some of the State experiment station plats in Appomattox County, Va., the sheep sorrel was practically eradicated or at least checked by the better growth of the clover. Plantain, daisy, and aster (stickweed), all food plants of the worms, are weeds which flourish in acid or worn-out soils. In all cases where data have been secured, the use of lime has resulted in a marked decrease in the abundance of these weeds. Most soils in the Piedmont region of the Eastern States are greatly benefited by lime, and its use has in many instances resulted in markedly increased yields of tobacco. In plats of alfalfa at the Appomattox experiment station

[1] Attempts to rear larvæ in cages containing only sheep sorrel were not successful.

there was scarcely any plantain (*Plantago lanceolata*) after a heavy application of lime had been made, and there was an excellent crop of alfalfa. In the unlimed check plats plantain nearly covered the ground, and there was a very poor growth of alfalfa.

Increased fertility of the soil may also aid in the extermination of a weed, as was noticed where heavy applications of acid phosphate had been made to meadow land on which there was a heavy growth of the oxeye daisy. The year following the application of the acid phosphate but few plants of the daisy could be seen. In this manner certain weeds may often be crowded out by grasses or clovers which are enabled to make better growth owing to greater fertility.

The experience of the best tobacco growers has shown that intensive culture gives largest profits, and no expense or trouble should be spared in putting the ground in the best possible condition in every respect before the crop is planted. By commencing the preparation of weedy land the year before it comes in corn or tobacco, an excellent opportunity is afforded to apply lime. Such land can often be conveniently plowed in winter and during spring or early summer, and easily be put in condition for such crops as crimson clover, cowpeas, etc., which may be profitably followed by tobacco or corn the succeeding year.

FERTILIZERS.

From observations of tobacco fields during the seasons of 1910 and 1911 it is evident that where the land receives heavy applications of nitrogenous fertilizers the damage from the worms is not so great as where light applications are made. Just as many plants are attacked by the worms, but vigorous and rapidly growing plants are more apt to recover from injury. This was very noticeable in the fertilizer test plats of the Virginia experiment station at Appomattox in 1910.

INSECTICIDES AND REPELLENTS.

The following insecticides and repellents were tested: Arsenate of lead, Paris green, tobacco extract, nicotine sulphate, tobacco dust, kerosene, kainit, and calcium cyanamid. In no instance were results secured which would indicate that the substances tested were of much practical value in combating the tobacco Crambus. The following field notes give details of some of the experiments:

ARSENATE OF LEAD.

In experiment A, with powdered arsenate of lead, 1½ ounces of the poison to 2½ gallons of water was used. Two hundred plants were treated, the entire plant being dipped into the solution. The plants were set in land which had been prepared a few days before. The field had been weedy and the worms were numerous. Two hundred untreated plants were kept as a check. On examining the plants five days later 22 injured plants were found in the poisoned plat and 36 injured plants in the check plat. Three live larvæ which had tunnelled in the stalks and were apparently uninjured were found in plants in the poisoned plat. All treated plants had lived, but were not as vigorous in appearance as those not treated.

In experiment B, with arsenate of lead paste, the poison was used at the rate of 2 ounces to $2\frac{1}{2}$ gallons of water. The tops only were dipped. One hundred plants were treated and 100 left untreated. The plants were examined five days after transplanting. There had apparently been some injury from the poison, as the plants were in best condition in the untreated plat, while those treated were somewhat stunted or dwarfed. Eight injured plants were found in the poisoned plat. Five plants were found injured in the untreated plat.

PARIS GREEN.

Paris green at the rate of one-fourth ounce to 3 gallons of water was used on 100 tobacco plants, and an adjoining row kept as a check. The entire plant was dipped in each case, and the plants set out at once. The field was weedy. It had been recently plowed and Crambus larvæ were numerous. A light rain fell a few hours after the plants were set. After eight days the plants were examined. Twenty-one plants were injured by worms in the poisoned row and 26 in the unpoisoned row. There had been some injury to the plants dipped in the poison solution, as the unpoisoned plants had a more vigorous start. In some instances plants in the poisoned row were only slightly eaten, thus indicating that the poison had acted as a repellent or had poisoned the worm before the plant had been badly eaten.

TOBACCO EXTRACT.

One row of tobacco plants in a field was sprayed with a 500-to-1 solution of tobacco extract, 320 plants in all being treated. The solution was applied with a compressed-air bucket sprayer. The substance did not prove effective in preventing injury. On June 6, five days after the mixture was applied, the plants were examined. Fourteen plants were found injured by worms in the sprayed row and 11 injured plants were found in the unsprayed row adjoining.

NICOTINE SULPHATE.

A 1,000-to-1 solution of nicotine sulphate was sprayed on 300 plants as in the foregoing experiment, and an adjoining row used as a check. The plants were examined four days after spraying. Eight plants had been attacked by worms in the sprayed row and 13 plants in the check row. While the foregoing substances did not prove of much value in preventing injury from the worms, they seemed to repel flea-beetles, as very few could be found on the treated plants whereas they were comparatively abundant on the unsprayed plants.

TOBACCO DUST.

Tobacco dust was scattered about tobacco plants directly after planting. One row containing 300 plants was used for the test and an adjoining row with the same number as a check. Eighteen plants were found injured by worms in the treated row. Few plants were found that were injured below the surface of the ground, the worm having entered the plant at the "bud" or terminal leaf in most cases. Sixteen injured plants were found in the row where the dust had not been applied. More of these plants had been injured below the surface of the soil than where dust had been applied, this indicating that the dust may possibly have some value as a repellent.

KEROSENE.

In the first experiment with kerosene the plants were dipped in a weak solution of kerosene emulsion and were set out on June 15. Only 30 plants were used in the test. None of these, when examined five days later, was found infested. There was apparently no injury to the plants from the kerosene. Two infested plants were found in the check row of 30 plants. The number of plants treated was not large enough to make this test of much value.

In the second experiment kerosene was mixed with sand and a small amount sprinkled around 100 tobacco plants. One hundred plants in an adjoining row were used as a check. A light rain fell a few hours after the sand was applied. On June 18, eight days after treatment, the plants were examined. Sixteen were found injured in the treated row and 22 in the untreated row.

KAINIT.

In one experiment kainit was mixed with the soil in the hill before planting. Too large a quantity of the kainit was used in the test, as a considerable number of plants failed to grow. One hundred tobacco plants were put out in soil mixed with the kainit, and 100 plants in an adjoining row were left for a check. A number of infested plants were found where the kainit had been used, the substance evidently not being of much value as a preventive, as the worms often enter the plant at the "bud" or whorl of terminal leaves.

TURPENTINE.

In certain sections of Tennessee and Kentucky turpentine is said to have been used as a repellent for Crambus larvæ and cutworms. Before planting, the roots of the tobacco plants are dipped in water in which a small quantity of turpentine has been stirred.

A test on 1 acre of tobacco was made by Mr. Charles Armistead, of Clarksville, Tenn., and the field kept under observation by the writer. Entirely negative results were obtained. The following are details of the experiment: The tobacco was on weedy land containing an abundance of white top (*Erigeron annuus*) and plantain. The first planting was entirely destroyed. When the tobacco was replanted turpentine was used at the rate of 1 teaspoonful to 1 gallon of water, the roots of the plants being dipped in the mixture. On June 27, two weeks after planting, the tobacco was examined. Worms were still very numerous. Over 80 per cent of the plants had been entirely destroyed, in both treated and check plats. There seemed no apparent difference in infestation and damage between the treated tobacco and that on which no turpentine had been applied.

CALCIUM CYANAMID.

Calcium cyanamid (lime nitrogen) is said to have a repellent or poisonous effect upon insects, and on the suggestion of Mr. E. H. Mathewson, Crop Technologist of the Bureau of Plant Industry, Mr. B. G. Anderson, superintendent of the Tobacco Experiment Station at Appomattox, Va., and the writer made a test of the material during 1911, using the calcium cyanamid at the rate of 300 pounds per acre. The land selected had not been cultivated for several years. There was a rank growth of buckhorn plantain, oxeye daisy, and stickweed, and Crambus larvæ were exceedingly numerous, making conditions ideal for the test. The plat, containing one-twentieth of an acre, was divided into series of two rows each. The calcium cyanamid was used on two rows and the next two rows were kept as a check. On the treated rows commercial fertilizer at the following rate per acre was used:

	Pounds.
Calcium cyanamid	300
Acid phosphate	600
Sulphate of potash	100

On the check rows the fertilizer used (rate per acre) was as follows:

	Pounds.
16 per cent blood	300
Acid phosphate	600
Sulphate of potash	100

The calcium cyanamid analyzed about 17 per cent ammonia, this making the amount of plant food in the treated and check rows practically the same. The fertilizer was applied 14 days before the plants were set, as calcium cyanamid has the effect of stunting tobacco plants if applied directly before planting. It was applied to the rows with a drill, and thoroughly mixed with the soil by running a cultivator over the rows. The plants were set on June 8. By June 30 the plants in both treated and check rows had been almost completely destroyed by the Crambus larvæ, there being no indications of any beneficial effect from the calcium cyanamid in preventing injury. The tobacco was not replanted.

LEAD ARSENATE AND PARIS GREEN USED WITH COAL TAR ON SEED CORN TO PREVENT INJURY BY CRAMBUS LARVÆ.

Experiments in the use of arsenate of lead and Paris green with coal tar on seed corn to prevent injury by Crambus larvæ were conducted in 1910 on the J. F. Purdum farm.

In experiment A, arsenate of lead in paste form was used at the rate of 1 ounce to 1 gallon of water. One peck of shelled seed corn was allowed to soak in the solution about 10 minutes and dried by mixing with fertilizer (acid phosphate). A very little coal tar (about a tablespoonful) was then poured on the corn, which was thoroughly stirred until a thin coating of the tar covered each kernel. Fertilizer was then used to dry the tar. With an ordinary planter one-half acre was planted in seed prepared as just described. Fully one-third of the corn failed to germinate, possibly owing to exclusion of moisture from the seed by the tar, as the weather was dry. No benefit in preventing injury by the worms seemed to result. In the check plat the stand of corn was practically perfect. On June 16, four weeks after planting, a count was made in the treated and check plats of hills of corn showing Crambus injury. Eleven per cent of the hills showed injury in the treated plat and 13 per cent in the check plat.

In experiment B, 1 ounce of Paris green was used to 1 peck of shelled seed corn. A small amount of tar (about one tablespoonful) was poured over the corn, which was thoroughly stirred until a thin coating of tar covered each kernel. The corn was then dried by mixing with fertilizer to which Paris green had been added. One-half acre was planted with seed prepared in this manner. About one-fifth of the seed failed to grow. In the check plat the stand was practically perfect.

A count of hills of corn showing Crambus injury, made on June 16, four weeks after planting, showed the results of the treatment to be as follows: Injury in treated plat, 11 per cent; injury in check plat, 9.5 per cent.

SUMMARY OF ECONOMIC CONTROL.

(1) The eggs of the tobacco Crambus are deposited in weedy fields during July and August. They hatch in a few days. The larvæ remain over winter in the soil and complete their growth during June and July. They are in their most active feeding stage at the time tobacco or corn is planted.

(2) Injury to tobacco or corn occurs when these crops are planted on land which was weedy during the previous year. Crops planted on land which has been under clean cultivation are immune from injury.

(3) The weeds which have been found to be the more common natural food plants of the worms are the buckhorn plantain, oxeye daisy, stickweed, and whitetop. The presence of these weeds in meadows accounts for injury to tobacco or corn when planted on sod.

(4) The worms when once established in land where their natural food plants are abundant have been found difficult to control.

(5) Various insecticides and repellents have been tested, but without satisfactory results.

(6) Fall or winter plowing has been found to reduce injury, but is only partially effective, as some of the weeds remain alive and furnish food for the larvæ until the tobacco or corn is planted.

(7) Damage is best prevented by crop rotations, or by cultural methods that prevent growth of the weeds which are food plants of the worms, thus making conditions unfavorable for egg deposition by the moths *the summer before tobacco or corn is planted.* Summer plowing, thorough preparation of weedy land, and the growing of crops of cowpeas or crimson clover, preferably cowpeas, the year before crops subject to injury are planted, have been found to be the most satisfactory and practical means of control.

BIBLIOGRAPHY.

1860. Clemens, Brackenridge. Contributions to American lepidopterology. No. 5. Proc. Acad. Nat. Sci. Phila. for 1860, p. 203–221, June, 1860.

The original description of *Crambus caliginosellus*, p. 204.

1880. Grote, A. R. Preliminary list of North American species of Crambus. Canada Ent., v. 12, no. 4, p. 77–80, Apr., 1880.

Gives habitat, N. Y., p. 79.

1887. Moffat, J. A. Further additions to the list of Canadian microlepidoptera. Canad. Ent., v. 19, no. 5, p. 88–89, May, 1887.

Specimen of *Crambus caliginosellus* in collection of Mr. Moffat, Hamilton, Ont., determined by Fernald.

1891. Beckwith, M. H. Notes on a corn crambid. U. S. Dept. Agr., Div. Ent., Insect Life, v. 4, no. 1–2, p. 42–43, Oct., 1891.

Brief mention. Dr. J. B. Smith reports insect as injuring corn in New Jersey. Dr. L. O. Howard reports insect as abundant in Maryland in 1886.

1891. Beckwith, M. H. Notes on a corn crambid. Del. Col. Agr. Exp. Sta., Bul. 14, p. 13–15, fig. 1, Dec., 1891.

Mention of species as injurious to corn in Delaware. Account of feeding habit of larvæ.

1894. Felt, E. P. On certain grass-eating insects. Cornell Univ. Agr. Exp. Sta., Bul. 64, p. 47–102, 14 pls., Mar., 1894.

"The sooty crambus," p. 61–62. Brief account of moth; description of eggs and newly hatched larvæ.

1896. Fernald, C. H. The Crambidæ of North America. Mass. Agr. Col. Ann. Rpt. 33 (Pub. Doc. 31), p. 77–165, pls. 6 & A–B, Jan., 1896.

Redescription of moth, p. 137–138.

1897. Johnson, W. G. Notes on some little-known insects of economic importance. U. S. Dept. Agr., Div. Ent., Bul., n. s., no. 9, p. 83–85, 1897.

"*Crambus caliginosellus*," p. 84. Account of injury to corn in Maryland.

1898. Johnson, W. G. Report on the San Jose scale in Maryland and remedies for its suppression and control. Md. Agr. Exp. Sta., Bul. 57, 116 p., 26 figs., Aug., 1898.

"*Crambus calignosellus*," p. 9. Account of injury and feeding habits of larvæ.

1898. Johnson, W. G. Notes from Maryland on the principal injurious insects of the year. U. S. Dept. Agr., Div. Ent., Bul., n. s., no. 17. p. 92–94, 1898.

"The corn crambus," p. 93. Brief mention as destructive in various parts of the State.

1899. JOHNSON, W. G. The stalk worm: A new enemy to young tobacco. U. S. Dept. Agr., Div. Ent., Bul., n. s., no. 20, p. 99–102, 1899.

An account of injury to tobacco by *C. caliginosellus.* States that tobacco growers in southern Maryland reported injury for last fifteen years, or possibly longer. Recommends system of crop rotation aimed at control.

1900. JOHNSON, W. G. Notes on insects of economic importance for 1900. U. S. Dept. Agr., Div. Ent., Bul., n. s., no. 26, p. 80–84, 1900.

Brief mention of *Crambus caliginosellus.* Reports insect as destructive to tobacco on sod lands, p. 83.

1902. SANDERSON, E. D. Insects injurious to staple crops. New York, 1902.

"The corn-root webworm (*Crambus caliginosellus* Clem.)," p. 130-134. Account of injury to corn and tobacco. Recommendations concerning control.

1903. CHITTENDEN, F. H. The principal injurious insects in 1902. U. S. Dept. Agr. Yearbook for 1902, p. 726–733, 1903.

Brief mention of *Crambus caliginosellus.* One of the most destructive insects to corn in Delaware in 1902, p. 729.

1907. MCNESS, G. T., Mathewson, E. H., and Anderson, B. G. The improvement of fire-cured tobacco. Va. Agr. Exp. Sta., Bul. 166, p. 186–234, May, 1907.

Account of difficulty of securing a satisfactory stand of tobacco in experimental work; description of injury to plants.

1909. MATHEWSON, E. H. Intensive methods and systematic rotation of crops in tobacco culture. U. S. Dept. Agr. Yearbook for 1908, p. 403–420, pl. 33–37, 1909.

Mention of tobacco "wireworm" or "stalkworm" and effect of crop rotation on control, p. 411.

1911. RUNNER, G. A. Report upon tobacco insect investigations. Va. Polytech Inst. Agr. Exp. Sta., Ann. Rpt. for 1909 and 1910, p. 40–43, 1911.

Amount of economic importance of insect, food plants, feeding habits of larvæ. Recommendations concerning control, p. 41–42.

1911. MORGAN, A. C. Insect enemies of tobacco in the United States. U. S. Dept. Agr. Yearbook for 1910, p. 281–296.

Brief mention of tobacco Crambus, p. 291.

1912. HUNTER, W. D. Relation between rotation systems and insect injury in the South. U. S. Dept. Agr. Yearbook for 1911, p. 201–210, 1912.

Discussion of importance of systems of crop rotation in relation to control.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

DIV. INSECTS.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 88

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
April 30, 1914.

THE CONTROL OF THE CODLING MOTH IN THE PECOS VALLEY IN NEW MEXICO.

By A. L. Quaintance, *in Charge of Deciduous Fruit Insect Investigations.*

INTRODUCTION.

For some years complaints have been received by the Bureau of Entomology from the fruit growers in the Pecos Valley, N. Mex., of the severe injury to apples and pears by the codling moth (*Carpocapsa pomonella* L.). The methods employed in the control of this insect in other apple-growing regions have, in the Pecos Valley, been stated to be there much less efficient, so that a considerable portion of the crop of fruit has been wormy and unsalable.

The codling moth should yield as readily to treatment in the Pecos Valley as elsewhere, though, owing to favorable climatic conditions, it was surmised that it might develop an additional generation. It was not believed, however, that the behavior of the insect in that region was essentially different from its behavior in other sections, and the lack of satisfactory results from spraying operations, it was thought, probably resulted from failure to accomplish this work in a thorough and timely manner.

Beginning in the spring of 1912 an investigation of the codling moth was undertaken by the Bureau of Entomology, with headquarters at Roswell, N. Mex., and Mr. A. G. Hammar, who had had much experience with this insect at other field stations of the bureau, was assigned to the work. During that year he was assisted by Mr. Earl R. Van Leeuwen, and during 1913 by Mr. L. L. Scott and Mr. E. W. Geyer. Owing to the unfortunate death of Mr. Hammar there devolves upon the writer the necessity of preparing for publication, for the benefit of the Pecos Valley fruit growers, the results of Mr. Hammar's experiments. The investigations carried out by Mr. Hammar comprise a thorough inquiry into the life history and habits of the codling moth in that region, and experiments with sprays in orchards. The results of the life-history studies will be given in another paper.

Note.—This bulletin describes the codling moth as it affects fruit growing in the Pecos Valley, N. Mex. It is of interest to fruit growers in the Southwest.

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The present article deals with results obtained in spraying in 1913. Work was carried out in two orchards, namely, that of Messrs. Sherman & Johnson and that of Mr. Robert Beers. Unfortunately the report of results in the latter orchard is not entirely complete, so that the details of these experiments can not be given. In general, however, the results obtained in the Beers orchard agree with those secured in the Sherman & Johnson orchard, and the latter are given in detail in the following pages.

EXPERIMENTS IN THE SHERMAN & JOHNSON ORCHARD.

A portion of the Sherman & Johnson orchard, about 5 acres in extent, was selected for spraying experiments and was subdivided into plats, as shown in figure 1.

The trees were large, and codling-moth conditions were fairly typical for the valley. Plat I received three applications; Plat II, four applications; and Plat III, five applications of arsenate of lead spray. Plat IV was left unsprayed throughout the season for purposes of comparison. A good power sprayer was used, capable of supplying three or four leads of hose, and maintaining a pressure of 200 to 225 pounds. (See fig. 2, showing outfit in operation, and size of trees used.) Further information concerning the treatments and the dates of spray applications for the respective plats is given in Table I.

TABLE I.—*Treatments and dates of applications of sprays for codling moth, Sherman & Johnson orchard, Roswell, N. Mex., 1913.*

Dates of applications.	Plat I (3 applications).	Plat II (4 applications).	Plat III (5 applications).	Plat IV (unsprayed).
Apr. 24–25 (After falling of petals.)	Arsenate of lead, 6 pounds to 200 gallons of water. Bordeaux nozzles. 16½ gallons per tree. 225 pounds pressure.	Arsenate of lead, 6 pounds to 200 gallons of water. Bordeaux nozzles. 16½ gallons per tree. 225 pounds pressure.	Arsenate of lead, 6 pounds to 200 gallons of water. Bordeaux nozzles. 16½ gallons per tree. 225 pounds pressure.	Unsprayed.
May 7–8	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 13¾ gallons per tree. 200 pounds pressure.	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 13¾ gallons per tree. 200 pounds pressure.	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 13¾ gallons per tree. 200 pounds pressure.	Do.
June 16–17	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 15¾ gallons per tree.	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 15¾ gallons per tree.	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 15¾ gallons per tree.	Do.
July 14–15		Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 17¼ gallons per tree.	Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 17¼ gallons per tree.	Do.
Aug. 2			Arsenate of lead, 8 pounds to 200 gallons of water. Vermorel type nozzles. 9⅓ gallons per tree.	Do.

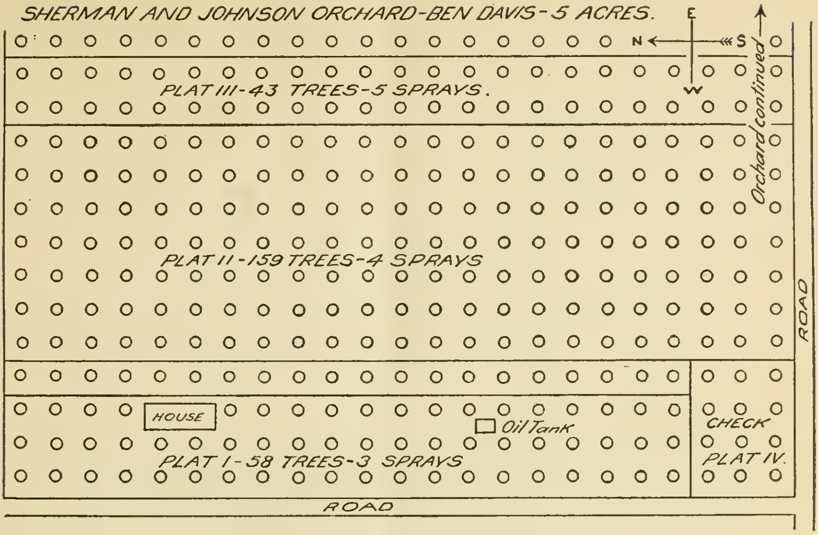

Fig. 1.—Diagram showing arrangement of trees used in codling-moth experiments, Sherman & Johnson orchard, Roswell, N. Mex. (Original.)

Fig. 2.—View in Sherman & Johnson orchard, Roswell, N. Mex., showing size of trees and power sprayer in operation. (Original.)

It will be noted from Table I that the amount of spray used in all applications was large, and probably considerably in excess of that used by the average fruit grower in the valley. The amount of spray applied immediately following the falling of the petals (April 24–25) exceeded somewhat the amount given in any subsequent application. It will be noted also that Bordeaux nozzles were used at this time, whereas in subsequent treatments the so-called eddy chamber or Vermorel type of nozzle was used, producing a fine cone-shaped spray.

In Table II are shown the number and percentage of sound fruit from each of five trees of each plat, as well as the total number and total percentage of sound and wormy fruit for the five trees of the respective plats.

TABLE II.—*Number of sound and wormy apples from each tree of each plat, Sherman & Johnson orchard, Roswell, N. Mex., 1913.*

Plat and condition of fruit.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Tree 5.	Total fruit for plat.	Total per cent sound fruit.
Plat I.							
Wormy	138	141	153	179	152	766	
Sound	2,918	2,022	3,382	3,418	3,239	14,979	
Total	3,056	2,166	3,535	3,597	3,391	15,745	
Per cent sound	95.48	93.35	95.67	95.02	95.52	....	95.13
Plat II.							
Wormy	86	39	33	37	70	265	
Sound	4,271	4,086	3,378	3,344	5,504	20,583	
Total	4,357	4,125	3,411	3,381	5,574	20,848	
Per cent sound	98.02	99.05	99.03	98.90	98.74	....	98.72
Plat III.							
Wormy	51	18	40	25	14	148	
Sound	6,283	4,479	4,494	4,618	4,442	24,316	
Total	6,334	4,497	4,534	4,643	4,456	24,464	
Per cent sound	99.19	99.59	99.12	99.46	99.68	....	99.39
Plat IV.							
Wormy	5,308	2,671	3,813	3,486	3,336	18,614	
Sound	2,871	2,349	2,873	2,765	1,958	12,816	
Total	8,179	5,020	6,686	6,251	5,294	31,430	
Per cent sound	35.12	46.79	42.97	44.23	37.03	....	40.77

It will be seen that Plat I, which received a total of three applications of an arsenate of lead spray, gave 95.13 per cent sound fruit. Plat II, with four applications, yielded a somewhat higher quantity of sound fruit, namely, 98.72 per cent; while from Plat III, which received five spray applications, 99.39 per cent of the fruit for the season was sound. Plat IV, which was not sprayed during the season, shows only 40.77 per cent of the fruit free from codling moth injury. In determining these results, examinations were made as to worminess of all the apples produced on the five count trees throughout the season; that is, the fruit which fell, the fruit which was picked from the trees in thinning, and that picked at harvest time.

It would appear that with the minimum of three applications, made as shown in Table I, injury from the codling moth in the Pecos Valley may be reduced to less than 5 per cent of the total crop of apples produced. For each of the two additional applications an increase in sound fruit is shown, but probably not in proportion to the expense involved. It should be borne in mind, however, that in these experiments applications were made with much thoroughness, and unless the orchardist will do equally as thorough work it will be better for him to make the additional applications.

PLACES OF ENTRANCE OF FRUIT BY CODLING MOTH LARVÆ.

Many observations in different parts of the country have shown that the majority of codling moth larvæ normally enter the apple at

FIG. 3.—Showing condition of calyx lobes of Ben Davis apple: *a*, Two days after falling of petals; *b*, ten days after falling of petals. (Original.)

the calyx end. A careful study of the places of entering sprayed fruit by larvæ, whether at calyx, side, or stem, throws much light on the relative effectiveness of the respective spray applications. All experiments corroborate the statement that the treatment given immediately after the falling of the petals is by far the most important one and that its omission can not be corrected by subsequent treatments, however thoroughly made.

A study of the behavior of the calyx lobes of the recently set apples in the Roswell section furnishes evidence of value in timing spray applications. Ordinarily in the East there is a period of about 10 days following the dropping of apple blossoms during which the calyx lobes remain open, so that the spray may be successfully directed into the calyx cups. In New Mexico, however, it would appear that the calyx lobes of the little apples do not draw together nearly so quickly after the falling of the petals and may remain open in suitable condition for calyx spraying for a period of from two to three weeks, varying somewhat with the variety and season. (Figs. 3 and 4.)

This condition renders it possible to apply the second spray in a way to supplement the first spray into the calyx cups.

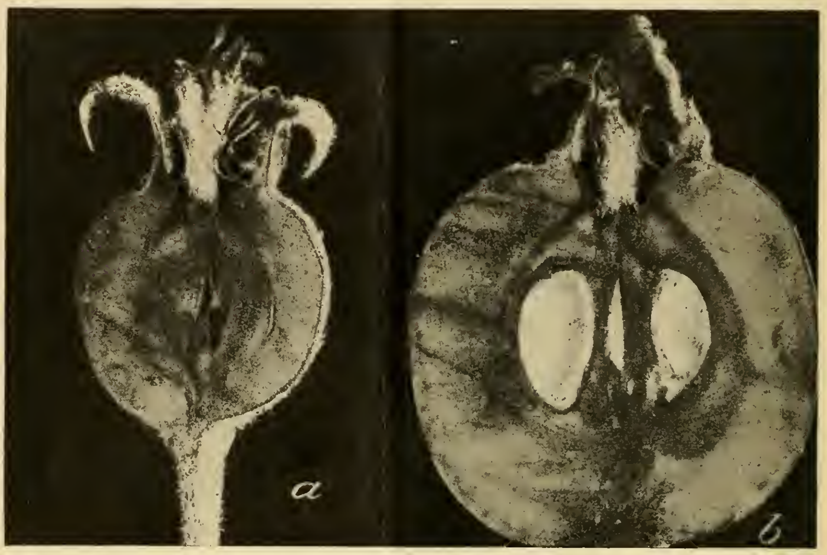

FIG. 4.—Showing condition of calyx lobes of Ben Davis apple: *a*, 18 days after falling of petals; *b*, 30 days after falling of petals. (Original.)

The effect of spraying in changing the relative proportion of larvæ which succeed in entering the fruit at the calyx, side, and stem is shown for Plats I to III in Table III. The normal behavior of the larvæ in entering the fruit may be seen by referring to the figures for Plat IV of this table. It will be noted that on the unsprayed plat somewhat over one-half (53.72 per cent) of the total larvæ for the season entered the fruit at the calyx end.

TABLE III.—*Number and percentage of codling moth larvæ entering fruit at calyx, side, and stem for Plats I-IV, Sherman & Johnson orchard, Roswell, N. Mex., 1913.*

Total larvæ for plat for season entering at—	Plat I.	Per cent.	Plat II.	Per cent.	Plat III.	Per cent.	Plat IV.	Per cent.
Calyx	19	2.31	17	6.27	10	6.76	12,663	53.72
Side	789	96.45	249	91.88	128	86.48	9,622	40.82
Stem	10	1.24	5	1.85	10	6.76	1,285	5.46
Total	818	100.00	271	100.00	148	100.00	23,570	100.00

This table also shows the destructive influence of sprays in lessening the actual number of larvæ. Thus on Plat I, which received three sprays, there was a total of 818 larvæ for the season, on the five count trees; on Plat II, which received four sprays, the number of larvæ for the five trees was 271; while on Plat III, which received five sprays, only 148 codling moth larvæ were found in fruit from the five "count trees" during the year. The foregoing figures are in marked contrast with the total number of larvæ found in fruit from the five unsprayed trees, namely, 23,570.

RECOMMENDATIONS BASED ON THE FOREGOING RESULTS.

While the results reported herewith are very clear-cut, the bureau would not be warranted in formulating definite recommendations based upon the work thus far carried out in the Pecos Valley were it not for the reason that these results substantiate the results obtained from a large series of spraying experiments against the codling moth in many parts of the United States. In Table I, showing treatments and dates of applications, the reader will note that the first applications were made with Bordeaux nozzles and the later applications with eddy chamber nozzles. Entomologists of certain Western States who have experimented with the codling moth under arid conditions insist upon the advantage of a coarse spray given at the time immediately following the dropping of the petals. Tests of the comparative value of coarse and fine sprays under eastern conditions show that there is apparently but little difference as regards the effectiveness in the control of the insect of a coarse and fine spray. The Roswell experiments did not include a comparison of coarse and fine sprays and no specific information can be furnished on this point, and it would appear safer for the orchardist to follow the methods used by Mr. Hammar until further information is obtained. It will also be noted that spraying was done under high pump pressure. This should not be construed to mean that effective work in the control of the codling moth can not be accomplished except by use of power outfits working at high pressure. Very good results have been obtained from the use of barrel sprayers working at perhaps 100 to 120 pounds pressure.

The prime essential in the control of the codling moth is that the treatment given immediately after the falling of the blossoms shall be made with great thoroughness, in order to insure the lodgment of poison in the calyx cup of each and every apple. This result is best secured by so handling the spray rods that the spray is directed downward into the upright clusters of the little apples. This spraying especially should be made rather deliberately and with great pains. Frequent examination of sprayed trees should be made to determine how thoroughly calyx cups are being filled with poison.

First application.—As soon as the petals have fallen, spray the trees with arsenate of lead, using the poison at the rate of 6 pounds to 200 gallons of water. Direct the spray straight into the calyx cups, for which purpose an elbow or crook should be used on the end of the spray rods. In spraying high trees a tower is indispensable, as shown in figure 2.

Second application.—About two weeks after the falling of the petals spray with arsenate of lead at the rate of 8 pounds to 200 gallons of water. Make an effort to apply this spray before the calyx lobes are more than three-fourths closed, which may be determined by careful examination in the orchard. (See fig. 3.) Direct this spray, also, as much as possible straight into the calyx cups, and at the same time take care to coat the leaves and fruit.

Third application.—Eight or nine weeks after the falling of the petals spray again with arsenate of lead at the rate of 8 pounds to 200 gallons of water. In this treatment cover the foliage and fruit as uniformly as possible with the poison.

Subsequent applications.—The three applications specified, if thoroughly made, should effectively control the codling moth, as shown by the results of experiments herewith reported. If these applications have not been thoroughly made, and it is seen that the codling moth will do considerable injury, additional applications will doubtless be desirable to check the insect as much as possible. Thorough work, especially in applying the first and second applications, should largely obviate the necessity for more than three treatments.

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DIV. INSECTS

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 90

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
May 19, 1914.

THE ROSE APHIS.[1]

By H. M. Russell,
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INTRODUCTION.

Because of its beauty, and its hardiness as an outdoor plant, the rose has long been one of the most popular ornamental flowers in this country. Yet in spite of the appreciation given it the blossoms and young foliage are frequently permitted to suffer great damage from the rose aphis (*Macrosiphum rosæ* L.), whereas a few minutes' attention on the part of the owner each week would remedy the injury and greatly increase the beauty of the bloom and foliage. This common rose pest was first described by Linnæus[2] in 1735, and since that time has often been mentioned in systematic works by both European and American writers. However, the writer has seen no account of it in American entomological publications in which the life history, habits, or control have been treated with anything approaching completeness. The writer, therefore, in 1910, while stationed at Los Angeles and under the direction of Dr. F. H. Chittenden, began a study of the life history and habits of the rose aphis in its occurrence on the outdoor roses so largely grown in southern California. At a later period the work was carried on to some extent in Washington, D. C. While this study is still incomplete, enough has been learned to give the rose lover a fair understanding of the habits of this insect and of the means for controlling it.

RECENT RECORDS.

During the fall and winter of 1909 and the spring of 1910 the writer found the rose aphis attacking roses and causing extensive damage to the buds and blossoms throughout the city and in the vicinity of Los Angeles. On October 21, 1909, when first observed,

[1] This bulletin is of interest to rose growers everywhere.

[2] Linnæus, C., Systema Natur., ed. 12, vol. 1, pt. 2, p. 734, 1767.

this insect had become quite common, and many of the buds were covered with the females and young. Examination of surrounding localities disclosed the same conditions of infestation. The aphides increased rapidly until the cold weather in December checked, although it did not entirely stop, their reproduction and growth. In January, warmer weather again prevailing, the rosebushes began to grow rapidly, and the rose aphis became very abundant on the tender stems and buds. It continued abundant and developed rapidly during the months of February and March, although syrphus-fly larvæ devoured thousands. Early in April, however, there occurred several very warm days when the temperature rose to 100° or 101° F., and immediately the numbers of aphides were greatly reduced. Afterwards the aphis occurred scatteringly on the roses and caused very little damage. This was due in part to extreme heat and the work of parasitic and predaceous enemies, and to the fact that in June the roses became more or less dormant and ceased active growth for some weeks. By the middle of August the rosebushes had resumed active growth, and this insect again began to increase rapidly and to cause damage, continuing to multiply and injure the roses until October 1, 1910, when observations ceased.

At Washington, D. C., during October and November, 1912, this aphis was very abundant and injurious to roses grown in the yards and gardens of the city. But by November 29 only a few aphides remained on the plants, although these persisted as late as December 16.

DESCRIPTION.[1]

The rose aphis occurs in two forms, one in which the body is of a pinkish color and the other in which the pink is replaced by bright green. Both forms may be present on the same bush or twig, and in some cases all on one bush may be green and all on another near it pink. It would appear from the writer's observations that the green aphides are much more abundant during the cooler months than the pink forms.

The winged female (fig. 1, *a*) has a pear-shaped body which in one form is pinkish and in the other bright green. The thorax is largely black, apparently deeper black in the green form, and there is a row of black spots on either side of the abdomen. These colors may vary slightly in shade. The antennæ, cornicles, ends of femora, and the tarsi are black, while the other parts of the legs are whitish. In both pink and green forms, however, the head may be entirely black, and the black antennæ and cornicles may be hyaline at the tips. The

[1] Another aphis commonly found on the rose is known as the small green rose aphis (*Myzus rosarum* Walk.), but this can be distinguished by its smaller size and by the fact that it has only a green form. This species is shown in figure 2, in both winged state (*a*) and wingless state (*b*) with many details of structure. This aphis will yield to the same treatments as the common rose aphis.

eyes are dark red, the cauda is yellowish, and the veins of the wings are light yellow. The legs, antennæ, and cornicles are very long and slender, the antennæ longer than the body. The length of the body is about one-twelfth of an inch (2.5 mm.) from the front to the tip of the cauda and the length of wing about one-sixth of an inch (4.2 mm.).

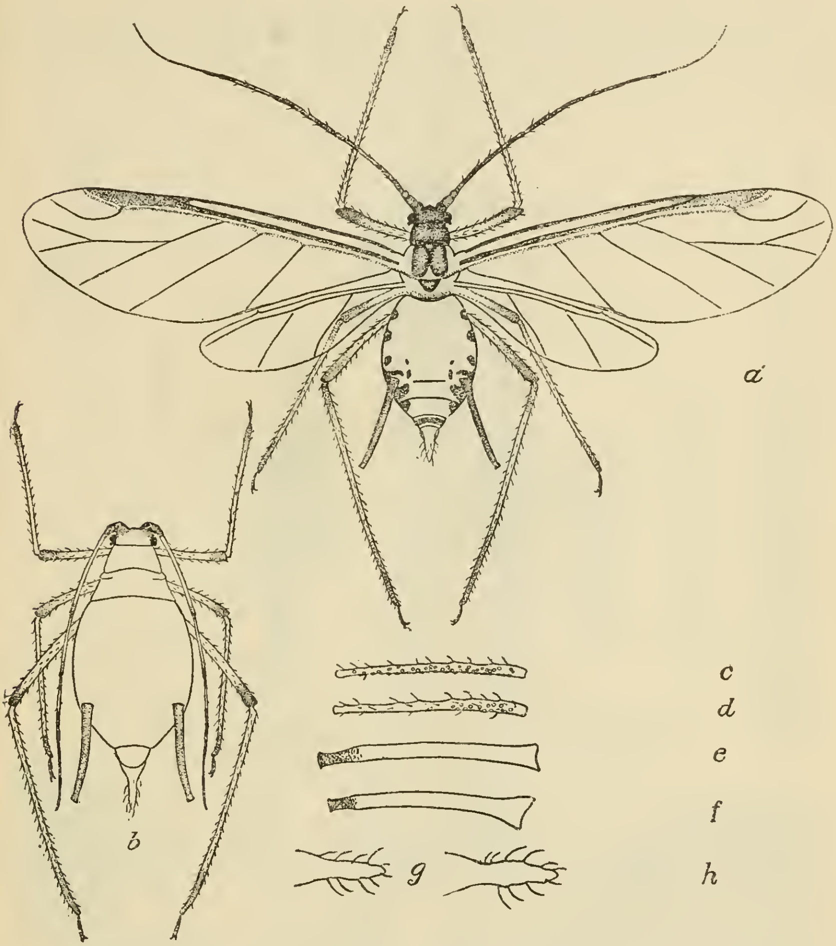

FIG. 1.—The rose aphis (*Macrosiphum rosæ*): *a*, Winged viviparous female; *b*, wingless viviparous female; *c*, *e*, *g*, third antennal article, cornicle, and style, respectively, of winged female; *d*, *f*, *h*, same of wingless female. Greatly enlarged. (After Essig.)

In the wingless female, also (fig. 1, *b*), the body is pear shaped, more or less blunted at the posterior end, and pinkish or bright green in color. The eyes are red. The antennæ are as long as the body and very light green. The cornicles and legs are long and slender and light green. The length of the body is about one-twelfth of an inch (2.5 mm.).

DISTRIBUTION.

The rose aphis is distributed over the entire United States, having been recorded from Massachusetts, New Jersey, Illinois, Iowa, Minnesota, Colorado, and California. It also occurs in Europe, from which country it was first described.

The writer has collected it in southern California on all the commoner varieties of roses growing outdoors and has also taken it, in 1913, in Connecticut, Maryland, the District of Columbia, and Virginia.

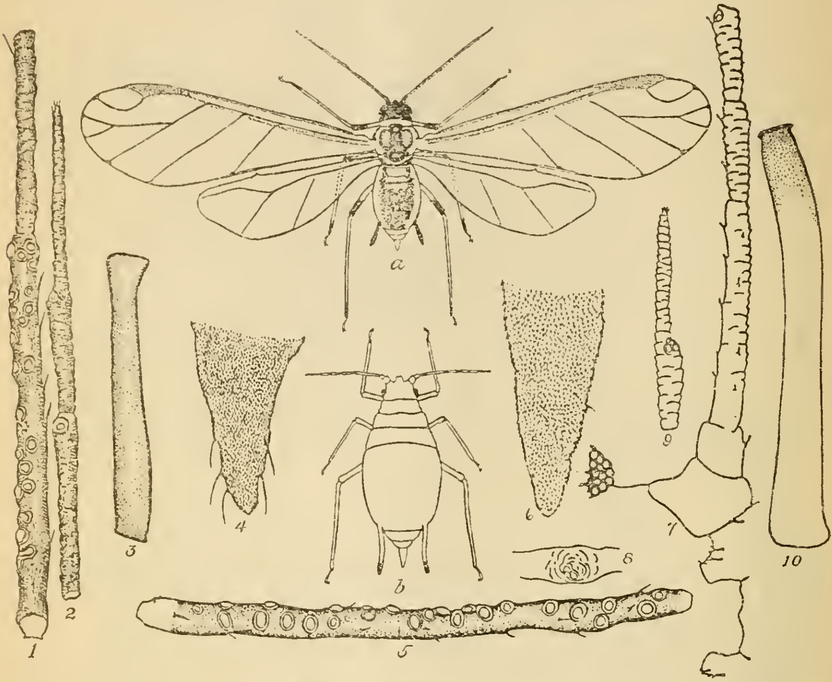

FIG. 2.—The small green rose aphis (*Myzus rosarum*): *a*, Winged viviparous female; *b*, wingless viviparous female; *1*, *2*, antennal articles of winged female; *3*, cornicle of same; *4*, style of same; *5*, third antennal article of same; *6*, style of wingless female; *7*, *9*, front and antenna of same; *10*, cornicle of same; *8*, process of sixth antennal article of same. Greatly enlarged. (After Essig.)

CHARACTER OF INJURY.

This insect, like all aphides or plant-lice, obtains its food by suction. The slender beak with which it is furnished is inserted into the plant attacked, and through this the plant juices are taken up. The rose aphis in feeding chooses the tender and growing shoots and flower buds or the young unfolding leaves, and by feeding in large numbers checks the growth, the leaves and flowers being curled or distorted and prevented from attaining their perfect form. (Pls. I, II.)

ROSE BUDS SHOWING INJURY BY THE ROSE APHIS (MACROSIPHUM ROSAE). ENLARGED. (ORIGINAL.)

ROSE BUDS SHOWING COLONIES OF THE ROSE APHIS (MACROSIPHUM ROSAE). ENLARGED. (ORIGINAL.)

Because of the feeding of this rapidly reproducing insect, the flowers may be largely spoiled for decoration, or, since the rose aphis, like all aphides, secretes a sweet sticky liquid called honeydew, the appearance of the foliage may be ruined because of the sooty mold that develops where this honeydew has collected.

HABITS.

About the time the wingless females become ready to reproduce they leave the parent colony and crawl or migrate to various parts of the rosebush. Upon finding a growing twig or bud, the female settles down with the head pointed toward the ground and begins to feed. In a day or two she begins to give birth to young, which ordinarily range themselves close together around the tender bud or stem behind the adult, and with the heads all pointing downward begin feeding. (Pl. II.) As the stem or bud becomes crowded many move out until the flower itself is covered with them. As the aphides continue feeding a large amount of honeydew is produced which falls to the leaves beneath, causing a disagreeable stickiness on the leaf, which either becomes covered with dust or black from sooty mold.

A very slight jar causes the aphides to let go with one pair of legs, and all begin to twitch from side to side on the remaining four legs until quiet is restored, while a severe jar causes many to fall to the ground. A number of the young develop wings, and when mature they fly to other buds and form new colonies.

When the nymph changes to the winged form the skin splits along the dorsum and the adult crawls slowly out. When newly transformed the adult is light reddish or green in color, with antennæ, beak, legs, and cornicles whitish or hyaline, and the wings, which are also white in color, appear as little sacks on the back. In about 20 minutes the wings become fully expanded, and two days later the aphis has the colors of the mature insect.

LIFE HISTORY AND REPRODUCTION IN CALIFORNIA.

In a climate as mild as that of southern California this insect reproduces continuously throughout the year and undoubtedly is capable of reproducing asexually and viviparously for an extended period. While under observation it has been found giving birth to living young throughout the entire year, and the writer has been unable to find eggs during the same period. It may be that in a climate such as exists in that part of the country, where very cold weather does not occur and where the roses continue to grow all winter, sexual forms and eggs of this species are not produced, at least until parthenogenetic reproduction causes deterioration.[1]

In other parts of this country where the winter conditions are more severe the rose aphis passes the winter in the egg stage. At Washington, D. C., on November 29, 1912, the writer found a few eggs of this species laid on the twigs of rosebushes. These small, oval, shining black eggs were fastened to the sides of dormant buds.

Buckton [2] described the eggs as follows:

> The eggs are at first yellow, but subsequently they become black by reason of certain changes shown by Balbiani to result from fecundation. Previous to this time the outer coats are sufficiently thin and transparent to allow the process of segmentation to be observed.
>
> Notwithstanding the great size of the ovum the female may carry five or more. These, however, are not equally large, but are found to vary in bulk as they approximate maturity and the time for expulsion.

In California during the fall and spring, while the rose shoots are growing vigorously and producing much tender growth, the rose aphis reproduces very rapidly. During the summer, however, the rate of reproduction seems to be much reduced, and, owing to the attack of natural enemies, this insect does not greatly increase. In the winter the time of development is lengthened and the rate of reproduction is considerably less.

During the months from October, 1909, to March 10, 1910, the author endeavored to ascertain the number of young produced and the average rate of reproduction under normal conditions. This was done by marking rose twigs having a single female and, after examining them every other day, removing all the young born at that time. Thus the aphides were exposed to temperature, rain, and all other natural conditions which might influence them. Under this method many females were knocked from the bushes and lost, but as this would occur naturally it demonstrates fairly well the average rate of reproduction, if not the maximum, under the conditions most favorable for the adult. These records have all been included in Table I.

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[1] B. M. Lelong, in the Report of the State Board of Horticulture for California, for 1889, page 213, states that "Kyber, in 1815, has had the rose aphis producing young for four years. From his carefully conducted experiments and from corresponding ones made by other naturalists a law has been educed, which we dare not destroy, 'that under certain circumstances, a female aphis may without coupling continue *propagating to infinity*, provided that the necessary conditions for the development of the young—food and heat—are not wanting.'"

[2] Buckton, G. B., Monograph of the British Aphides, vol. 1, p. 107–108, 1875.

Table I.—*Reproduction and development of the rose aphis, Macrosiphum rosae, in southern California, 1909–10.*

Date of birth of female unknown; gave birth to first young Oct. 20, 1909:

	Number of young.
Oct. 20	4
21	5
22	5
23	7
24	5
25	7
26	([1])
Total	33
Average per day	5½

Date of birth of female unknown; date of birth of first young unknown:

	Number of young.
Nov. 3	6
4	4
5	2
7	4
8	([1])
Total	16
Average per day	3+

Female born Nov. 18, 1909; gave birth to first young Dec. 6, 1909:[2]

	Number of young.
Dec. 6	1
8	5
10–11	6
12	3
13–14	4
15–16	9
17	2
18–19	3
20–21	6
22–23	5
25	2
28	([3])
Total	46
Average per day	2½

Date of birth of winged female, red form, unknown; date of birth of first young unknown:

	Number of young.
Nov. 18	[4]18
19	3
20	5
21–22	12
23	10
24	([1])
Total	48
Average per day, about	6

Date of birth of female unknown; gave birth to first young Nov. 19, 1909:

	Number of young.
Nov. 19	2
20	2
21–22	4
23	4
24	2
25	2
26	(?[5])
27	2
28	2
29	2
30	([1])
Total	22
Average per day	2

Date of birth of wingless female, green form, unknown; gave birth to first young Nov. 19, 1909:

	Number of young.
Nov. 19	2
20	5
21–22	6
23	5
24	4
25	3
26	(?[5])
27	4
28	([1])
Total	29
Average per day	3+

Wingless female born Nov. 18, 1909; gave birth to first young Dec. 6, 1909:[2]

	Number of young.
Dec. 7–8	3
8	([5])
10–11	3
13	7
15–16	7
17	3
18–19	6
20	1
21	([3])
Total	30
Average per day	2

[1] Aphis lost.
[2] Period from birth to reproduction, 18 days.
[3] Aphis dead.
[4] Up to date.
[5] Rain.

TABLE I.—*Reproduction and development of the rose aphis, Macrosiphum rosae, in southern California, 1909–10*—Continued.

Date of birth of female unknown; gave birth to first young Jan. 3, 1910:	Number of young.
Jan. 3	2
4	2
6	9
8	(1)
Total	13
Average per day	3
Winged female, red form; gave birth to first young Mar. 3, 1910:	
Mar. 3	5
4	5
5	9
6	5
7	5
8	3
9	(1)
Total	32
Average per day	$5\frac{1}{3}$
Mar. 7	5
8	5
9	7
10	(1)
Total	17
Average per day	$5\frac{2}{3}$

Two females were observed that produced 30 and 40 young, respectively, after which they died under normal conditions. They produced young on an average of 2 and $2\frac{1}{2}$ per day for 15 and 20 days, respectively, during the month of December. Other females observed during the same period, but lost possibly before reproduction was completed, gave birth to from 15 to 45 young at an average of $3\frac{1}{2}$ per day. Two females observed in the month of March, however, produced young at the rate of $5\frac{1}{3}$ and $5\frac{2}{3}$ a day, showing quite plainly how the reproduction was accelerated during the prevalence of warmer temperatures. Two females in October reproduced young at the rate of $5\frac{1}{2}$ a day for 6 days, or until lost.

From these observations it may be said that this insect is able to reproduce for at least 20 days during the winter in southern California and to give birth to as many as 45 young, while in the warmer seasons the number of young is probably greater and the period of reproduction is considerably shorter. The reproduction experiments were too few in number to justify making any statements more generalized than these.

LIFE HISTORY AND REPRODUCTION IN THE GREENHOUSE.

During the fall of 1912 the rose aphis was under the direct observation of the writer in the insectary greenhouse at Washington, D. C., and the life cycle was observed for a few individuals.

A wingless female born October 10 matured and gave birth to young on October 19, or in 9 days. During the next 7 days she gave birth to 45 young, or an average of $6\frac{3}{7}$ per day.

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[1] Aphis lost.

Of four other aphides, born on October 10, two became adult and gave birth to young on October 22, or in 11 days, while another required 12 days, and the fourth 13 days.

Another aphis was born on October 19 and emerged as a winged female on November 3, reaching maturity in 15 days. This insect lived as an adult for 17 days and gave birth to living young for 14 days. During this time she gave birth to 87 young, or an average of $6\frac{3}{14}$ per day. During this time the average mean temperature was 67° F.

LIFE CYCLE IN CALIFORNIA.

During the winter months of 1909–10 the life cycle was observed in California in a number of cases. Aphides born on the 18th of November became adult wingless females and began to reproduce young in from 15 to 18 days, and in two cases the offspring of these same insects became mature and began to reproduce in from 18 days for wingless females to 21 days for winged females. Aphides born November 26 emerged from nymphal skins as winged adults in from 23 to 25 days. Thus the wingless forms developed in all cases from 7 to 8 days sooner than winged forms.

This was the maximum life cycle, and during the rest of the year the growth must have been much faster, but observations were not made owing to press of other matters.

GENERATIONS.

Taking 25 days as a maximum, this would allow more than 12 generations annually, but with the shorter life cycle required during the warmer part of the year this number must be exceeded by at least 7 or 8 generations. In greenhouses there are probably 25 to 30 generations in a year.

LONGEVITY.

During the winter these insects are long lived for such delicate creatures. One lived under the direct observation of the writer for 40 days and another for 33 days. Probably this is longer than for the same insect the rest of the year.

NATURAL CONTROL.

RAINS.

In southern California the rainy season extends from about October 1 to May or June. Usually before the rains set in the weather becomes cooler, but the rains are not as a rule hard and dashing, as are those so fatal to aphides in the East, and this apparently explains their slight effects as observed on the rose aphis. Undoubtedly some are washed away and destroyed by rain, but not to the extent occurring in the East, although reproduction seems to be greatly checked during a rainstorm. In the East this insect is many times nearly exterminated by a hard, dashing rain.

HEAT.

During the early part of April, 1910, when the aphis was very abundant on the roses throughout the entire city of Los Angeles, three or four very hot days occurred during which the temperature rose as high as 100° F., and within a day or two thereafter the numbers of this aphis had become very much diminished. After this it did not seem to occur in large numbers again until about the middle of August.

BIRDS.

On March 19, 1910, the writer, with field glasses, watched a white-crowned sparrow (*Zonotrichia leucophrys leucophrys*) on a rosebush, 10 feet away, eating the rose aphides as fast as it could pick them from the bush. This was continued for fully 10 minutes, during which time many hundreds must have been eaten, as the plant was almost cleaned up by this bird.

On March 30, 1910, a California house finch (*Carpodacus mexicanu frontalis*) was observed by the writer eating this aphis from a rosebush for fully 15 minutes.

PARASITIC INSECT ENEMIES.

There are many different species of parasitic insect enemies that attack aphides, and some of these will attack the rose aphis. On June 13, 1910, many specimens of *Macrosiphum rosæ* were found which showed signs of parasitism by an undetermined insect. These aphides were rounded and fastened to the underside of the rose leaves. The parasite when full grown had killed the host and, cutting its way out beneath the body, spun a tiny cocoon between it and the leaf. Unfortunately all of the parasites failed to emerge. While the parasite was not rare, at least during the past year, it did not seem to check the rose aphis to any extent.

Ephedrus incompletus Prov., a braconid, was reared by the writer from this aphis at Washington, D. C., in 1912.

PREDACEOUS INSECTS.

Among the predaceous enemies the larvæ of syrphus flies and ladybirds were observed feeding on the rose aphis, and without a doubt the most important check to this insect in 1910 was due to the larvæ of syrphus flies. While these did not seem able to clear a plant altogether, still it was many times observed that strong thriving colonies of 50 to 60 aphides or more would be reduced by these insects in one or two days to a mere scattering here and there. During the year 1910 five different species of Syrphidæ were reared from larvæ feeding on *Macrosiphum rosæ*. These were *Syrphus ribesii* L. (fig. 3), *Syrphus opinator* O. S., *Allograpta fracta* O. S., *Eupeodes volucris* O. S. (fig. 4), and *Lasiophthicus pyrasti* L.

The adults of all these species seemed to have similar habits. They flew swiftly from twig to twig and hovered over them in the bright sunlight, the wings moving with extreme rapidity, always with a distinct humming sound. From time to time they alighted on the twigs or leaves and searched here and there for colonies of the aphis. The abdomen was generally kept in throbbing motion, and when an egg was to be laid a long slender ovipositor was thrust out and the egg was placed on a leaf or twig in the midst of or near the colony of the host insect. It was noticed that certain bushes shaded from the sun after 1.30 p. m. were immediately deserted by these flies until the next day.

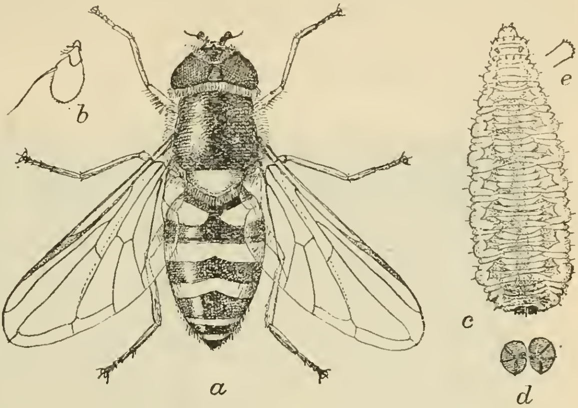

FIG. 3.—*Syrphus ribesii*, an enemy of the rose aphis: *a*, Fly; *b*, lateral view of head; *c*, larva or active immature form; *d*, anal spiracles; *e*, thoracic spiracle of same. All much enlarged. (From Chittenden.)

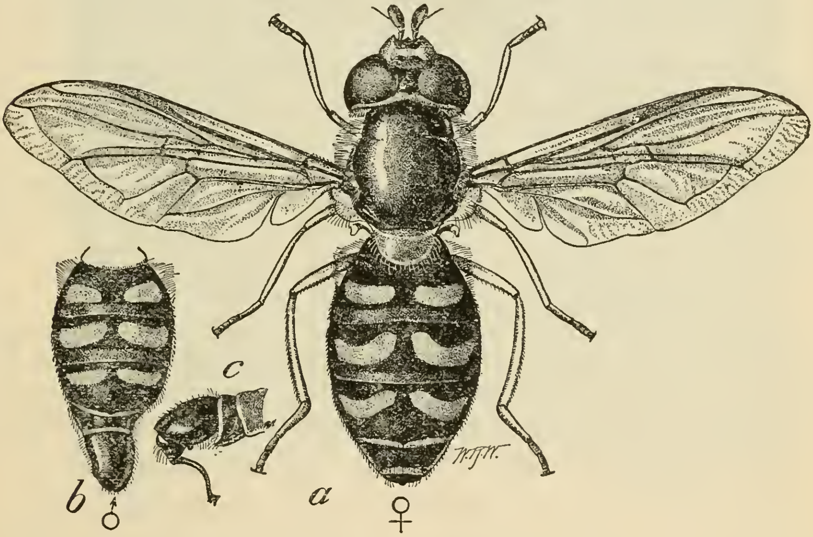

FIG. 4.—*Eupeodes volucris*, an enemy of the rose aphis: *a*, Female fly; *b*, abdomen of male fly; *c*, hypopygium of male fly. Much enlarged. (From Webster and Phillips.)

The rearing of five different species of syrphus flies from larvæ found feeding on the rose aphis rather surprised the writer, and he regrets that lack of time has prevented a continuation of the work that it might be ascertained if other species would also be commonly reared.

Although the ladybird *Hippodamia ambigua* Lec. was observed during the entire time occupied by the observations on the rose aphis, it occurred in small numbers, and on only one or two occasions did it seem to be feeding on *Macrosiphum rosæ.*

DISEASE.

On March 14, 1910, after a night of rain, one winged and two wingless aphides were found enlarged to fully five times their regular size, as if bloated. This was probably due to a fungous disease.

EXPERIMENTS WITH REMEDIES.

The abundance of the rose aphis is so marked in many years that frequently almost daily complaints of damage are made in the District of Columbia and vicinity. Wherever it has been convenient or desirable to eradicate this species on small acreages of plants, water, applied with a garden hose or syringe, has been the remedy employed, not alone by the writer but by many persons resident in Washington. Indeed this treatment, which consists in directing a forcible stream of water against the affected portions of the plants has been one of the standard remedies advised. Experiments have been made by Dr. F. H. Chittenden, by Mr. C. H. Popenoe, and by Mr. A. B. Duckett, all in the District of Columbia and vicinity. In other regions, Mr. W. B. Parker has undertaken experiments with nicotine sulphate, and the writer has conducted quite a series of experiments with the same compound. Among other compounds used by Messrs. Chittenden and Popenoe for this species are aphis punk and other nicotine papers, always with gratifying success. While treating other forms of insects on roses, such as "slugs" and thrips, the aphides were always the first to perish.

EXPERIMENTS IN THE DISTRICT OF COLUMBIA AND VICINITY. [1]

On March 28, 1913, at Washington, D. C., four rosebushes in the greenhouse, well infested by the rose aphis, were sprayed with "blackleaf 40," a preparation guaranteed to contain 40 per cent of nicotine sulphate, in combination with whale-oil soap in the following formula:

Nicotine sulphate	ounce..	½
Whale-oil soap	pound..	½
Water	gallons..	2½

Although the solution slightly injured the terminal buds and the tender shoots, the results were all that could be expected, 100 per cent of the aphides being killed. It is believed that the solution could have been reduced 25 per cent in strength with equally good results.

[1] By A. B. Duckett.

SPRAYING ROSE BUSH WITH COMPRESSED-AIR SPRAYER BY HAND.

On April 23, at a Virginia station near Washington, a number of large rosebushes trained on the side of a house and well infested with aphides were sprayed. Both winged and wingless forms of aphides were present. Nicotine sulphate was applied, with and without the use of soap as in the previous formula, at the rate of 1 part to 1,000 of water. In the experiments without the use of soap some difficulty was found in obtaining a spreading action of the spray, and consequently only about 90 per cent of the aphides were reached. It is believed that all reached by the spray were killed. When nicotine sulphate was used at the rate of 1 part to 1,400 parts of water and 1 part to 1,500 parts of water, results were not satisfactory, only about 25 and 10 per cent, respectively, being destroyed. With the use of soap 100 per cent of the aphides on the vines were killed, the results being very satisfactory. At the rate of 1 part of nicotine sulphate to 1,400 of water with a laundry soap added, 90 per cent of the aphides were killed; whereas the results with nicotine sulphate at 1 part to 1,600 of water and 1 part to 1,800 of water in combination with soap were unsatisfactory, only 70 per cent and 50 per cent being killed.

In these experiments a compressed-air sprayer with Bordeaux type of nozzle was used at an estimated pressure of 90 pounds, and a fine but driving spray was employed. The water used for the dilution of the insecticide was particularly soft, but contained a very small proportion of sulphur.

From these experiments it may be concluded that nicotine sulphate at the higher dilutions as used in these experiments is much more effective against the rose aphis when used in combination with whale-oil or other soaps, since the spreading action thus induced is much more favorable. The plants may, however, be injured in case the spray solution is too strong. It is not believed that the injury shown in the experiments was caused by nicotine sulphate used at too great a strength, since it has been applied experimentally to roses in the greenhouse at the rate of 1 part nicotine sulphate to 15 parts of water without injury other than the appearance of mildew, undoubtedly superinduced by the spraying. It is apparent from the results obtained that a spray can not be employed weaker than 1 part of 40 per cent nicotine sulphate to 1,400 parts of water with satisfactory results unless in combination with whale-oil or other soap.

ARTIFICIAL CONTROL IN THE GARDEN.

Experiments have been conducted against the rose aphis with different nicotine extracts under different conditions as to strength and weather. In no case, in the writer's experience, were the plants injured, whereas the insect was destroyed in enormous numbers. The aphis is easily controlled by spraying with nicotine solutions.

containing 40 per cent of nicotine at the rate of 1 part of the solution to from 1,000 to 2,000 parts of water, with whale-oil soap at the rate of 1 pound to 50 gallons of spray mixture. When only a few rose bushes require treatment the spray may be prepared in small amounts as follows: To 1 teaspoonful of 40 per cent nicotine solution add 1 to 2 gallons of water and one-half ounce of whale-oil soap. The soap should be shaved fine and dissolved in hot water.

There are on the market numbers of solutions containing less nicotine than the foregoing which may be used with good results with the addition of whale-oil soap, as advised, at the strength recommended by the manufacturers. If these are not obtainable, very good results may be accomplished by dissolving 1 pound of whale-oil soap or 2 pounds of common laundry soap in from 4 to 6 gallons of water. Wherever possible, however, the nicotine solutions should be used, as better results will be obtained.

This species, like practically all of the green aphides, can also be controlled by repeated applications of a forcible stream of cold water. Since the roses in California and some other localities are much subject to mildew, repeated use of this method has the disadvantage of increasing injury by this disease. In the case of the appearance of mildew, however, either through syringing with water or through the application of nicotine sulphate, this disease may be readily controlled by adding to the nicotine sulphate solution copper sulphate or blue vitriol at the rate of 1 pound to 50 gallons of water (approximately 1 ounce to 3 gallons). A solution of copper sulphate used at this strength and sprayed on the plants after the application of the water treatment is effective in controlling the mildew. Another common practice of florists for the prevention of mildew is to dust the plants immediately after sprinkling or watering with common flowers of sulphur.

In order successfully to fight this insect these sprays should be applied with a compressed-air sprayer (Pl. III) or bucket pump capable of creating a fine penetrating spray. These pumps can usually be purchased at the seed stores at from $3.50 up to $15. The nicotine solutions are also carried by most seed stores. Where a pump is not to be obtained much can be accomplished by dipping the infested twigs into a pail of the solution of nicotine.

From the experiments of the writer it is evident that this insect can be destroyed easily by the use of nicotine solutions of considerably less strength than have heretofore been used, but the treatment must be repeated at intervals to kill the aphides missed by former applications. With the different styles of pumps now on the market at low prices no one who cares for roses has the slightest excuse for allowing them to be injured by this insect.

TREATMENT IN THE GREENHOUSE.

For the treatment of the rose aphis as it occurs in greenhouses the nicotine solutions may be used, but at a lower strength than advised in the preceding paragraphs. Conditions vary somewhat, but it is believed that in most cases if the nicotine solution is used at the strength of 1 part to 2,000 of water it will not injure the rose plants if applied on a dark day or late in the afternoon so that the plants will not be exposed to reflected sunlight through the glass.

When greenhouses containing different forms of plants are syringed with a forcible stream of water or with neutral soaps of the castile or similar types for the red spider and other insects, the rose aphis and other green aphides will also be killed. The same is true in regard to fumigations with hydrocyanic-acid gas for other rose pests. Directions for the use of hydrocyanic-acid gas for the fumigation of greenhouses and cold frames are given in Circular No. 37 of the Bureau of Entomology. In the experience of Dr. A. F. Woods, the author of that publication, the young growth of roses is particularly sensitive and has been more or less injured in experiments in the use of this gas. This is particularly true of such varieties as "Perle des jardins," "Mermet," and "Bride."

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DIV. INSECTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 92

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
May 15, 1914.

DESTRUCTION OF GERMS OF INFECTIOUS BEE DISEASES BY HEATING.

By G. F. White, M. D., Ph. D., *Expert, Engaged in the Investigation of Bee Diseases.*

INTRODUCTION.

To reduce the losses due to bee diseases beekeepers have often employed heat in one form or another. The direct flame has been used in scorching or burning the inside of hives that have housed infected colonies. Before being fed back to bees honey is often heated for the purpose of destroying the germs of bee diseases, should any be present. Heat is used in the rendering of wax and in the making of comb foundation. It is natural and very appropriate, therefore, that beekeepers should inquire about the amount of heating that is necessary to destroy the germs that produce diseases among bees.

As no work had been done to determine the facts relative to this question with any degree of accuracy, the writer has performed during the last two years a number of experiments for the purpose of ascertaining them. Of these experiments 55 are summarized in the three tables included in this paper. It may be of interest to beekeepers to know in a general way how these experiments were made. A brief description of the methods used will serve also to make the tables more readily understood. An aqueous suspension of larvæ sick or dead of the disease is made and placed in a small glass tube. This tube is immersed in water of the temperature desired in the heating. After the germ-containing material is heated in this way it must be tested to determine whether or not the germs have been destroyed. In the case of American foul brood this can be done by inoculating a suitable artificial medium with the heated material and observing the presence or absence of growth of *Bacillus larvæ*, the germ of this disease. As there is no artificial medium now known suitable for cultivating the infecting agent of either European foul brood, sacbrood,

Note.—This paper is of interest to beekeepers in all parts of the United States; it was read before the New York State Beekeepers' Association, February 10, 1914, at Ithaca, N. Y.

35960°—14

or Nosema disease, healthy colonies of bees must be inoculated in making the test in case of these diseases. This is done by feeding the bees the heated germ-containing material in sirup. If the disease is produced by this feeding, naturally the infecting agent has not been destroyed by the heating; but if the disease is not produced, it virtually has been destroyed by it. By repeated experiments of this kind in which the temperature used in the heating is varied, the minimum temperature at which any virus is killed can be determined. As will be seen from the tables, 13 experiments for European foul brood, 22 for sacbrood, and 20 for Nosema disease were made in which healthy colonies were inoculated with heated germ-containing material from these three diseases, respectively. In the last disease the stomachs from diseased bees furnished the germ-containing material for heating and feeding. In these experiments the temperature was maintained for 10 minutes as a rule.

DISEASES OF THE BROOD OF BEES.

Nearly a century and a half ago the name "foul brood" was used for a destructive brood disorder of bees, and for almost a century later it was apparently the custom to diagnose as foul brood any destructive disease of the brood. About half a century ago beekeepers began to note that all of the brood diseases are not the same. They began, therefore, to write of different forms of foul brood. At the present time it is known that there are at least three infectious diseases of the brood of bees. All of these diseases are more or less destructive, and it is quite likely that each of them has now and then been diagnosed as foul brood. In America these brood diseases are now known as European foul brood, American foul brood, and sacbrood.

EUROPEAN FOUL BROOD.

In European foul brood death occurs early, the larvæ dying usually before the time for cell capping. There is no viscidity (ropiness) to the decaying larvæ as a rule, and no pronounced odor present.

Numerous samples of this disease have been examined from the United States, and some from Canada. Its presence also in England, Germany, Switzerland, and Denmark is strongly suggested by written reports from these countries. It is very probable that the disease has a much wider geographical distribution than these facts indicate.

Two years ago the fact was demonstrated that the germ causing European foul brood is the microorganism to which the name *Bacillus pluton* is given. In a paper[1] announcing the fact it was stated that the studies then made indicated that the germ is easily killed by heat. This belief has been confirmed by further experiments.

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[1] White, G. F., 1912. The Cause of European Foul Brood. U. S. Dept. Agriculture, Bureau of Entomology, Cir. No. 157.

Table I gives a brief summary of 13 inoculation experiments performed for the purpose of determining approximately the amount of heating necessary to destroy the germ of European foul brood.

TABLE I.—*A summary of the experiments made to determine approximately the minimum amount of heating necessary to destroy the germ causing European foul brood.*

Dates of inoculation.	Temperature.	Time of heating.	Results of inoculation.
	°C.	*Min.*	
Sept. 12, 1912	75 to 80	10	No disease produced.
Do........	65 to 70	10	Do.
Sept. 23, 1912	64 to 66	10	Do.
Oct. 12, 1912	64 to 65	10	Do.
Oct. 1, 1912	62 to 63	10	Do.
Oct. 8, 1912	62 to 63	....	Do.
Oct. 10, 1912	62 to 63	10	Disease produced.
Oct. 4, 1912	61 to 62	10	Do.
Aug. 8, 1913	60	20	Do.
Sept. 3, 1912	60	10	Do.
Sept. 20, 1912	58 to 60	10	Do.
Sept. 28, 1912	57 to 60	20	Do.
Sept. 20, 1912	55 to 56	10	Do.

It will be observed by an inspection of Table I that European foul brood was produced in every instance where healthy colonies were fed disease material which had been heated for 10 minutes at temperatures below 63° C. (145.4° F.), but that no disease was produced when temperatures higher than 63° C. (145.4° F.) were used for the same length of time. The minimum temperature that can be used, therefore, in destroying the germ of European foul brood, if it is applied for 10 minutes, lies somewhere between 60° C. (140° F.) and 65° C. (149° F.), being near 63° C. (145.4° F.).

AMERICAN FOUL BROOD.

American foul brood is the disease of the brood of bees that is best known to beekeepers and is the one the presence of which they have been able to recognize most easily. In this disease the larvæ usually die after the cells containing them are capped. The disease is characterized especially by the marked viscidity (ropiness) manifested by the decaying larvæ that are dead of the disease. The pronounced odor noticeable within hives housing colonies affected by this disease, especially in its later stages, is another well-known characteristic.

This disease is very widely distributed geographically. Samples of it have been received from many localities in the United States, from Switzerland, New Zealand, Germany, England, and France, and it is very probable that it has a much wider geographical distribution even than is indicated by these facts.

Until seven years ago the cause[1] of American foul brood was not known. At that time the fact was demonstrated positively that the

[1] White, G. F., 1907. The Cause of American Foul Brood. U. S. Dept. of Agriculture, Bureau of Entomology, Cir. No. 94.

germ causing the disease is the one to which the name *Bacillus larvæ* is given.

The facts obtained to date are too meager to justify anything more than a general statement regarding the minimum amount of heating that can be employed in rendering material containing the germ of American foul brood noninfectious. Taking rather wide limits, it may safely be said that the minimum temperature at which this can be done, if the temperature is applied for 10 minutes, lies somewhere between 90° C. (194° F.) and 100° C. (212° F.). It seems quite probable, indeed, that a temperature less than 98° C. (208.4° F.) will suffice if applied for 10 minutes. When 100° C. was used the spores of *Bacillus larvæ* were killed in less than five minutes.

SACBROOD.

Observant beekeepers have for many years noted the presence of dead brood which seemed to them to be different from that dead of foul brood. Some were inclined to believe that the disease was an infectious one; a larger number apparently were disposed to ascribe the trouble to such causes as an unsatisfactory queen, starvation, and the like. This brood disease has been recently demonstrated to be an infectious one, and the name "sacbrood" has been given to it. Larvæ that die of this disease do so almost invariably after the time of cell capping. The most characteristic symptom of the disease is the saclike appearance of the dead larvæ when they are removed from the cell. This fact suggested the name "sacbrood" for the disease.

Sacbrood is frequently met with. Its presence has been diagnosed by Dr. A. H. McCray and the writer in 367 samples received from 44 States of the Union and in 13 samples received from Canada. Reports from England, Switzerland, and Australia indicate strongly that this disease exists in these countries also. It is very probable that it has a much wider geographical distribution than is shown by these facts.

More than a year ago it was again the writer's fortune to determine the cause of another brood disease. Unlike the cause of either European foul brood or American foul brood, the infecting agent causing sacbrood has not yet been seen. It was demonstrated, however, that the infecting agent in this disease passes through the pores of earthenware filters. For this reason the cause of sacbrood is spoken of as a filterable virus.

In a paper[1] announcing the cause of sacbrood the statement is made that the germ causing the disease is destroyed by a comparatively small amount of heat. This belief is confirmed by the results of the experiments summarized in Table II.

[1] White, G. F., 1913. Sacbrood, a Disease of Bees. U. S. Dept. of Agriculture, Bureau of Entomology, Cir. No. 169.

TABLE II.—*A summary of the experiments made to determine approximately the minimum amount of heating necessary to render sacbrood material noninfectious.*

Dates of inoculation.	Temperature.	Time of heating.	Results of inoculation.
	° C.	*Minutes.*	
July 27, 1912	95 to 100	2	No disease produced.
Aug. 8, 1912	95 to 100	2	Do.
Aug. 29, 1912	75 to 80	10	Do.
Sept. 5, 1912	65 to 70	20	Do.
Sept. 3, 1912	55 to 60	20	Do.
Aug. 26, 1913	80	15	Do.
Do.	75	15	Do.
Do.	70	15	Do.
Do.	65	15	Do.
Do.	65	15	Do.
Sept. 2, 1913	65	15	Do.
Sept. 3, 1913	60	20	Do.
Sept. 9, 1913	60	15	Do
Sept. 10, 1913	60	15	Do.
Sept. 17, 1913	60	10	Do.
Sept. 10, 1913	58	10	Do.
Sept. 17, 1913	58	10	Do.
Sept. 18, 1913	57	10	Sacbrood produced.
Sept. 9, 1913	55	20	Do.
Sept. 10, 1913	55	10	Do.
Sept. 17, 1913	55	10	Do.
Aug 6, 1913	50	30	Do

From Table II it will be observed that when larvæ dead of sacbrood were heated 10 minutes at a temperature of 57° C. (134.6° F.) or less and then fed to a healthy colony, sacbrood was produced; if, on the other hand, the dead larvæ used in making the feeding were heated to 58° C. (136.4° F.) or higher, the disease was not produced. The conclusion to be drawn from these experiments is that the minimum temperature, when maintained for 10 minutes, at which the infecting agent causing sacbrood is destroyed lies somewhere between 55° C. (131° F.) and 60° C. (140° F.), being near 58° C. (136.4° F.).

DISEASES OF ADULT BEES.

Very little is known about the diseases of adult bees. Many names have been used for the purpose of designating them, but the number of such diseases is probably small. There is only one adult disease that can be diagnosed at present by laboratory methods. This one is the Nosema disease.

NOSEMA DISEASE.

Fifty-seven years ago Dr. Dönhoff made a more or less brief study of a disease of adult bees in Germany. He observed that the stomach was the organ that was primarily affected. By feeding to healthy colonies in sirup the crushed stomachs from affected bees Dönhoff demonstrated that the disease could be transmitted to healthy colonies. It was therefore infectious.

The work by Dönhoff had been practically forgotten, apparently, when Zander,[1] of Erlangen, Germany, five years ago observed the

[1] Zander, E., Aug., 1909. Tierische Parasiten als Krankheitserreger bei der Biene. Münchener Bienenzeitung.

presence of a disease among adult bees. From the evidence at hand it seems most probable that the disorder encountered by Dönhoff and the one encountered by Zander are one and the same disease.

Aside from rediscovering the disease Zander has identified the germ causing it as a protozoan (a one-celled animal parasite) and has given to it the name *Nosema apis*. For the disease he has used the name "Nosema Seuche." This is an appropriate one, as it suggests somewhat the nature of the disease. The name "Nosema disease," which the writer suggests as the common name for this disease, is, it will be observed, only a translation of the German name used by Zander.

The germ *Nosema apis* gains entrance to the body of the bee by way of the alimentary canal. In the walls of the stomach the growth and multiplication of the parasite take place to an enormous extent, causing the abnormal appearance manifested by the organ. When the disease reaches an advanced stage the stomach is white and fragile and reveals upon a microscopic examination the presence of the parasite in very large numbers. In the spring of the year, especially, many weak colonies show upon examination a high percentage of Nosema-infected bees. Quite often, indeed, in the examinations that have been made of such colonies, 50 to 90 per cent of the bees in samples taken from them were found to be infected with the parasite. It is an interesting and important fact that a very large number of colonies which are strong and apparently doing well are found upon examination to contain at least a small percentage of Nosema-infected bees.

Nosema apis has a very wide geographic distribution. It has already been encountered in Germany by a number of investigators; it has been found in Australia, Switzerland, and England. The writer has found it in samples of bees received from 27 different States in the United States and in two samples of adult bees from Canada.

From the facts gathered it would seem that many of the cases called "spring dwindling" by the beekeepers are caused, in part at least, by *Nosema apis*. This statement is not by any means to be interpreted as saying that Nosema disease and spring dwindling are always the same.

It has been demonstrated experimentally that colonies can be weakened and killed by feeding to them material containing *Nosema apis*. For this and other reasons it seems certain that the disease causes a loss to apiaries, but, for want of sufficient data, the extent of such loss can not now be estimated at all definitely. From the facts at hand one is justified in at least drawing the conclusion that Nosema infection in a colony tends to weaken the colony. *Nosema apis* is therefore a germ in which the beekeeper is economically interested.

For the purpose of determining approximately the minimum amount of heating that is sufficient to destroy the germ *Nosema apis* the inoculation experiments summarized in Table III were made.

TABLE III.—*Summary of experiments in which the germ, Nosema apis, was heated and fed to healthy colonies.*

Dates of inoculation.	Temperature used in heating.	Time of heating.	Results of inoculation.
	° C.	*Minutes.*	
Oct. 29, 1912	95 to 100	5	No Nosema infection produced.
Nov. 12, 1912	95 to 100	5	Do.
Oct. 29, 1912	80	20	Do.
Nov. 9, 1912	80	10	Do.
Nov. 11, 1912	68 to 70	10	Do.
Do.......	68 to 70	10	Do.
Nov. 12, 1912	65	20	Do.
Jan. 8, 1913	65	10	Do.
Nov. 11, 1912	60	10	Do.
Do.......	60	10	Do.
Nov. 20, 1912	60	10	Do.
Feb. 8, 1913	58	10	Do.
Oct. 4, 1913	58	10	Do.
Feb. 8, 1913	57 to 58	15	Do.
Oct. 15, 1913	57	10	Do.
Do.......	57	10	Do.
Oct. 4, 1913	56	10	Nosema infection produced.
Oct. 15, 1913	56	10	Do.
Jan. 8, 1913	55	20	Do.
Jan. 31, 1913	55	10	Do.

It will be observed from Table III that when *Nosema apis* was heated to 57° C. (134.6° F.) or higher for 10 minutes and fed to healthy bees no infection took place, but when held at temperatures below 57° C. (134.6° F.) for the same period of time the bees became Nosema infected. It is shown, therefore, that the minimum temperature that will destroy the germ *Nosema apis* in 10 minutes lies somewhere between 55° C. (131° F.) and 60° C. (140° F.), being quite near 57° C. (134.6° F.).

By way of parenthesis it might be well to say a word or two further regarding Nosema disease. The studies of this disease disclose the interesting fact that it is not a new one in American apiaries. There is no cause, therefore, for anticipating any additional losses to our apiaries. Indeed, since the presence of the disease is known, hopes may be entertained that methods will be determined for reducing the losses due to it. Considerable work must yet be done, however, before methods for its control can be recommended.

Nosema disease is being studied in England, Germany, Switzerland, and Australia. During the last two years the writer has devoted considerable time to its study in America. The plan is to continue the studies during the present year, after which it is hoped a further discussion of this disease will be justified.

SUMMARY AND GENERAL REMARKS.

The results of these experiments show that when they are maintained for 10 minutes the minimum temperatures that can be used for destroying the germs of the four bee diseases now known to be infectious are as follows:

(1) The minimum temperature for European foul brood lies somewhere between 60° C. (140° F.) and 65° C. (149° F.), being approximately 63° C. (145.4° F.).

(2) The minimum temperature for American foul brood lies somewhere between 90° C. (194° F.) and 100° C. (212°) F., being probably less than 98° C. (208.4° F.).

(3) The minimum temperature for sacbrood lies somewhere between 55° C. (131° F.) and 60° C. (140° F.), being approximately 58° C. (136.4° F.).

(4) The minimum temperature for Nosema disease lies between 55° C. (131° F.) and 60° C. (140° F.), being approximately 57° C. (134.6° F.).

It will be noted, therefore, that 63° C. (145.4° F.) for European foul brood, 98° C. (208.4° F.) for American foul brood, 58° C. (136.4° F.) for sacbrood, and 57° C. (134.6° F.) for Nosema disease are the approximate minimum temperatures at which the germs of these diseases, respectively, are destroyed. Since there are varying factors in experiments of this nature that tend to produce slight variations in results, these temperatures are referred to as being approximate. It is probable that future experiments may cause slight changes to be made in these conclusions. Nothing more than a comparatively slight variation is to be expected, however. In practice the beekeeper, in destroying these germs by heating, will naturally use a quantity of heat somewhat in excess of the minimum amount that is absolutely necessary.

Some generalizations may now be made which will be of interest to the beekeeper. The melting point of beeswax is between 62° C. (143.6° F.) and 64° C. (147.2° F.), inclusive. It will be observed that this same temperature in 10 minutes will destroy the germ causing European foul brood, and that it is about 10° F. above that which will destroy the germs of sacbrood and Nosema disease. A further interesting generalization may be made concerning the heating of honey. Honey when heated to 160° F. reaches a temperature 15° F. above the temperature necessary to destroy the germ of European foul brood and about 25° F. above the temperature that will destroy the infecting agents of sacbrood and Nosema disease. The infecting agents of these three diseases of the bee, therefore, will be destroyed when the temperature of 160° F. is used in the commercial handling of honey. Finally, it is believed that the results of this work on the thermal death point of the viruses of the bee diseases will be directly applicable to the control of these diseases.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 93

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
April 30, 1914.

THE TEMPERATURE OF THE HONEYBEE CLUSTER IN WINTER.

By E. F. Phillips, Ph. D., *In Charge of Bee Culture Investigations*, and George S. Demuth, *Apicultural Assistant*.

INTRODUCTION.

The care of bees in winter is one of the most perplexing problems confronting the beekeeper, especially in the North. This appears to be due chiefly to the fact that it is difficult to determine by direct observation the normal activities of the bee colony in winter, and consequently it is well-nigh impossible to determine what external conditions are most favorable except by the gross results of experience. Nor can we by a study of our wintering successes and failures determine definitely whether the same conditions of temperature and humidity are desirable throughout the entire winter. On account, therefore, of the lack of accurate knowledge of the activities of bees in the winter season this problem has been taken up with the aid of certain special apparatus and equipment. This preliminary report is not to be considered as giving definite recommendations as to the care of bees in winter, but rather is issued to make known to beekeepers some of the interesting results obtained in the first season's work on the behavior of the bees during the winter season.

American beekeepers lose thousands of dollars annually in winter from the actual death of colonies and even still more from those colonies that do not die, but which are reduced in numbers and vitality. The wintering problem is therefore a vitally important one. The factors influencing the welfare of the colony and the behavior of the bees are numerous and closely interrelated. Of the chief ones may be mentioned external temperature, food, ventilation, humidity, the condition of the colony at the beginning of winter, and various forms of irritation. In the present paper special emphasis is placed on heat production, by which is meant the responses of the bees of the cluster to the outer temperature and to changes in the outer temperature as manifested in the generation of heat by the bees.

Note.—This bulletin presents studies of bees as affected by temperature conditions during winter and is of special interest to beekeepers in the North.

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A special reason for this emphasis in a preliminary paper is that all previous work on the temperature of the cluster in winter, of which there has been considerable, has failed to show definitely what the normal responses are. The data are often those of abnormal conditions and are therefore misleading, making them almost valueless for purposes of application. One source of error which is to be found in all the records known to the authors is the use of the mercury thermometer, for, when such a thermometer is used, it is almost impossible to avoid disturbing the cluster at each reading so that it reacts abnormally. Furthermore, as the authors will attempt to show at a later time, disturbances of the colony may influence the temperature of the cluster for a considerable period, often more than one day. Usually no account has been taken of the necessary corrections to be made for the mercury thermometer.

Because of the errors in other work on the subject, due to the use of mercury thermometers, the thermometers chosen for the work here recorded are of another kind. Electrical thermometers are used, by means of which readings can be made without approaching the hive, and the thermometers (couples) are of course permanently fastened in place. These are of the type known as thermocouples or thermal junctions and the readings are made by means of a potentiometer indicator and a sensitive galvanometer of the d'Arsonval type. The wires used in the thermocouples are copper and constantin (a copper-nickel alloy), giving an electromotive force of about 40 μV per degree centigrade. A detailed description of the apparatus is impossible here, and it need only be stated that the method as used gives readings to an accuracy of 0.09° F. (0.05° C.); the thermometers are practically instantaneous in their action—that is, show changes in temperature without a "lag"; the readings of many thermometers can be made consecutively on one carefully calibrated instrument, insuring uniformity, which is impossible in using many mercury thermometers; and, a point of importance in such work, the readings can be made at the rate of two a minute, which would be impossible with widely scattered instruments. In all, 161,617 temperature readings were made during the winter 1912–13, and the work is being continued.

Part of the colonies are kept in a well-insulated room (used as a "bee cellar") in the zoological laboratory of the University of Pennsylvania, Philadelphia, Pa., which can be kept at a temperature usually varying not over 2° F., far more uniform than the ordinary bee cellar. Abundant ventilation is provided, and the room is completely darkened to avoid possible disturbance by light. The temperatures of the indoor colonies are read from an adjoining laboratory to eliminate the possible errors due to disturbance, and the room is entered rarely (about once a week on an average and, if possible, only after the day's records are made) and only when absolutely necessary. It is found that entering the constant-temperature room may under some conditions influence the behavior of the bees in a marked manner.

Other colonies are kept on the roof of the same laboratory, where they are left untouched from the beginning to the end of a series of readings. The wires of the thermometers are led to the room below through rubber tubes, and all the temperature readings are made at a distance, as is absolutely necessary to eliminate disturbance. Disturbances of outside colonies have also been found to influence their behavior in a pronounced manner, especially in cold weather.

By studying the temperature of various fixed points within each hive it has been found possible to use the temperature readings as a substitute for direct observations. After becoming familiar with the normal temperature and the temperatures incident to various activities one can tell the shape, location, and various activities of the cluster by a study of the temperature of different points within the hive and can, in fact, form an opinion as to the welfare of the colony. It has therefore been possible to follow closely the activities of each cluster without opening the hives and even without going near them.

THE INFLUENCE OF EXTERNAL TEMPERATURE ON HEAT PRODUCTION.

The colony (A) to be discussed under this heading was wintered out of doors (1912–13) on the roof, where the bees were free to fly whenever the weather permitted. It was in a 10-frame Langstroth hive, with the entrance reduced to $\frac{3}{8}$ inch deep and 8 inches wide, and was not packed or given additional protection. This hive contained 19 of the electrical thermometers—12 among the combs, 4 in the corners of the hive, and 3 on the bottom board. Readings were made hourly from 9 a. m. to 4 p. m. through the winter (Sept. 26 to Mar. 28), except Sundays and holidays, and at intervals additional readings were made every 15 minutes (or sometimes every 30 minutes) during the night (5 p. m. to 8.45 a. m.) for periods of several days each. In all, 41,413 temperature records were made for colony A.

The reaction of the cluster in heat production, as induced by changes in external temperature, is well shown by the records made from noon November 13 to 2 p. m., November 15 (1912), when readings were made hourly from 9 a. m. to 4 p. m. and every 15 minutes at night. From noon on November 13 the outside temperature dropped slowly until 6 a. m., November 15, and the weather was cloudy, so that the bees did not fly. It will be seen from the accompanying diagram (fig. 1) that at noon on the 13th the outside temperature was about 69.2° F. and all the points within the hive were

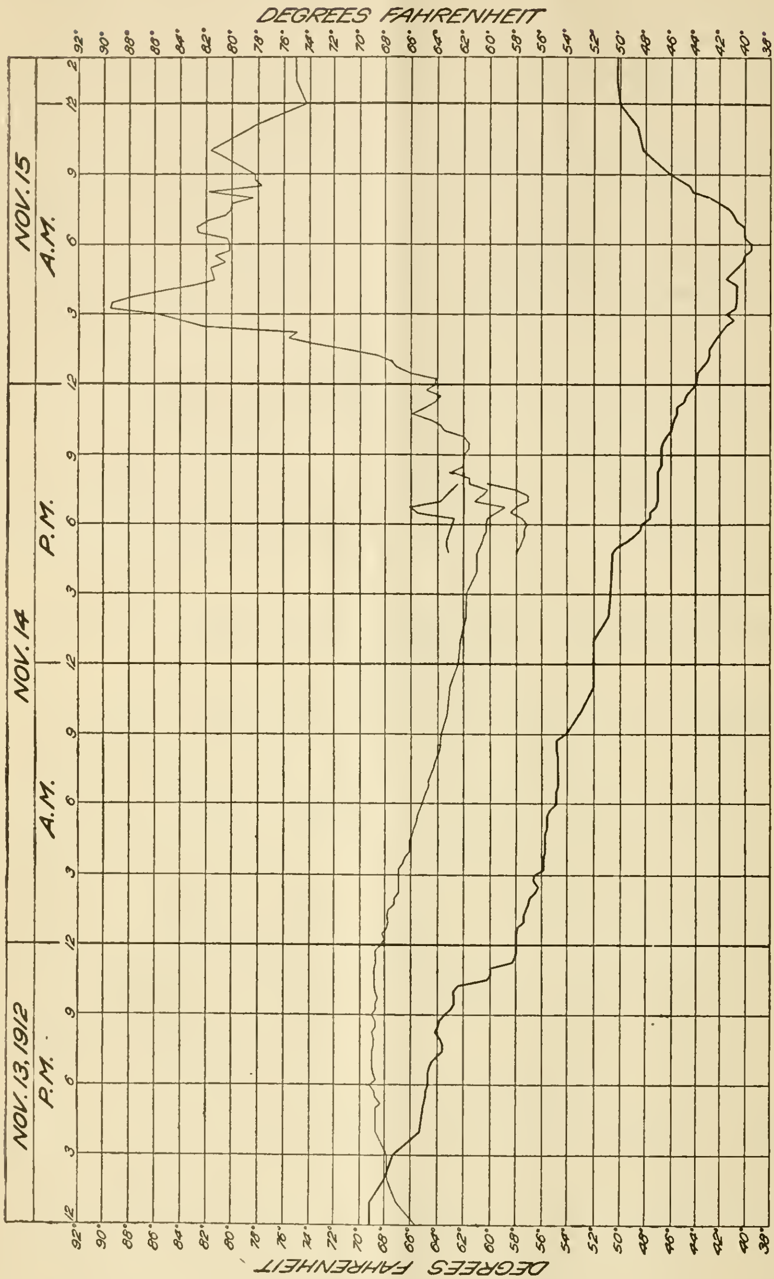

FIG. 1.—The outdoor temperature and temperature of the center of the cluster of bees in colony A from noon Nov. 13 to 2 p. m. Nov. 15, 1912. Outdoor temperatures are indicated by the heavy line. Short lines show temperatures of couples on the outer edge of the cluster at the time of first heat production.

then cooler than the outside air, due to the fact that it took some time for the inside of the hive to warm up. At 4 p. m. the outside temperature had dropped to 65.3° F., when it was lower than any of the points within the cluster, which had in the meantime become warmer. From this time until 6 p. m. the next day (14th) the temperature within the cluster gradually dropped as the outer air cooled, until the lowest one (No. 9) was 57° F. (Outside temperature, 48.2° F.) The generation of heat began at 6.15 p. m. at this point, which was to one side of the cluster, and is to be attributed to the movement of the bees in forming a definite cluster. At 6.30 p. m. a rise in temperature was noticed on thermometer 19, at the other side of the cluster. Until 10.15 p. m. the changes in temperature are probably to be interpreted as incidental to the formation of a compact cluster, and from this time until the next day at the close of the series of readings the thermometers within the cluster showed a considerably higher temperature than the outer air, or than the thermometers outside the cluster. The maximum in this series was reached at 3.15 a. m., November 15, when thermometer 12 in the center of the cluster registered over 89.4° F.

After the coldest outside temperature was reached and the outer air began to get warmer (6.15 a. m., November 15), there was a tendency for the cluster temperatures to drop. This is somewhat noticeable in the case now being discussed, and is more clearly seen in records obtained in other series. In general, after a period of cold, when the outside temperature begins to rise, the cluster temperatures drop slowly to meet the outside temperature. The generation of heat is reduced, or even discontinued, only to be increased when the outside temperature again drops, or when it gets high enough to induce greater activity, as in flight. It is found also by taking more frequent readings when the cluster temperature is above about 69° F. that it is less constant than when it is below this temperature, indicating that at temperatures above this point the bees move about to some extent, while between 57° and 69° they are quiet, unless flight is desirable owing to a long confinement.

This series of readings is supported by numerous records taken on this and other colonies throughout the winter and, since all the observations tend to confirm what was first seen on the record presented here, the authors feel justified in presenting a definite statement of the reactions of the cluster to outside temperatures. It may be added that a careful study of the records of previous investigators fails to show a similar statement on this subject. When a colony is without brood, if the bees do not fly and are not disturbed and if the temperature does not go too high, the bees generate practically no heat until the coolest point among the bees reaches a temperature of about 57° F. At temperatures above 57° F. a compact cluster is not formed, but the bees are widely distributed over the combs. At the lower critical temperature, which is for the present stated as 57° F., the bees begin to form a compact cluster, and if the temperature of the air surrounding them continues to drop they begin to generate heat within the cluster, often reaching temperatures considerably higher than those at which they were formerly quiet and satisfied. It is evident, therefore, that the temperature within the cluster is far from being uniform in winter, as has been, in a sense, assumed among practical beekeepers. At the temperature at which other insects become less active (begin hibernation) the honeybee becomes more active and generates heat, in some cases until the temperature within the cluster is as high as that of the brood nest in summer. To sum up, when the temperature of a colony of undisturbed broodless bees is above 57° F. and below about 69° F. the bees are quiet and their temperature drifts with the outer temperature; at lower temperatures they form a compact cluster, and the temperature within it is raised by heat generated by the bees.

The authors desire to state that while the lower critical point, 57° F., appears rather well established, the observations up to the present do not justify too definite a statement concerning the upper limit of quiescence. It must be emphasized that these conditions do not apply when the colony has brood. The rearing of brood in winter causes a marked increase in heat production and constitutes a condition which may become one of the most disastrous that can befall a confined colony. This will be discussed at a later time.

When the heat production of the colony is explained, we are able to understand to some extent the divergence in the records obtained by other observers. It has, of course, long been known that bees generate heat, and it has been pointed out that during cold weather the temperature of the cluster is often higher than during warmer weather. While the temperatures previously recorded are in most cases abnormal, due to disturbance, the chief difficulty in understanding the phenomena which take place is due to insufficient observations. For example, if between noon November 13 and 2 p. m. November 15 only a half dozen temperature records had been made for the cluster (and perhaps without finding the warmest part of it) and the outside air, it would have been impossible to determine the limits of heat production. Most observers have been satisfied with a few observations, and seemingly everyone who has inserted a thermometer in a hive has felt called upon to publish the results, thereby only confusing the problem.

THE EFFECT OF CONFINEMENT AND THE ACCUMULATION OF FECES.

Before beginning a discussion of the effect of confinement and the accumulation of feces, it may be recalled that during the active summer season the length of life of worker bees is in a sense determined by the work done by them, rather than by days or weeks. The greater the necessity for excessive activity the shorter the term of life. The authors believe that they have evidence to prove that this applies to the winter also, and this belief is entirely supported by the experience of beekeepers everywhere. That bees may come out of winter quarters strong in numbers and vitality it follows that the work to be done by the bees in the winter should be reduced to a minimum; and the winter problem, as thus interpreted, is therefore to find the conditions under which broodless bees do the least work. The work which broodless bees do in winter consists, so far as has been determined, solely in the production of heat or in activity incident to flying on warm days (if free to fly), and therefore the problem, so far as it is under the control of the beekeeper, is primarily to obviate the necessity for the production of heat. If brood is reared the work of the bees is necessarily enormously increased, and their vitality is correspondingly decreased. So far as evidence is available in this work, the colony is not fully recompensed for this expenditure of energy by an increase in the strength of the colony by bees thus reared.

The colonies[1] to be discussed under this heading (Nos. 1 and 3) were wintered in the constant-temperature room in special 6-frame hives (to economize space and concentrate the colony so that fewer thermometers would be required) with full entrances and were not propolized or sealed at the top. During the regular series of readings the room was kept at a temperature which rarely dropped below 40° F. or went above 45° F., and the average temperature from October 14 to March 6 was 42.67° F. This temperature was chosen as being nearly the one usually considered best by beekeepers. The foods given these colonies were stored in the combs, just as placed by the bees. There was some pollen available in colony No. 1. (Fig. 2.)

According to what has been said in the previous section, we should expect bees at such a temperature to maintain a compact cluster and to generate some heat at all times. This was actually the case, the temperature of the interior of the clusters dropping below 64° F. only a few times in either colony.

Colony No. 1, on honey stores, was in the constant-temperature room from October 12, 1912, to March 24, 1913, or 163 days.[2] It

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[1] In order that the young bees might all get a flight before the winter confinement, the two colonies here discussed were placed in the constant-temperature room after the brood had been removed. They were kept here several days, removed for a flight, and then returned to the room for the regular series. The significance of this manipulation must be reserved for a later discussion. This explanation is made to show how it was possible to put these colonies in the room so early in a climate as mild as that at Philadelphia. The object was, of course, to increase the time available for observation. Bees are usually not wintered in cellars in climates as mild as that of Philadelphia.

[2] In all, 24,077 temperature records were made for this colony.

was then removed for a flight and put back the same evening, where it remained until March 28. From March 7 at 9 a. m. until March 28 at 4 p. m. readings were made on this colony every 15 minutes night and day, with the exception of the period between 9 a. m. and 7 p. m. on the 24th, when it was out of doors. During this period of three weeks the temperature of the room was changed slowly, being raised as high as 64° F. and cooled to 13° F.

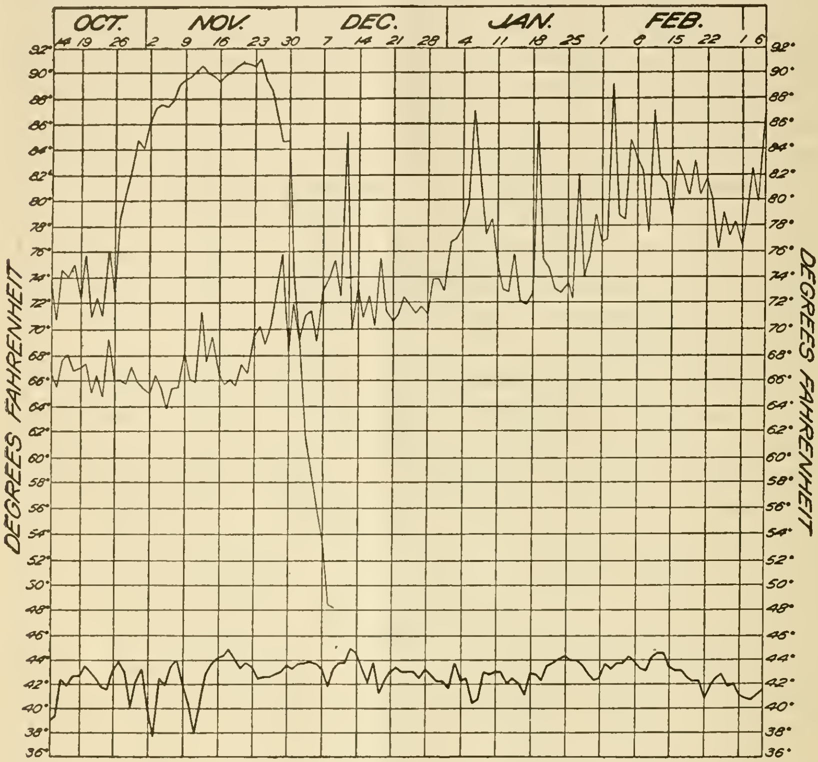

FIG. 2.—Average daily temperatures of the center of the cluster of bees in colonies 1 and 3 and room temperatures, Oct. 14, 1912, to Mar. 6, 1913. Taken from readings made hourly from 9 a. m. to 4 p. m. The room temperatures are indicated by the heavy line.

When this colony was first placed in the room for the regular series of readings, after a preliminary confinement, October 12 (the readings were begun Monday, Oct. 14), it maintained a cluster temperature which usually lay between 64° and 68° F., the daily average temperature departing from these rather narrow limits only four times up to November 22. The average temperature is 66.5° F. During the first five weeks the temperature of the room was less regular than later (due to faulty working of the regulating apparatus), and this doubtless accounts for some irregularities in the cluster temperature. At first the three thermometers in the cluster (1, 2, and 5) gave temperature readings quite close together, while thermometer 6, which was near the cluster, gave readings intermediate between the three thermometers of the cluster and the four others in the hive, farther from the cluster. After November 22 the records of the thermometers in the cluster were more widely separated and the temperature of the center of the cluster (shown on thermometer 5) tended to rise gradually. It varied constantly, but by December 7 and from then until the end of the month, it averaged between 69° and 75° F. On November 29 and December 12 the cluster temperature rose to over 88° F. From the 1st of January until March 6, which ended the regular series of readings, the cluster temperature became more and more irregular, and on January 20 the cluster moved (probably to accommodate itself to the stores) until thermometer 2 was nearer the center and showed a higher temperature than thermometer 5. The size of the cluster was gradually decreased by the death of bees, and all the thermometers except 2 and 6 show a gradual decrease in temperature until finally, from about February 25 to March 6, they are all low and of nearly equal temperature. The two thermometers giving high readings continued to show in general a higher and higher average temperature and to become more irregular (except from February 15 to March 1), the periods of increased heat becoming more frequent. There was absolutely no regularity in these intervals. After February 1 the temperature of the cluster varied between 75° and 91° F., the average from February 1 being 85.4° F.

On March 6 all colonies in the constant-temperature room except two were removed. The colony described above (No. 1) and one other (No. 12), not to be described at present, were left. On March 7 at 9 a. m. the temperature of the room stood at 42° F., and the temperature of the interior of the cluster was about 84° F. The brine which cooled the room was then shut off and the temperature of the room rose very slowly and regularly, until on March 11 at 8.45 a. m. it was 64° F. For the first day the temperature of the cluster was slightly variable, and at 10.45 p. m. thermometer 6, which had been cooler than thermometer 2, showed a rise in temperature (probably due to a shifting of the cluster), and from then on to the 24th they were nearly of the same temperature at all times. On March 8, at 3 a. m., thermometer 2 rose to 87° F. (room temperature, 48.5° F.), having previously shown a cooling. The cluster temperature then dropped slightly, showing relatively little variation until at 4.15 p. m., March 9, it stood at 77.3° F. (room temperature, 55.7° F.). As the room temperature continued to rise, the cluster temperature increased still more rapidly, until at 8.15 a. m., March 11, it reached 93° F. (room temperature, 64.2° F.). A little brine was now turned on, sufficient to lower the temperature gradually to 58° F. at 9 a. m., March 12, and it again rose to 63.3° F. at 5.45 p. m., March 15. During this period the cluster temperature followed the room temperature, but remained constantly over 20° warmer. The room was again cooled slowly, and the cluster temperature dropped until on March 16, at 3 p. m., the room was 49° F. and the cluster 77.5° F. As the room continued to cool, the cluster temperature increased, the bees responding to the colder temperature, until at 4.15 a. m., March 17, the room was 48° F. and the cluster 88° F. The room then gradually warmed, and again the temperature of the cluster dropped and then again rose with the room temperature, remaining always over 20° warmer. At 6.45 p. m., March 19, the brine was turned on full and the room cooled rapidly, reaching the minimum of 13° F. at 9 p. m., March 20. At no time, however, did any of the thermometers in the hive record a temperature below 33° F. Here it remained constant within 0.1° F. for about six hours, during which time the cluster temperature varied between 86.5° and 89.5° F. (a difference between the room and the cluster temperatures of 73° to 76° F.). The brine was now shut off and the room again warmed until 9 a. m., March 24, when it reached a temperature of 44.5° F. During this warming the cluster cooled until at the close it was varying between 72° and 79° F.

As stated above, the colony was now (9 a. m., March 24) removed for a flight and put back the same day at 7 p. m. In the meantime the room was cooled to 33° F. When the bees were put back into the room the temperature of the entire inside of the hive showed great variation and naturally an increase due to the warming up while out of doors and to the activities of a good flight. The points outside the cluster dropped rapidly, but it was midnight, March 25 (31 hours), before the curves of temperature again appeared normal. The room was slowly warmed to 63.2° F. at 6.30 p. m., March 26, and then slightly cooled to 54° F. at 6 a. m., March 27, and again warmed to 58.5° F. at the close of the series, 4 p. m., March 28. After the flight the temperature of the cluster never dropped below 89.5° F., and the highest temperature reached was over 95° F. (soon after the flight). Thermometer 6 remained high, but thermometer 2, which had previously been high, now approached the other thermometers, probably due to a rapid loss of bees and to a decrease in the number of bees during the flight. It must be recalled that these bees had been confined for an abnormally long time and were subjected to treatment which is at least unusual. After this colony was taken from the room for the last time it was found that thermometer 6 was over a patch of larvæ, and, estimating as accurately as possible, the eggs from which these hatched must have been laid at the time when the room was coldest (March 20–21) and when the cluster temperature was at its highest point. There had been no brood previously, according to the temperature records as compared with those of this colony earlier and with those of other colonies, nor was there much evidence of increased heat production due to the presence of brood until after the flight. Probably no extra heat was produced for the eggs, and possibly the hatching of the eggs was somewhat delayed by the low outer temperature. The effects on the cluster temperature which might be expected from a flight, in relieving the accumulation of feces, were not observed, because brood rearing had been begun.

Colony No. 3 was placed in the constant-temperature room October 12, 1912, after a good flight, and readings were begun on Monday, the 14th. In all, 2,165 temperature records were made on Colony 3. The stores provided this colony consisted of honeydew honey, which was gathered in the department apiary and which, since it granulated almost at once, had been removed by melting up the combs which contained it. After this operation it remained liquid. During the summer of 1912 some of this honeydew honey was fed to a colony in the open, during a dearth of nectar, and was stored in new combs above the brood chamber, in which no cells of pollen were to be found. After the second storing the honeydew honey was clear, well ripened, and did not granulate. This colony was also in a 6-frame hive, as previously described, and contained five thermometers (Nos. 14–18) among the combs. It is of course well known to beekeepers that honeydew honey is not a good food for winter.

When this colony was first put into the constant-temperature room it behaved much as did Colony No. 1, except that the temperature varied between 69° and 78.7° F. for the first week, being slightly higher and more variable than that of Colony No. 1. The second week it remained much the same, the temperature, however, varying between 69° and 80° F. From this time on the temperature of the center of the cluster rose rapidly, never dropping below 79° F. from October 29 almost to the close of the readings. After November 4 the temperature remained above 86° F., and after November 11 it dropped below 89° F. only twice until the end. Thermometer 17 at first read about 4° below thermometer 14, but after November 11 they were close together until November 25, when thermometer 17 began to cool rapidly, due to loss of bees, and after November 30 thermometer 14 cooled rapidly until, on December 9, it showed that no more bees remained alive. From December 2 to 7, inclusive, there was little heat generated, due to the scarcity of bees. It is of interest to observe the records of thermometer 16, near the cluster, but usually outside of it. It at first showed a temperature but little higher than the two thermometers away from the cluster, but on October 31 it began to rise until, on November 12, it reached 80.5° F., when it was doubtless covered by the bees. Even the two thermometers (15 and 18) clear to the back of the hive rose until, on November 13, they recorded 61.5° F. These thermometers showed about the same temperatures for about 10 days, and then these two and thermometer 16 showed a cooling, since the bees were dying so fast that there were no longer enough to warm up these thermometers away from the center of activity. It was to be expected that this colony would die, and the experiment was performed to learn the phenomena incident to the loss.

Before summing up the results of these two colonies, Nos. 1 and 3, it may be stated that, so far as the evidence here presented is concerned, the results as far as here discussed are confirmed by records from 10 other colonies kept in the constant-temperature room, but fed other foods and otherwise different. There is in all of the records no evidence which the authors can interpret as at all contrary to the views here stated. A discussion of these other colonies is reserved.

It is evident from the behavior of colony No. 1 that at least one factor entered which gradually caused the bees in the cluster to generate more and more heat until at the beginning of the special series, March 7, the cluster temperature was about 20° warmer than it was at the same room temperature at the beginning of the confinement. It is also seen that during the special series, March 7–24, the cluster temperature always remained at least 20° above the room temperature, whereas from the discussion of bees unconfined (Colony A) we might expect them to cease heat generation when above the lower critical temperature (57° F.). In the case of colony 3, fed on honeydew honey stores, the factor which caused more heat to be produced evidently increased much more rapidly. As stated previously, honeydew honey is a poor food for winter and is so recognized. It contains the same sugars as honey, but contains in addition a considerable amount of dextrin, the particular lot fed to colony 3 containing 4.55 per cent while good honeys contain only a fraction of 1 per cent. From the evidence at hand it appears that dextrin can not be digested by bees and, whether or not this is the explanation, honeydew honey causes a rapid accumulation of feces which usually results in the condition known as dysentery, in bad cases of which the feces are voided in the hive. In the case of colony 3 the whole hive inside and out, as well as the frames and combs, were spotted badly, the inside of the hive being practically covered. Even with fine honey stores such a spotting is usually noticed after a prolonged confinement, especially in severe weather (or during brood rearing). It therefore appears that the accumulation of feces acts as an irritant, causing the bees to become more active and consequently (see later section) to maintain a higher temperature. We are therefore justified in believing that the cause of poor wintering on honeydew honey is due to excessive activity, resulting in the bees wearing themselves out and ultimately in the death of the colony.

In the case of colonies on good stores (e. g., colony 1) the feces accumulate more slowly and the excess activity is not so marked and is induced more gradually. The accumulation of feces due to confinement causes increased activity and this in turn is the cause of excessive heat production, resulting in a reduction in the vitality of the bees.

It therefore follows that excessive activity causes the consumption of more food, resulting in turn in more feces, so that colonies on poor stores are traveling in a vicious circle, which, if the feces can not be discharged, results in the death of the colony. In the work here recorded no attention was paid to the theory that dysentery is due to an infection, since there is nothing in the observations made that lends any support to that idea. If there is more than one kind of dysentery, as has been held, then the observations here recorded must be considered as applying only to the type which can be induced at will in any confined colony by giving poor food and which, as has been long recognized, can be relieved at once by an opportunity for flight.

While the activity of the cluster is greater at some times than at others, there are not, as has been held, regular intervals of activity at which the colony rouses itself to take food. At no time is a colony kept at a room temperature of 45° F. or less in a condition which can be characterized as inactive. Presumably the reported "intervals of activity" have occurred when the colony made a noise due to disturbance by the beekeeper.

The bees in colony 3 were compelled to work constantly to maintain so high a cluster temperature. In fact, they did more work than colonies wintered in the open air. Keeping these bees in a cellar protected them from low outside temperatures, but the lack of opportunity for a normal ejection of feces caused a condition more serious than extreme cold weather. We seem to have here an explanation of the fact, often observed by beekeepers, that some colonies wintered in the cellar are in worse condition in the spring than colonies that are exposed to severe cold. Poor food is evidently a more serious handicap than low temperature.

METHODS OF HEAT PRODUCTION AND CONSERVATION.

A colony of bees in cold weather forms a compact, approximately spherical cluster, but this cluster is not, as is usually believed, uniformly compact. In order to study the formation of the cluster and as an aid to interpreting the temperature records in terms of action, a colony (C) was placed out of doors in a narrow hive with double-glass sides and top, and the stores were so arranged that the only space available for the formation of the cluster was next to the glass on one side, where it could be kept under direct observation. Since the bees did not have room for a spherical cluster, they formed a ring on the glass. Thermometers were then placed close together in the outside space, so that the temperatures of various points could be determined as desired. This hive was on the roof, and, while one person watched the bees, constant communication could be kept up with the person reading the temperatures in the room below by means of a telephone, arranged so that the hands of both observers were free. This colony was of course in the light, but the normal cluster was nevertheless observed. It was disturbed as little as possible.

The nearly spherical cluster of bees consists, between the combs and sometimes above or below them, of an outer shell of bees close together with their heads toward the center. This ring may be several layers thick. The position with the heads inward is typical, except when condensed moisture drops on the cluster as it often does in cool weather, when the bees at the top turn so that their heads are upward. The bees in this outer shell are quiet except for an occasional shifting of position. Inside this rather definite shell the bees between the combs are not so close together nor are they headed in any one way. Considerable movement, such as walking, moving the abdomen from side to side, and rapid fanning of the wings, takes place inside the sphere and when a bee becomes unusually active the adjoining bees move away, leaving an open space in which it can move freely. Two bees may often be seen tugging at each other. In addition to the bees between the combs, placed as above described, others are in the empty cells of the comb on which the cluster is always formed, always with their heads in. A verification of these statements is contained in the following observations, and the experiment may easily be repeated by anyone. For the purpose of obtaining a colony without combs for another experiment, a hive was opened December 15, 1913, while the outside temperature was low enough to cause the formation of a compact cluster. When the combs were separated the circle of bees in the shell was clearly observed. When a comb from the center of the cluster was shaken the active bees in the center of the circle dropped off readily, and those in the outer shell which were somewhat sluggish were removed with more difficulty. After this was done those occupying empty cells in the center of the sphere backed out of the cells and were shaken off. Finally those occupying cells in the border of the sphere backed out, showing a well-marked circle on the combs. Evidently the bees in the shell, whether in the cells or between the combs, are less active than those in the interior of the cluster. Naturally such a manipulation as this is not to be recommended, except for purposes of demonstration.

It is clear from observations previously recorded that the highest temperatures are those of points in the center of this shell, and this is to be expected, as the heat is generated here. The outer shell constitutes an ideal insulator for the conservation of the heat, since the bees arranged so close together form small dead air spaces in their interlacing hairs, especially those of the thorax, and afford still more insulation with their bodies. The abdomens of the bees in the outer row are practically separate one from another, and must often be exposed to severe cold. That this method of conserving heat is effective is shown by observations on undisturbed colonies out of doors. For example, on January 14, 1914, there was at 9 a. m. a difference of 68° F. between thermometers 14 (center of the sphere) and 16 (outside the cluster) of Colony D, which were less than 4½ inches apart on the same level in the same space between combs, and a difference of 75° F. between this couple and the bottom board 4¼ inches below it. What this difference might sometimes be in colder climates may be imagined. Examples of this kind might be multiplied indefinitely from the records of these experiments.

The source of the heat of the cluster must, of course, be the oxidation of the food consumed by the bees. The bee is classed as a cold-blooded animal in that the temperature of the individual bee is practically that of the surrounding medium. There is obviously, from the records just given, no internal regulation of the temperature of the body such as is found in birds and mammals, for the temperature of a broodless cluster varies greatly. From the observations made on the various colonies, especially Colony C, it is clear that heat for the warming of the cluster is produced by muscular activity. While, of course, some heat is doubtless liberated by other life processes, this is practically negligible when bees are quiet, as in Colony A when above 57° F. That higher temperatures may be produced, greatly increased muscular activity is required, and in Colony C in cold weather bees in the center of the shell of insulating bees were seen fanning vigorously and executing other movements, such as shaking and rapid respiration. We thus have the paradoxical condition that bees fan to heat the cluster in winter as well as to cool the hive in summer. Observations of this kind were repeated beyond number, and this theory of the method of heat production is entirely supported by the repeated observation of a humming noise from the cluster during cold weather.

A few details of the observations on Colony C may be of interest. For example, one bee was observed fanning vigorously for 7½ minutes (9.53 to 10.00½ a. m., Jan. 23) while the other bees kept a space cleared for it. The temperature of the nearest thermometer rose ½° F. during this time. At 9.52 this thermometer was almost a degree cooler than at the time of greatest heat during the fanning. The rapidity of fanning of the wings varied, and toward the end of the time it became so slow that the outline of the wings was distinguishable. After the excessive activity this bee stood in the same place for a time. Rapid respiration may play a more important part in heat production than at first appears. One bee was observed to breathe 21 times in 14 seconds and then cease the rapid respiration. On other occasions 50 or more bees would begin shaking their bodies from side to side.

It has been shown in earlier sections that feces in the rectum cause irritation, which induces increased activity and causes greater heat production. It has also been found that other kinds of irritation bring about the same result, but a discussion of these points can not be undertaken here. It is at least evident from the records obtained in this work that colonies of bees in winter, either in cellars or out of doors, should be disturbed as little as possible. This appears to apply especially to cold weather out of doors or in the cellar, especially after the colony has been confined for some time.

The facts mentioned concerning the ability of the bees to conserve the heat generated will perhaps raise the question as to the temperature of the hive outside the cluster in cold weather, when the cluster is compact. In the case of Colony A the temperature of the hive outside the cluster was often practically as low as the outside temperature. This colony was not packed and had a rather large entrance. If the cluster forms such an efficient insulator in itself it might be presumed that packing about the hive is of little value and that it might even be harmful, in that it would not serve to conserve heat and would prevent the heat from the sun from penetrating to the cluster. This line of reasoning, however, does not follow, and in any case it is unsafe to speculate about these things without mo' facts. The effects of various forms of packing are being studied.

In closing it may be desirable again to state that too hasty conclusions must not be drawn from the facts here presented. For example, the records on heat production might be interpreted as indicating the desirability of a cellar temperature higher than beekeepers usually believe to be best. Experiments to test such a theory are now being carried on, and it is found that a broad statement as to the best cellar temperature can not yet be given. Under most conditions colonies can not be brought to the critical temperature, 57° F., without disturbance. It is hoped that more work will throw some much-needed light on this important subject.

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DIV. INSECTS.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 95.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 9, 1914.

INSECT DAMAGE TO THE CONES AND SEEDS OF PACIFIC COAST CONIFERS.[1]

By JOHN M. MILLER,
Entomological Assistant, Forest Insect Investigations.

INTRODUCTION.

Recent damage by insects to the cones and seeds of conifers has been brought to notice by the collectors of forest seeds. Compared with other commercial seeds the market price of forest seeds is high, owing to the limited demand, the special knowledge required for their collection, and the irregular production of conifer crops. A heavy percentage of damage materially decreases the profits of seed collection and may result in time and money fruitlessly spent. Seed that is badly infested or damaged by insects can not be sold to reliable dealers when its character is recognized.

It has been found that insects sometimes destroy practically all of the seed crop of a tree species in one locality in a season. In this respect insects have a certain relation to the future supply of timber, as the natural reproduction of forests is assured only by the production of a prolific supply of uninjured seed. (Pl. I, fig. *a*.) The artificial reforestation of denuded areas must also depend upon the collection of sound forest seed. An example of how insects may interfere with reforestation by a desired species has been furnished by the white fir on western national forests. Much of the seed of this species collected recently has been worthless for planting, a great percentage of this loss being due to insect damage in the cones and seeds.

Some information regarding insects that affect forest seeds and reproduction has been given in previous publications of the Bureau

[1] The names of the insects are not mentioned in this preliminary contribution because many of them are not yet named or described. When this has been done it is intended that a special bulletin on the subject shall be prepared by the same author.—A. D. HOPKINS, *in Charge of Forest Insect Investigations.*

NOTE.—Information regarding insects that seriously affect forest seeds, especially in the coniferous forests of the Pacific coast. A practical paper, of interest to seed collectors, dealers in forest seeds, and planters of forest areas; of particular application to Pacific coast regions.

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of Entomology.[1] This bulletin gives further facts regarding the character and extent of damage to the seed of coniferous forests of the Pacific slope. It also furnishes preliminary information on the more important groups of insects causing this damage, and their habits, that it may be available to seed collectors during the present spring and summer.

CHARACTER AND CAUSE OF DAMAGE.

Damage to the seed of conifers is caused by various species of insects which feed upon the buds, flowers, immature cones and seed, and mature seed. Great damage is accomplished while the cones are immature and before the seed ripens. Cones which are infested, or "wormy," are often found when the areas for seed collection are being located. Wormy cones and seeds are caused by the adults and grubs of small beetles, the "worms" or caterpillars of moths, the maggots of gnats, and the larvæ of tiny wasps known as seed chalcidids. In his work the seed collector usually encounters these immature stages of insects which depend upon the cone scales and seeds as their principal source of food supply. With the exception of the cone beetles the adult insect is seldom found in the immature cone. The insects may be found in almost any part of the cone or seed, the feeding habits varying much with the different species. In many cases the presence of these insects in the cone is evident and may be recognized by the peculiar type or class of injury. Where this is the case the damage may be approximately estimated during the summer.

With the more important seed-infesting insects the damage will be recognized in one or more of the following classes:

BLIGHTED CONES.[2]

The cones are sometimes killed when small and immature. As a result they wither and dry, and none of the seeds fill. Cones so affected are often described as blighted. Most of the injury of this character occurs in the cones of pine and is caused by the cone beetles. The attack is usually on the second-year cones, although the small first-year cones are sometimes killed. Some of the cone worms, also, bore into the cones in such a manner as to kill them and cause the same blighted condition. Sugar-pine cones attacked by the beetle nearly always fall to the ground during July and August. The cones of other species usually adhere to the tree for a winter or two. Damage of this type is easily recognized and can be estimated after the middle of July.

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[1] Hopkins, A. D., Catalogue of exhibits of insect enemies of forests and forest products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. U. S. Dept. Agr., Div. Ent., Bul. 48, p. 13–14, 33, 1904.

Hopkins, A. D., Insect enemies of forest reproduction. U. S. Dept. Agr. Yearbook, 1905, p. 250–251, 1906. (Yearbook Separate 381.)

Rohwer, S. A., VI, Chalcidids injurious to forest-tree seeds. U. S. Dept. Agr., Bureau of Entomology, Tech. Ser. 20, Pt. VI, p. 157–163, Feb. 10, 1913.

[2] Pl. I, figs. *c1*, *d;* Pl. II, figs. *a*, *b*.

WORMY AND ABORTED CONES.[1]

In some forms of injury the cone is not killed, but may show masses of resin on the surface, castings caused by the feeding of larvæ, or little burrows through the scales, seed, and pith which contain small larvæ. In rare cases the cone may be aborted or deformed, forming a peculiar growth or shape. The cone, however, continues to grow and matures at the close of the season very much like a normal one. The seeds which are not mined or eaten by the insects fill and mature. Damage of this character may be found in practically all species of conifers. Much of it is caused by the caterpillars of different species of moths, some of which show nothing on the surface of the cone to indicate their work in the interior. The amount of damage to the seed of western yellow pine and Jeffrey pine throughout northern California and southern Oregon in 1912 was estimated by the writer to vary from 50 to 90 per cent of the crop.

WORMY SEED.[2]

This class of injury is found only in the seeds. The cone is not affected and shows no indication of the insect. Practically all of the reported damage of this type is caused by the larvæ of tiny wasps called seed chalcidids. A certain percentage of the seeds will be infested by a small, white, headless larva. The infested seeds are of normal size and appearance. The larvæ feed entirely within the inner lining of the seed. Damage of this type can be found only by cutting the seed open. Seeds which have been attacked are hollow and usually contain the small headless larvæ of the chalcidid. After the seed has been stored over winter some of the adults emerge, boring small clean-cut holes through the outer shell of the seed. This is the first external indication of these insects. Quite often seed infested by the seed chalcidid is collected and sold before the infestation is detected. Injury of this type is very common in certain species of fir, in which the damage has sometimes been found to run as high as 75 to 90 per cent of the cleaned seed. Species of seed chalcidids have also been found in the seed of western yellow pine and Engelmann spruce.

MAGGOTY CONES.

Many cones are injured by the maggots of flies and midges, some of which cause no appreciable damage to the seed. Small whitish or pink-colored maggots are found in the cones of nearly all conifers. They are the larvæ of tiny gnats, or midges. The pinkish maggots cause little masses of resin among the scales but do not seriously affect the seeds. The whitish maggots in fir cones cause considerable damage to both cone and seeds. (See Pl. III, figs. *a*, *c*.) They are often present in vast numbers and leave the cones when these are

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[1] Pl. I, fig. *b*

[2] Pl. III, figs. *b*, *d*.

spread to dry. They are among the most common insects noted in the work of seed collecting.

IMPORTANT GROUPS OF SEED-INFESTING INSECTS.

There are four important groups of insects which cause practically all of the serious damage under the four classes described.

CONE BEETLES.

Cone beetles are small, dark, cylindrical beetles which attack the cones of pines. The cones are killed by the attack of the adult, which bores a small tunnel into the axis to deposit its eggs. (Pl. II, fig. *b 1*.) The larvæ (Pl. I, fig. *d*) feed on the seeds and scales of the withering cone and develop to the beetle stage within the dead cone, where the beetles usually remain over winter. The attacks of several species of these beetles are very common in western yellow pine and sugar pine. The damage to crops of sugar pine is considerable, as these beetles have been noted in some seasons to kill from 25 to 75 per cent of the cones over large areas.

CONE WORMS.

Cone worms are most frequently met with in the cones in the caterpillar stage. They represent several species of moths which infest the cones of pines, firs, hemlocks, and spruces, and even the seed of incense cedar has been found to be attacked by the tiny larvæ. The moths are small and in most species dull colored and inconspicuous. The small white larvæ of one species are very common in the cones of western yellow pine and Jeffrey pine. They feed upon the seeds and scales without killing the cone and overwinter as larvæ and pupæ in galleries in the pith of the cone axis. (Pl. I, fig. *b*.) Another species is a very common enemy of Douglas fir seed on the Pacific slope. The larvæ mine a gallery through the scales, leaving an opening at the surface through which resin and larval castings exude. The pupæ overwinter near the axis in resinous cocoons among the scales. Nearly all species feed without killing the cone, but a large caterpillar feeding on western yellow pine sometimes kills the immature cone, the damage resembling that of the cone beetle.

SEED CHALCIDIDS.

The adults of seed chalcidids are tiny wasps (Pl. III, fig. *d*). The larvæ (Pl. III, figs. *b*, *d*) live within the seeds, apparently developing as the seeds grow, so that the infested seeds reach normal size and

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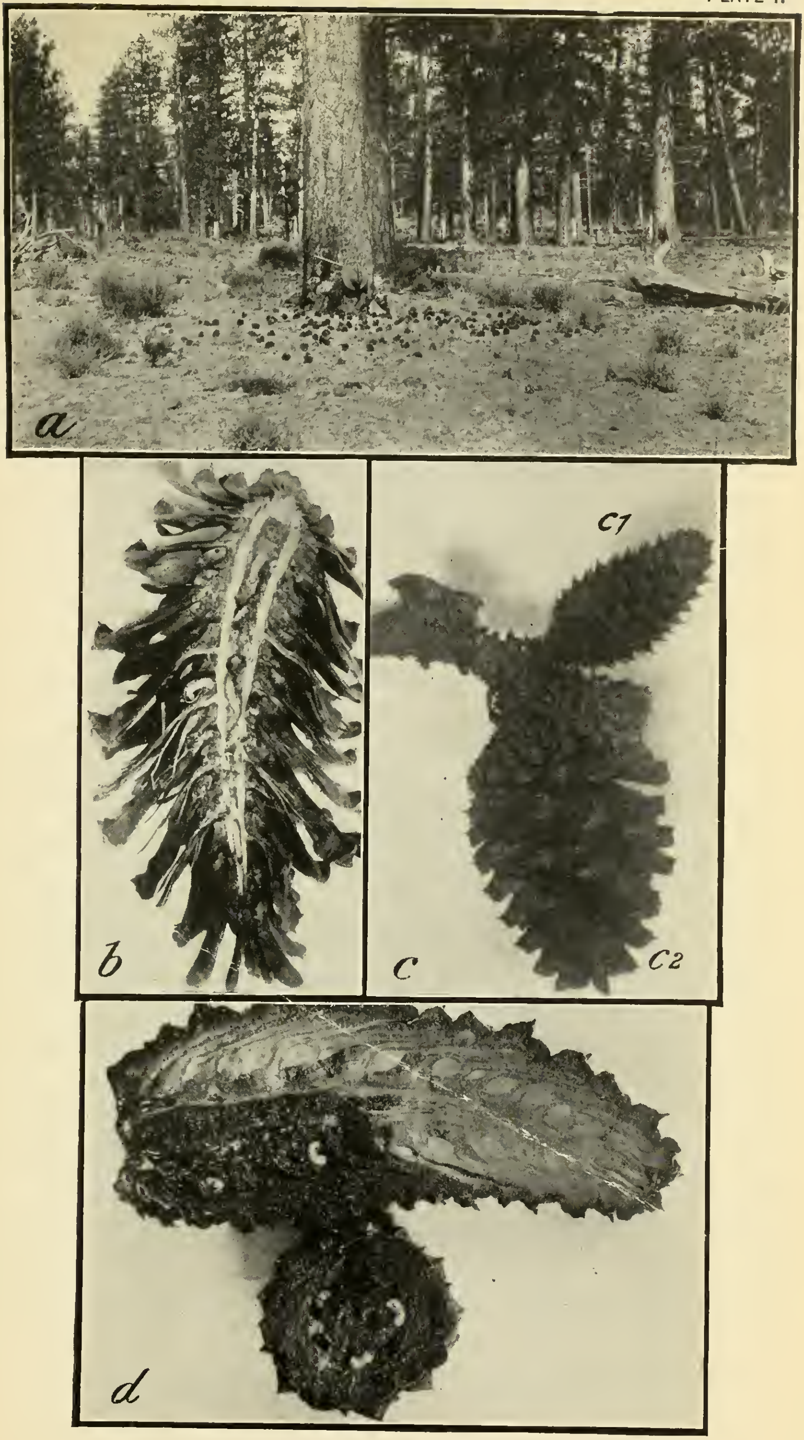
EXPLANATION OF PLATE I.—*a*, Photograph near Bray, Cal., showing cones of western yellow pine on ground, but poor reproduction; *b*, mature western yellow pine cone, showing pith occupied by the cone worm and seeds destroyed by it; *c1*, blighted western yellow pine cone caused by the cone beetle; *c2*, normal cone; *d*, young living western yellow pine cone, greatly enlarged, to show character of damage by the cone beetle and its larvæ. (Original.)



INSECT DAMAGE TO REPRODUCTION OF WESTERN YELLOW PINE.

[For explanation of plate see note at foot of page 4.]

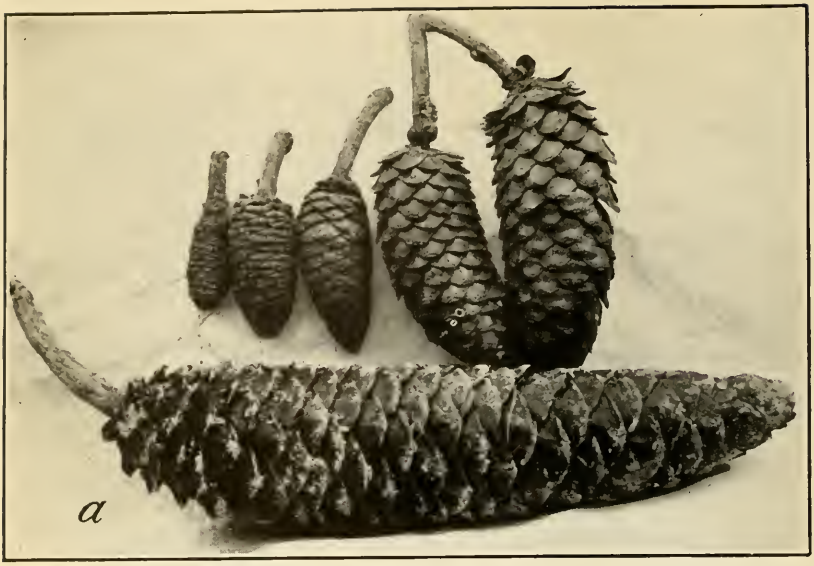


FIG. A.—SUGAR-PINE CONES ATTACKED BY THE CONE BEETLE AT DIFFERENT STAGES OF GROWTH OF THE CONE. (ORIGINAL.)

[The longer cone, which is about 11 inches long, resisted attack, while the others were killed.]

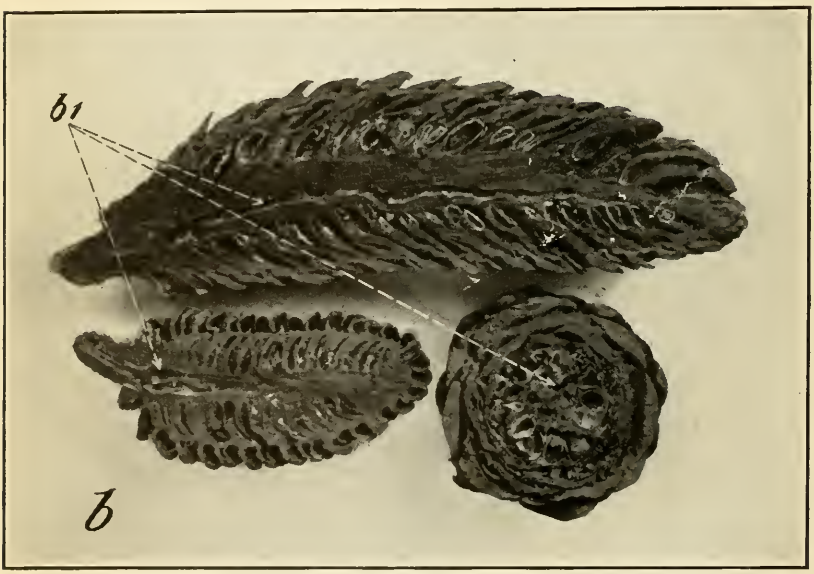
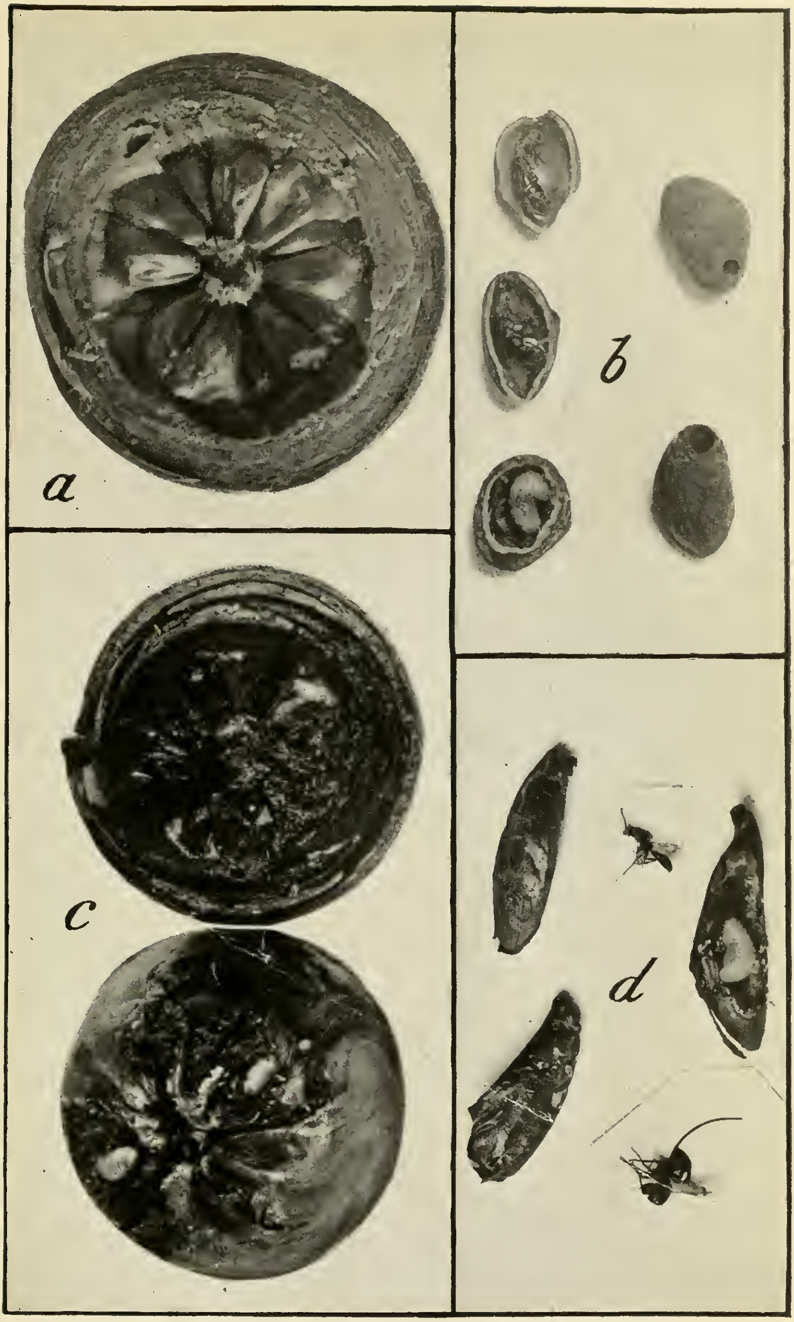


FIG. B.—LONGITUDINAL AND TRANSVERSE SECTIONS OF SUGAR-PINE CONES, NATURAL SIZE, SHOWING PRIMARY EGG GALLERIES, B1, MADE BY THE CONE BEETLE. (ORIGINAL.)

WORK OF THE CONE BEETLE IN SUGAR PINE.



WORK OF A CHALCIDID IN SEEDS OF PACIFIC COAST CONIFERS.

a, Cross section of sound, mature white fir cone with unaffected seed; *b*, yellow pine seed, enlarged, infested by larvæ and newly transformed adults of a seed chalcidid; two unopened seeds show exit holes made by these insects; *c*, cross sections of two maggoty white fir cones; *d*, male and female adults of seed chalcidid, larva in opened seed of red fir (*Abies magnifica*), and exit holes in two other seeds of same. (Original.)

form. There are several species, one of which is very destructive to the seed of Douglas fir, white fir, and red fir.

FIR-CONE MAGGOTS.

Fir-cone maggots are the larvæ of small gnats which have been found in the cones of white fir, red fir, and alpine fir. They mine through the scales and seeds, causing great damage. The larvæ do not winter in the cones but burrow into the ground as soon as the cones fall. They form small puparia within an inch or so of the surface, and there they overwinter.

ADAPTATION OF THE INSECTS TO THE INTERMITTENT CONE-PRODUCING HABITS OF THE HOST TREES.

There is a general life cycle for most of the cone-infesting insects corresponding to the period required by the host tree to develop the seed crop. The adult insect, whether beetle, moth, fly, or seed chalcidid, deposits the eggs in the spring or early summer while the cones are small and undeveloped. With some species the attack is such that the cone is killed; with others the attack and feeding of the larvæ do not interfere with the growth of the cone, which matures at the normal time, although much of the seed may be destroyed. The feeding of the larvæ ceases, however, when the cone matures, usually during September. The insects then undergo a long dormant period either as larvæ, pupæ, or new adults. This dormant period continues until there is another crop of cones in a proper condition for attack; that is, the soft, immature cones which are found in the spring or early summer. Some insects pass this dormant period in the pith of the cones or in resinous masses among the scales. Other species leave the cones and form the pupæ in the ground or in débris on the surface.

The intermittent character of the seed production of conifers is a well-established fact.[1] A few cones are produced every year, but a good crop occurs at intervals of from two to five years. The years of total failure are known as "off years." It is evident that if the entire brood of any of these species of cone-infesting insects emerges annually, it will sooner or later encounter an off year of the host tree. This would mean the complete failure of the food supply for one generation and would result in the almost complete extinction of the species within the forest area affected by the crop failure. As a matter of fact, observations show that this seldom happens. All the individuals of a brood of overwintered insects do not emerge the following spring. Many of them do emerge after the first winter, but a large percentage of the brood, in some species 50 per cent or more,

[1] U. S. Dept. Agr., Forest Service, Bul. 98, p. 13, Nov. 18, 1911.

continues for another year in the same condition in which the first winter was passed. Usually this retarded part of the brood emerges at the end of the second winter or spring.[1] This is an adaptation which to a certain extent accounts for the continued infestation of certain species of insects in the seed of forest trees. In the case of a species of gnat which infests the cones of white fir it was found that the entire brood of insects which destroyed the 1911 crop of seed on an area in northern California did not emerge at all in the spring of 1912, but remained in the pupal state through the summer of 1912 and the following winter. The adult flies finally emerged in the spring of 1913. Under this adaptation it would appear that only a continued failure of the crop through a series of years would result in the reduction of the numbers of the infesting species on a forest area. Undoubtedly other agencies are responsible for the uninfested condition of the seeds of certain trees during some seasons.

INDICATIONS OF INSECT DAMAGE.

Attack of the cone beetle in the seed crop is indicated by a small entrance hole at the base of the cone, with castings or small pitch tubes, during the early summer; later, by the brown, withered-appearance of the cone.

The attack of the cone moth may sometimes be recognized by little masses of pitch and larval castings on the surface of the cone and sometimes by withered cones, but it is best to look for the caterpillar among the scales and in the seed and pith. It is always best to cut the cone open, sectioning it several different ways, in making the examination.

The attack of the fir-cone maggot can also be found by cutting or breaking the cone open. The larval mines will be found in the scales and seeds, in which will usually be found the small, white, active larvæ.

The seed chalcidids show no external evidence, and the seeds must be sectioned or otherwise opened to find the larvæ of these insects. Unless test is made the amount of damage can not be determined, and seed that is badly infested may be taken as sound.

METHODS OF PREVENTING LOSSES.

There are areas of light infestation by these insects in certain species of trees, and there are areas where the damage is very heavy. The amount of infestation in the seed may also vary with succeeding seasons. A careful examination of the cones before the seed matures, during July and August, will usually reveal immature stages of the seed-infesting insects. If cones of the past season are examined during the winter and spring, they will indicate whether or not the

[1] This retarded emergence has not been observed in the case of the cone beetles, but it has been observed in the more important cone worms, fir-cone maggots, and seed chalcidids.

area is infested by these insects. In the collection and cleaning of forest seeds there is opportunity for use of the information which is now being gathered on this subject. An intelligent selection of the seed-collecting areas will prevent much of the loss due to gathering seed which is afterwards found to be infested or worthless.

A count of the number of infested cones and of damaged seeds will give a clue to the percentage of damage in the crop. Whether or not the damage is sufficient to make collection of the seed unprofitable on the area will have to be determined by the collector.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

DIV. INSECTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 96

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 22, 1914.

(PROFESSIONAL PAPER.)

THE TEMPERATURE OF THE BEE COLONY.[1]

By Burton N. Gates, Ph. D.,
Formerly Apicultural Assistant, Bureau of Entomology.

INTRODUCTION.

There has been a decided need of accurate knowledge of the temperatures and changes in weight of colonies of bees, particularly ring the winter. Previously existing data have not been gained under controlled conditions, but generally by casual observations, limited in number. Most of the previous work has also been for a short period of the year. In this work an effort has been made to get more reliable information by collecting data for practically the cycle of a year. The knowledge of the changes in temperature and weights is needed in a careful study of methods for successfully wintering bees. This is one of the greatest difficulties which the beekeeper has to meet, and it is hoped that the present work may furnish data for a further study of the wintering problem. The scope of the work here recorded is indicated by the following figures:

Period of experimentation, October 22, 1907, to September 26, 1908.
Number of observations, 2,576+.
Number of separate readings, 20,000+.

APPARATUS.

The apparatus was constructed to meet emergencies which might arise, which accounts for its many parts. It was planned so that the complete apparatus could be upon the scales at all times, thus obviating complications from corrections in weighings.

THE SCALES.

A finely adjusted platform scales was specially constructed, which registered with a sensitivity of 10 grams to a maximum of 200 kilograms. It was expected that it would be possible to record

[1] This report of work done for the Bureau of Entomology has been accepted by the faculty of Clark University, Worcester, Mass., as a dissertation in partial fulfillment of the requirements for the degree of doctor of philosophy, and accepted upon the recommendation of Dr. C. F. Hodge. The author has been appointed to the position of assistant professor of beekeeping, Massachusetts Agricultural College.

Note.—A study of the effects of temperature on bees, and of interest to beekeepers generally.

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slight changes in consumption or increase of stores. By means of a double beam it was possible to counterbalance for extra thermometers or other small special apparatus which might be added temporarily, without necessitating a correction of the hourly readings. The scales were found to be relatively satisfactory, but in times of heavy wind extra precaution was necessary in order to overcome the influence of drafts on the scales. In winter this could easily be accomplished by closing the door of the shed in which the experiment was carried on. For outdoor work, however, some difficulty was experienced, as will be explained. The agate-set bearings were also sensitive to jar, which was constantly guarded against.

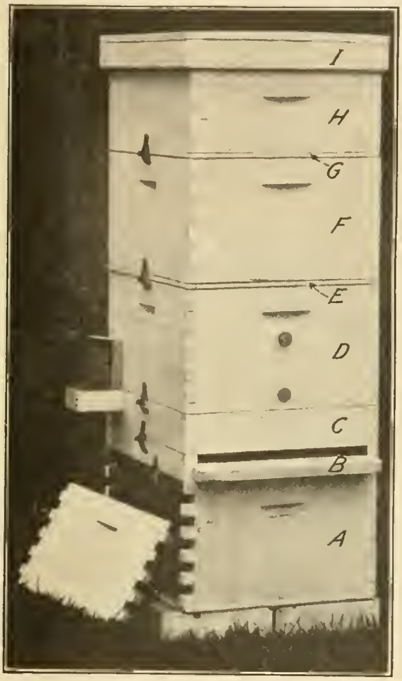

FIG. 1.—The hive used in the experiment on the temperature of the bee colony: *A*, storage chamber for accessories, with door; *B*, bottom board with entrance; *C*, collar with feeder; *D*, brood chamber; *E*, perforated zinc honey board; *F*, second story for surplus; *G*, thin board with holes for thermometers; *H*, case protecting thermometers *a–e*; *I*, outside cover.

THE THERMOMETERS.

Seven mercury thermometers were used, of the type known as incubator thermometers, which have a long stem and can be read to fifths of a degree. One instrument, however, used to register the temperature of the outside air was an ordinary chemical thermometer. These instruments were standardized and were graduated to the centigrade scale.

THE HIVE AND ITS APPLIANCES.

Figure 1 illustrates the general appearance of the hive, showing the five stories. Only one of these was occupied by bees, as will be explained. The hive was of the standard 10-frame Langstroth type. Throughout the experiment it stood on the scales (fig. 2). The several parts were as follows:

A. The lower part consisted of a hive body with one side removed. To the bottom was nailed a thin cover board, which served as the floor of the compartment. The purpose of this chamber was to store fixtures, such as frames, "dummies," extra thermometers, and the like, while they were not in use. In this way it was unnecessary to compute in the weighings for any change in the apparatus. For example, in the winter, when four frames in the brood chamber were replaced by the "dummies," these were taken from the storage chamber and the frames hung in their place, without altering the weighings.

B. An ordinary bottom board.

C. This wooden collar contained the feeder and increased the space between the bottoms of the brood frames and the bottom board. thus allowing the insertion of a thermometer below the frames. The feeder was what is known as an Alexander feeder. The end may be seen extending out of the collar at the rear of the hive. In this projection, which was provided with a wooden cover, the sugar sirup is poured without disturbing the hive. The cover prevents drafts of air through the feeder.

D. Above the collar was the hive body in which the bees were located. The frames were spaced with metal spacers (fig. 3), and wedges between the central frames held all firmly in place. In this way everything was sufficiently secure to enable any possible manipulation, even to turning the hive upside down, should it be necessary, without displacing parts. The wedges also increased the space between the central frames sufficiently to allow for the insertion of the stems of thermometers. The gauge in frames 3 and 4 permitted the insertion of thermometer *e* (fig. 3). The frames were wired and filled with full sheets of foundation before insertion. Two holes were bored in the middle of the front above the entrance, for use in case it should become desirable to insert thermometers. Throughout the experiment these were closed with corks.

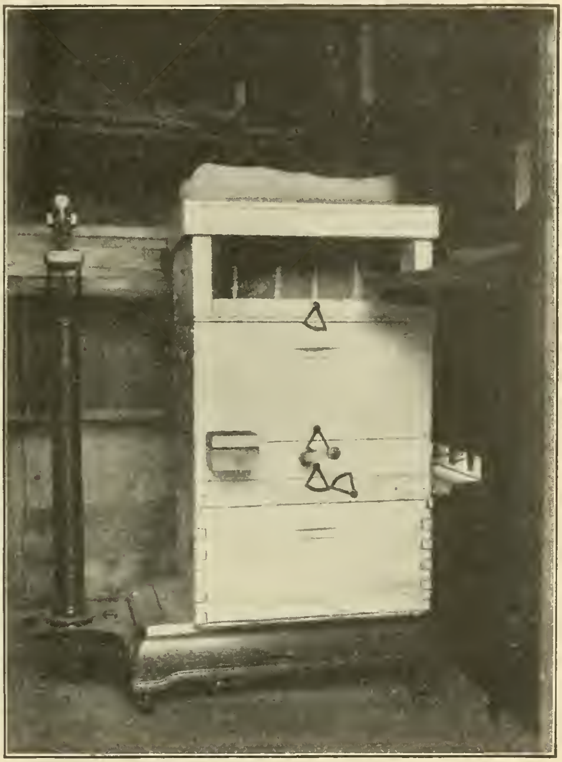

Fig. 2.—Hive on scales in shed where it was kept during the winter.

E. Between bodies *D* and *F* was a perforated zinc honey board.

F. A second body was provided in case more comb space should become desirable.

G. The top of the hive proper was covered with a thin cover. This, as is shown in figure 3, had four holes drilled in the median line and one directly over the rear part of the space between frames 3 and 4. Through these holes thermometers fitted in corks were inserted.

H. This was a special hive body used as a protection for the thermometers. One side, shown in figure 2, was removable so as to permit easy reading of the instruments. In this chamber and around the thermometers were two cushions of ground cork, for the protection of the tops of the thermometers and for the conservation of the heat of the cluster in the extreme of winter.

I. A metal cover.

A series of clamps, which drew over screw heads, held the several parts firmly together, preventing the bodies from sliding and snapping the stems of the thermometers.

The "dummies" above mentioned consisted of ordinary frames into which boards were fitted snugly. These were used in the winter months instead of the two outside frames on either side of the hive, thus forcing the cluster to occupy six frames in the center of the brood chamber. In this way it was made certain that the cluster would not shift away from the thermometers during the winter. The "dummies" were removed when brood rearing became established in the spring. These were not intended primarily for protection and did not fit the hive tightly.

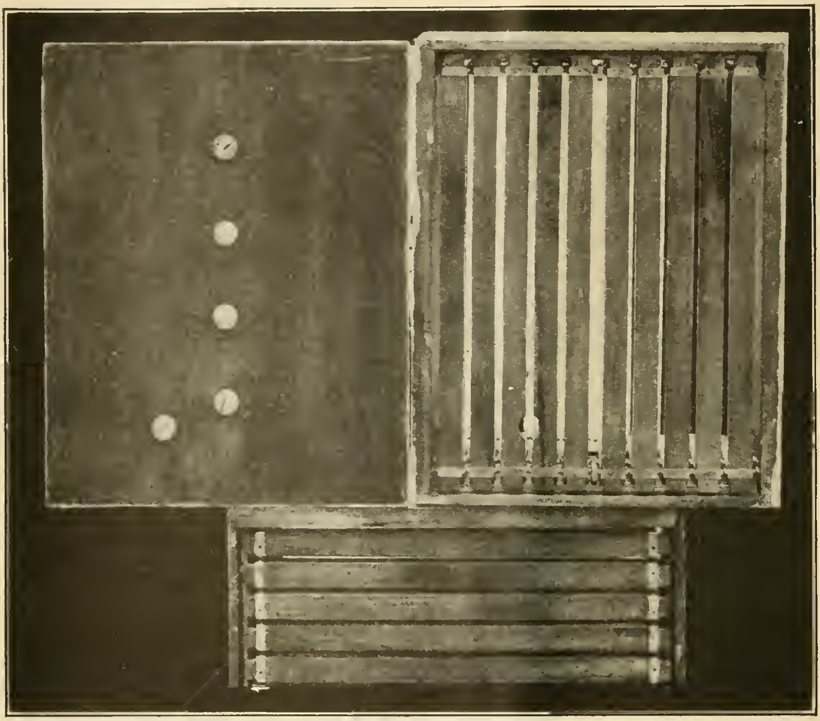

FIG. 3.—The hive from above, showing the spacing of the frames. The corks in the cover indicate the location of the thermometers.

In order to eliminate the annoyance and possible complications from propolizing, all the interior wooden parts were varnished and polished to a piano finish.

It should be said that not all of the parts of the apparatus provided were pressed into service. The extra body, *D*, was not needed, and consequently the honey board, *E*, was not used. The outfit as actually used and as it appeared in position until the writer was forced to move the experiment to the country in July, 1908, is shown in figure 2.

THE BEES.

Throughout the experiment Caucasian bees were used. Two colonies were necessary. The first drew out the foundation in the frames and was used during September and October, 1907. The second was hived in November, 1907, and served throughout the remainder of the experiment. This colony did not swarm.

THE ARRANGEMENT OF THE THERMOMETERS.

The thermometers were designated *a*, *b*, *c*, *d*, *e*, *f*, and *o*. Thermometers *a*, *b*, *c*, and *d* were inserted between the central combs. They were arranged at regular intervals, *a* being at the front of the hive and nearest to the entrance. Thermometer *e* was placed at the rear of the hive between combs 3 and 4, and was expected to represent the temperature of the margin of the cluster. Thermometer *f* was inserted beneath the frames through the collar, as is described above. Its purpose was to record the temperature of the air below the cluster and which was likely to be affected by currents from the entrance. Its bulb was directly below the central frames. The first five thermometers extended about 7 inches below the cover. The outside thermometer, *o*, was suspended close to the hive in such a way as to register the temperature of the air which surrounded the apparatus.

LOCATION OF APPARATUS.

The apparatus was installed in a shed on a third-story back piazza in southwest Washington, as is shown in figure 2. While the shed afforded shelter from storms, which was necessary for the protection of the apparatus and in taking observations, windows and door were left open, making the conditions relatively like out of doors. The shed was on the south side of the building.

In July, 1908, it was necessary to transport the experiment to College Park, Md. This, however, was found not to have affected the results. The apparatus was arranged in a situation comparable to the shed in Washington.

CHECK COLONY.

Besides the colony on the scales, in which the thermometers were suspended, a check colony in a hive with glass top and bottom was set up close by. The hive was constructed with a glass bottom board, and a wooden shield to cut out light. The cover was also of glass sealed to the hive, on top of which were several thicknesses of felt paper and an ordinary hive cover. By removing the bottom shield and the top protection it was possible at any time of day or night to look between the combs at the cluster. These protective coverings were applied so as to be removed with the minimum jar. At night, or even in the daytime, by means of a reflector, lantern light could be thrown up between the frames. In this way the writer was able to watch from day to day the shifting of the cluster and the reaction of the bees to their environment and to compare this with the readings of the thermometers in the hive on the scales. It was necessary to maintain this check only during the winter period.

METHODS OF OBSERVATION AND RECORDING.

Since none of the instruments recorded automatically, it was necessary to make frequent readings of both the weights and temperatures. The experiment proper lasted from October 22, 1907, to September 26, 1908. The first colony, used to prepare the combs, was also under close observation, so that the whole period of experimentation was almost a year. Readings were taken at least every hour throughout the working day. Whenever the hive was manipulated, or when peculiar meteorological conditions prevailed, readings were taken half hourly, or even quarter hourly. On the average of about once in three weeks, by means of assistance, it was possible to take consecutive hourly readings for a period of two or three days. In this way practically the whole activity of the colony for a period of a year was recorded. During the summer months the readings usually covered a period of 14 hours daily.

The temperatures were read to fifths of a degree. Weighings were made to 10 grams. Every alteration or manipulation of the colony was recorded. Hourly changes in the weather and activity of the bees were also noted.

The readings were recorded on 12.5 by 20 cm. cards, the size standard to the office note file. Later from these tables the curves of the temperature and weights were plotted on millimeter cross-section paper, one sheet to a month. The method of plotting is obvious from examination of the several curves herein presented.

THE CONSUMPTION OF STORES IN WINTER.

At the outset of the investigations it was hoped by means of delicate scales, which have been described, that sufficiently accurate weighings could be made to show whether there is any correlation between the loss in weight and the temperatures of the cluster in winter. For instance, it was desirable to know whether there is any relation or rhythm in the consumption of stores to changes in temperature due to metabolism. It has not been possible to detect any such relations. Nevertheless several significant facts concerning the consumption of winter stores have been discovered.

The rate of consumption of stores, as is shown in figure 4, exhibits a relatively constant decrease from month to month. At the beginning of the season, before the cluster was well established, when bees were more active and before settled winter weather, food consumption was greater than in midwinter. As the season progressed, during February, for instance, consumption slackened. There are several factors which may account for this. In the first place, as the winter advanced there were fewer and fewer bees to be fed. The winter was also less severe, and consequently less generation of heat was necessary.

Humidity is another factor which noticeably influenced the daily weights for a considerable part of February. This also occurred

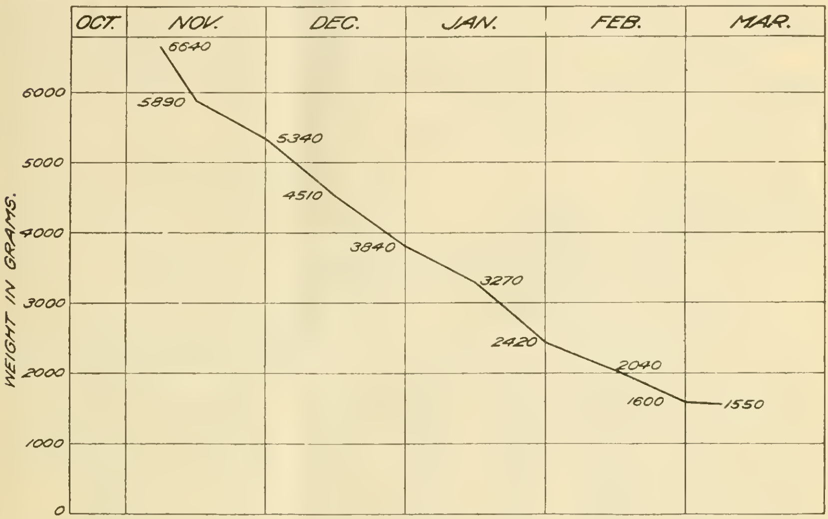

FIG. 4.—Graphic representation of the loss in weight of the bee colony from November 6 to March 7, due to the consumption of stores.

periodically in other months. Although condensation tended to prevent a drop or even to raise the curves during a period of bad weather, as will be shown below, the increased weight due to the condensed water vapor could neither be permanent nor affect the total loss of weight during so long a period as a month. Whatever water condensed during inclement weather would evaporate during the following days of fair weather. Thus, while the scales might register an increase during bad weather, consumption of stores was actually going on all the time, but could not be detected in the weights until fair weather had dispelled the moisture. Consequently the records of single days are less significant than the averages of a month or of the season.

There was, however, a gradual and constant lessening of the daily consumption of honey, as is apparent in Table I, which presents the monthly and average daily figures. From this table it will be seen that while in November the average daily consumption was 53.2 grams, in February the average was but 30 grams a day. For the entire winter 43.5 grams of honey were consumed, on the average, daily.

TABLE I.—*Monthly and average daily consumption of stores by wintering bees.*

Time.	Weight of stores.	Monthly loss.		Average daily loss.	
	Grams.	*Grams.*	*Pounds.*	*Grams.*	*Grains.*
November (Nov. 6, 9 a. m., to Dec. 1, 9 a. m.—25 days)	6,640 5,310	1,330	2.932	53.2	821
December (Dec. 1, 9 a. m., to Dec. 31, 9 a. m.—30 days)	5,310 3,820	1,490	3.284	49.6	765
January (Dec. 31, 9 a. m., to Feb. 1, 9 a. m.—32 days)	3,820 2,470	1,350	2.976	42.2	651
February (Feb. 1, 9 a. m., to Feb. 29, 9 a. m.—28 days)	2,470 1,630	840	1.852	30.0	463
Total loss for 4 months		5,010	11.045		
Average daily loss				43.5	671

TABLE II.—*Daily loss in weight of colony of wintering bees.*

Date.	Loss in grams.	Date.	Loss in grams.	Date.	Loss in grams.	Date.	Loss in grams.
Nov. 11	120	Dec. 10	+30	Jan. 10	70	Feb. 10	0
12	10	11	70	11	40	11	20
13	50	12	70	12	+10	12	20
14	70	13	60	13	30	13	0
15	50	14	20	14	50	14	+40
16	80	15	25	15	60	15	+20
17	90	16	25	16	40	16	130
18	60	17	60	17	50	17	20
19	10	18	40	18	50	18	40
20	70	19	40	19	40	19	+40

Although the foregoing figures represent the usual daily conditions, they do not by any means represent the actual daily consumption. As will be seen in Table II, there was no such degree of constancy as is represented by these averages. Taking the 10 days at the middle of each month, it is possible to represent prevailing conditions for that month. Thus the data of Table II are a fair representation of the actual variations as they occurred during the winter. It will be seen in this table that the daily variation in weight is all the way from a loss of 130 grams in some cases to no loss whatever or even an increase of 40 grams. Therefore it is hardly possible to assume that the weights of the entire hive will throw any light on the amount of honey consumed in a single day.

This increase in the weight of the hive during bad weather is a fact which, so far as the author is able to learn, has not heretofore attracted attention. It can not be said in any wise that this is an increase in the amount of stores. The phenomenon usually accompanied wet weather or fog and must be attributed to condensation of moisture. In the check hive moisture was frequently seen collected on the glass top and even on the frames and bees, but there the conditions were perhaps less normal than in the experimental colony. Root[1] says that he has seen confined moisture cause icicles to form in the hive. The condensation may become so great in extreme cases as to cause the bees to freeze together in a solid block when chilled down by severe cold. (Root, pp. 332–334.)

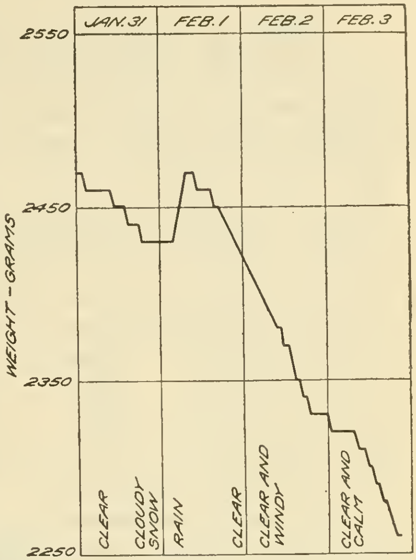

FIG. 5.—Curve showing changes in weight of the bee colony from Jan. 31 to Feb. 4.

Honey is well known to be hygroscopic, and if put into an ice chest or a damp cellar, it takes up moisture. Extracted honey has also been observed to accumulate enough moisture to dilute it considerably. In the present case the hygroscopic property of the honey can not be held wholly responsible for the increased weight, although it may have contributed. Following an increase of this kind, as has been mentioned, there was a marked decrease with the coming of fine weather and dryness. For illustration, the increase of 40 grams on February 1 (fig. 5) occurred during the early part of the day, when it was raining. That afternoon and the following day there were fair weather and wind. Then there came a marked decrease in weight, which not only compensated for the increase during the storm, but also showed that stores had been consumed constantly, although the weights

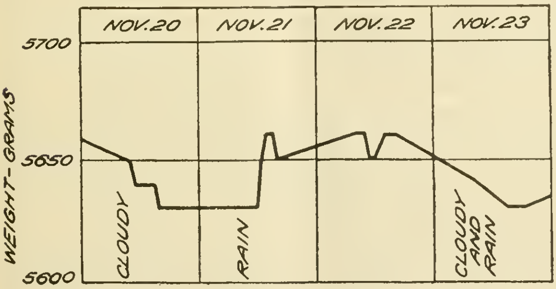

FIG. 6.—Curve showing changes in weight of the bee colony from Nov. 20 to Nov. 23.

[1] A B C and X Y Z of Bee Culture, 1908 ed.

failed to demonstrate it at the time. This same point is illustrated by the figures presented in figure 6. Such conditions suggest the complications which arise in attempting to correlate the colony temperature with the consumption of honey.

GENERAL PHENOMENA OF THE CLUSTER IN WINTER.

During the winter the bees are relatively quiet; the cluster expands and the bees fly only in the warmth of the warmest days. The heat maintained in the cluster has a general relation to the prevailing temperature of the air.

This relation of the cluster temperature to air temperature is especially evident in a comparison of the maximum and minimum temperatures of the several thermometers of the hive with the temperature at the outside thermometer, *o*. The daily maxima and minima were practically synchronous for all of the thermometers with the exception of *c*, which usually had its maximum when the temperatures registered by the other thermometers were lowest. Conversely, the minimum of *c* occurred when the outside thermometer and the others in the hive were at their highest points. This will be explained in detail under a following caption. With the exception of *c*, then, and for the particular conditions under which this colony was kept, the minima occurred daily some time between 6 a. m. and 12 m., but usually about 8 or 9 o'clock. The maxima occurred daily in the afternoon, usually between 2 and 4 o'clock.

While *c* registered the highest in cold periods, the temperature recorded by the other thermometers showed a similarity with the prevailing temperature of the air. Thus, in periods of cold, as for example in December, the thermometers in the hive as a whole registered lower than they did in warm periods. In warm periods, when the bees are able to expand the cluster and move about, the maximum cluster temperature lacked but a few degrees of the maximum summer temperature. This is repeatedly shown in figure 7; and in March, on a warm day, the temperature reached the extreme of 33.2° C. (91.76° F.). The temperature of the cluster did not fall below 17° C. (62.6° F.), and usually the bees did not permit the temperature of the cluster to fall below 20° C. (68° F.).

The amplitude of the fluctuations between the maximum and minimum temperatures showed a close relationship to the external conditions. In the center of the cluster, for instance, *c* registered much more constantly than the thermometers in the outside layer of the cluster. The daily oscillations of *c* were usually not greater than 1 to 5 or 6 degrees Centigrade. On the contrary, in the case of the other thermometers in the hive which were more affected by the rise and fall of the temperature out of doors, the amplitude of the oscillations was as great as 3 to 20 degrees Centigrade. The center of the cluster, therefore, shows more clearly the activities of the bees. The active portion of the cluster has a higher and more uniform temperature than the other parts, while the outside layers are subject more directly to the fluctuations of the winter weather. Most of the following study of the winter conditions of the beehive will be based on the records of the center of the cluster.

It would naturally be expected that the heat radiating from the bees would tend to delay the effects of the penetration of the cold of the outside air on the cluster. In other words, it might readily be expected that the cluster thermometers would reach their maxima and minima later than the outside thermometer. However, this occurred seldom and only in severe weather, when the changes were rapid and considerable. Even then there was a delay of only an hour or two at the most. This again suggests the sensitiveness and the responses of the cluster to the changes in the external air. The adaptation of the bees to changes in the atmospheric conditions will be more apparent when details are considered.

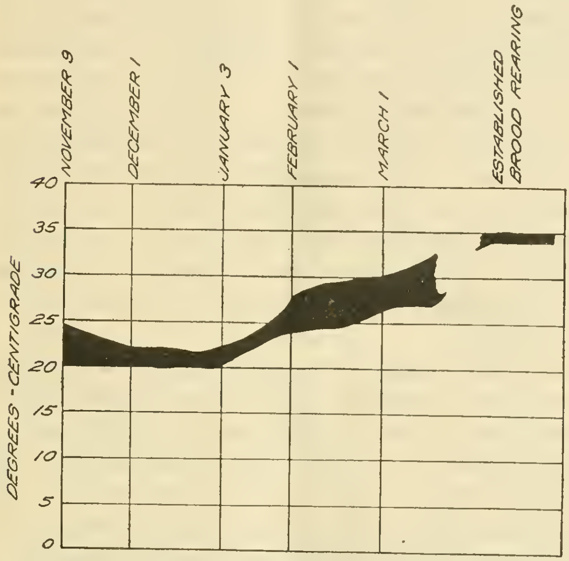

FIG. 7.—Schematic curve showing cluster temperatures of the bees during the winter and after brood rearing began.

As has been suggested above, there was a tendency for the cluster gradually to maintain a higher temperature as the season advanced toward spring and the beginning of egg laying. The schematic curve, figure 7, presents graphically the conditions of temperature at thermometer *c* throughout the winter. It will be noticed that during the month of November, when the bees were less definitely and constantly clustered, the amplitude of the daily variation and the general temperature of the cluster were higher than in the succeeding months. This is also evident in the fact that the curve of the thermometer *c* at this time of the winter tended to follow the curve of the outside thermometer *o* to some extent. In December, however, there was a change in the course of the temperatures at *c*, in response to the change in outside conditions. The conditions remained more nearly constant from this time until egg laying commenced in the spring, except that as the weather tended to warm up at the approach of spring the mean of the cluster temperature also raised. Finally when the days had considerably lengthened and were relatively warm, the amplitude of the cluster variations increased, as is shown in the schematic curve (fig. 7). When the summer season for the bees began, accompanied by the beginning of incubation, the temperature of the center of the cluster rose to 34° C. (93.2° F.) or 35° C. (95° F.) and continued practically at this level. For the winter, then, it might be said in a general way that the temperature prevailing for several days is in a measure an index of the temperature of the cluster.

TEMPERATURE BELOW FRAMES IN RELATION TO OUTSIDE AIR.

The thermometer *f*, situated below the bottom of the frames and cluster, as is shown in the general views of the apparatus (figs. 1 and 2), registered the temperature of the air at the bottom of the frames. It should have shown, if they were present, the effects of the cluster on the temperature of the air below the frames. It might be expected that the presence of the bees would have raised the temperature of the air in this part of the hive. For comparison with the other temperatures, thermometer *o* was hung in the shed in which the experiments were conducted, and registered the temperature of the air which enveloped the hive. Comparison of the readings of thermometers *f* and *o* reveal some significant facts not altogether in accord with the general belief of beekeepers.

During the winter as a whole these thermometers registered almost identically. Slight variations occurred, but only for a few hours at a time, and may be attributed to minor influences of the cluster, to peculiar atmospheric conditions, to drafts, and to the agitation of the bees. It should also be noted that the air which came in the entrance entered from outside the shed and the temperature of this air may not have been exactly that recorded by the thermometer *o*.

During the period of most protracted cold, from January 23 to February 1, when the outside air ranged about 0° C. (32° F.), thermometer *f* followed the outside temperature closely, and the course of the two curves is practically the same. In some cases, as for instance on January 26, thermometer *f* was slightly lower than the record of the outside air, which may possibly be explained by lack of ventilation or stagnation of the air of the hive. The lowest recorded outside temperature was −10° C. (14° F.). Since it was impossible to read these low temperatures on instrument *f*, and since the two curves are parallel so far as records were possible, it may be assumed that thermometer *f* would have registered almost the same as thermometer *o*.

During the warmest days and nights the recorded temperatures were the same. The maximum for the winter period came on March

15, when the outside thermometer reached 22.6° C. (72.68° F.). In all the other winter months there were days when the thermometers registered only 2 or 4 degrees less.

In conclusion it may be said that throughout the season the temperature below the frame was practically the same as that of the outside air. Of special significance is the fact that the daily extremes, the maxima and minima, no matter what were the variations at other periods of the day, were usually identical. From these observations

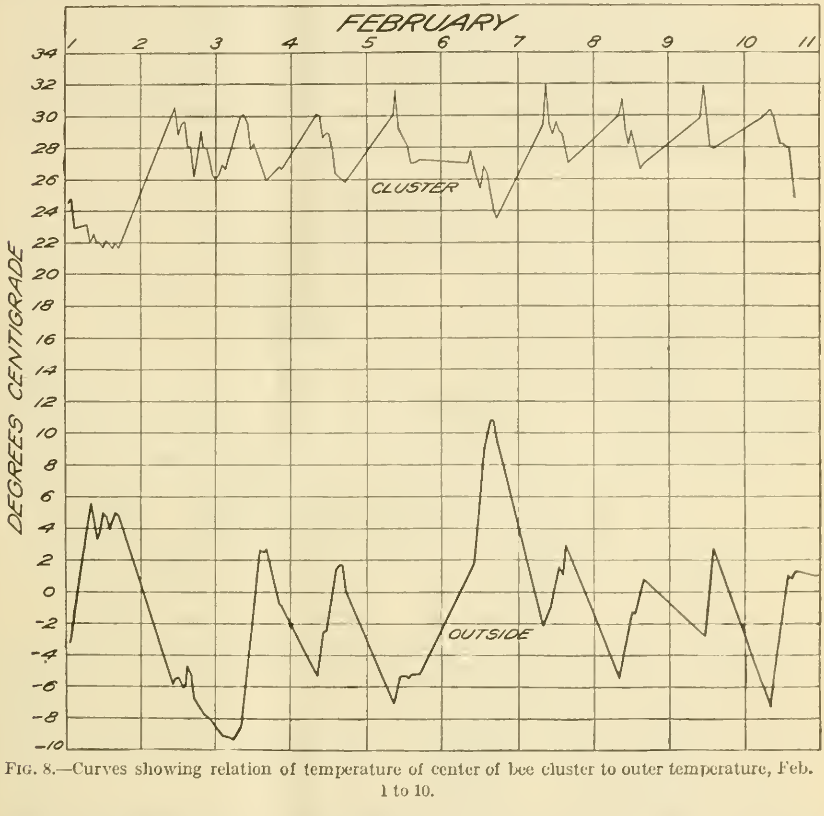

FIG. 8.—Curves showing relation of temperature of center of bee cluster to outer temperature, Feb. 1 to 10.

it would appear that the contraction of the entrance and the tight bottom board were not of much service in protecting the colony from cold. Colonies without bottom boards have frequently been known to survive extreme winter cold. It may be, however, an advantage to a colony to be protected from the sweep of violent winds; but there is no evidence that this colony appreciably warmed the lower part of the hive in which it was wintering. Under such conditions the bottom of the cluster is bathed in an atmosphere of the same temperature as the outside.

COMPARISONS OF TEMPERATURES OF THE CENTER OF THE CLUSTER AND OF THE OUTSIDE AIR.

The curves have revealed no more striking results than the relation observed between the temperature in the center of the cluster, *c*, as compared with the temperature of the outside air, *o*. These curves (fig. 8) at times show a peculiar inverse relation; for instance, when the thermometer out of doors registered low, below zero, the thermometer in the center of the cluster registered high, and vice versa. It should be observed that the maximum within the cluster occurs practically simultaneously with the minimum outside, and vice versa. Even minor changes outside are accompanied by corresponding inverse fluctuations in the cluster. The responses of the cluster to the outside temperature were shown particularly by the thermometer which recorded the temperature of the center of the cluster, *c*.

Up to the day of the first egg laying in the spring, March 9, the general courses of *c* and *o* continued relatively constant. But with the commencement of egg laying *c* changed its trend. The temperature of the brood cluster then became more and more constant, as may be seen in the results of the summer observations.

At first glance these curves might be interpreted as independent of each other, that the outside atmosphere has no effect on the center of the cluster, that it does not penetrate and modify the readings of *c* as it appears to have done in the case of the temperatures in the margin of the cluster. In all probability *c* more nearly represents the activities of the bees than do the other temperatures; but there is a relation of *c* to *o*. It might be supposed that the reaction registered by *c* is deferred for a period of hours and consequently appears at a time when *o* has changed. For instance, corresponding to the minimum of *o* on the 4th of February, the minimum of *c* came nine hours later. If this is due to a delay or "lag," maxima and minima in some cases are delayed for 24 hours or more. But this can not be; there are many minor variations which appear on the curves, and which are synchronous. Were there no relation of *c* to *o* these minor variations would either not have appeared in *c*, or, more especially, they would not have occurred simultaneously with a minor fluctuation in the outside temperature. It is therefore impossible to explain the phenomena on the ground of retardation (lag), for in that case it would be far more constant than is evident.

Related to the assumed explanation by delay or "lag," humidity or condensation, convection, radiation, and conduction might be assumed to be factors involved. The experimental colony furnishes no data for a consideration of humidity or condensation. The factors of convection, radiation, and conduction can not be conceived as slow enough to retard *c* from 9 to 24 hours nor would it account for its minor, synchronous variation. Without doubt of these three factors the loss of heat from the cluster by convection is sufficient to counteract the hypothesis of the lag. Coupled with this the other factors would be expected to participate. The convection is also modified by the generally known contraction and relaxation of the cluster, referred to elsewhere.

These physical phenomena are evidently unsatisfactory as an interpretation from this standpoint of the lag. Thorough comparison of the charts fails to provide suitable material for conclusions as to the cause.

Table III shows the relative increase of temperature in the cluster corresponding to the progress of the winter season, while Table IV shows the monthly maximum and minimum temperature of the center of the cluster during the period from November 9 to March 9.

TABLE III.—*Relative increase of temperature in the bee cluster corresponding to the progress of the winter season.*

Month.	Range of temperature.	
	°C.	°F.
November, beginning of winter conditions	20 to 24	68.0 to 75.2
December	20 to 22	68.0 to 71.6
Jan. 1 to 18	22 to 25	71.6 to 77.0
Jan. 19 to 31	23 to 28	73.4 to 82.4
February	24 to 30	75.2 to 86.0
Mar. 1 to 9	27 to 32	80.6 to 89.6
When brood rearing is established	34 to 35	93.2 to 95.0

TABLE IV.—*Monthly maximum and minimum temperature of the center of the bee cluster during the winter period, Nov. 9 to Mar. 9.*

Month.	Temperature of cluster.	
	Maximum.	Minimum.
November	27° C.	17° to 18.2° C.
	80.60° F.	62.60° to 64.76° F.
December	18.5° and 31.3° C.[1]	18.1° C.
	65.30° and 88.34° F.	64.58° F.
January	30.2° C[2]	19° C.
	86.36° F.	66.20° F.
February	32° C.[3]	21° C.
	89.60° F.	69.80° F.
Mar. 1-9	33.2° C.[4]	27° C.
	91.76° F.	80.60° F.

[1] On a very warm day, Dec. 28.
[2] This occurred on two occasions, Jan. 14 and 30, at 8 a. m., when the outside temperature was 4° C. or more below freezing.
[3] Approximated several times when outside temperature was below freezing.
[4] Occurred after a warm day; approaches summer conditions

EFFECTS OF MANIPULATION ON THE CLUSTER.

Good beekeepers know that it is not well to open a hive in winter, but perhaps few realize the resulting effects on the colony. In Washington there are days in every winter month which are sufficiently warm to permit opening a hive without chilling the bees. It was necessary, partially in order to observe the effects on the colony and partially to know their condition, to open the hive under experimentation. The results recorded by the thermometers on all of these occasions are pronounced. In the course of the observations on this colony it was found impossible to disturb the colony in the slightest degree, even to remove and replace a thermometer, to jar the colony, or to puff smoke in at the entrance, without noticeably affecting the temperature. These effects, as in the case of opening the hive, were not always temporary, but sometimes lasted for hours. Any disturbance resulted in an almost immediate rise in the temperature, and was appreciable throughout the cluster.

On March 12 the colony was opened for 15 minutes at 1 o'clock in the afternoon. The thermometers throughout the hive and even the one below the frames to some extent registered an immediate rise in temperature. When the hive was closed the cluster was soon reestablished but it was several hours before the temperature in the margins of the cluster became normal. On the interior of the cluster, however, the excitement and its effects were not so soon overcome. The curve for *c* shows that not until the next day did conditions approximate normal; the effects were appreciable even the day following the opening of the hive.

These results agree with the experience of many practical beekeepers, who consider it unadvisable to open their hives during the winter.

BEHAVIOR OF THE CLUSTER IN WINTER: OBSERVATIONS ON THE CHECK COLONY.

By means of the check colony with glass top and bottom, described on pages 5–6, it was possible to watch the movements of the bees throughout the winter at any time of day or night.

Various theories have been advanced by beekeepers to account for the behavior of bees in winter, but the writer is not aware that they are based on continuous and close observation. For instance, it has been maintained by some that bees semihibernate; by others it is affirmed that there is at intervals a general warming up of the colony in order that it may feed. The theory is that at stated periods bees generate enough heat to enable them to brave the cold and to expand the cluster sufficiently to enable them to reach fresh stores. It is not necessary to multiply theories on the condition and activities of bees in winter.

In a previous portion of the text the relation of the temperatures of the cluster to the temperature of the outside air has been sufficiently considered. It remains now to describe the activity of the bees as seen in the glass check hive. In some respects the movements or the reaction of the bees, and more particularly of the cluster as a whole, to the stimuli of changes in the atmospheric conditions was rather pronounced.

In watching this colony it was found that the density, and consequently the shape of the cluster, varied from day to day. When the air outdoors was warm, the cluster expanded; with cold, it contracted. The expansion usually did not cause the bees to cover more frames, but caused them to cover more completely those frames which they were occupying. Thus the expansion was usually downward toward the bottoms of the frames and in the direction of the entrance. With cold, the bees receded from the bottoms of the frames and from the top bars.

At all times the colony was sensitive to the slightest jar. The bees were also especially sensitive to the light which burst in upon them whenever the covering of the glass top was removed. If the hand were passed over the glass, bees would fly toward it as if to sting. This was noticed no matter how cold the day and shows that the colony, and particularly the outside of the cluster, is far from torpid, inactive, or semiquiescent. At practically all times there were bees moving on the outside of the cluster or on the top bars of the frames. Whenever the hive warmed up in the sun, although there were no bees flying, this was evident. There can be no question, therefore, of the alertness and activity of a colony in winter.

One of the most surprising observations was the apparent interchange of bees from the inside of the cluster with those on the outside of the cluster. As the writer watched the cluster, the head of a bee would gradually appear from below the bees forming the shell of the cluster. Finally this bee emerged and took her place with the others on the outside. Similarly, bees were frequently seen to disappear into the mass. The behavior was in no way general, but apparently was going on constantly and gradually. The phenomenon was repeatedly observed under all manner of conditions and at different times of day and night. By carefully arranging the covers, so that it was unnecessary to remove them, and thus cause a jar, it was proven that this behavior is normal and not the result of a disturbance of the bees. It must be concluded, therefore, that in this way the same bees may not be exposed to the outside cold for a long period. So long as they are able to keep up their own body temperature they remain outside, but when chilled they pass into the interior. Thus there must be a continual interchange of bees from the outside to the inside. Were it possible of observation, there would doubtless be found a relation of the interchange to the meteorological conditions. In cold weather the interchange may be expected to be greater.

In severe weather the bees were especially compact and their arrangement definite and constant. They were arranged side by side between the tops of the frames, with their heads downward. At the lower part of the cluster they were also arranged head down but with a little less regularity. It is difficult to see just what this means.

As further evidence that the colony is not torpid in cold weather, some of the other activities observed will be of interest. During the day, particularly, the bees were seen grooming and combing one another, feeding, and fanning at the outside of the cluster; and when the light was admitted to the top, they sometimes flew up as if to sting. It should also be stated that on nights of the most severe weather the bees in both this check colony and in the experimental colony were heard faintly and intermittently buzzing. This buzzing was even more noticeable on cold nights than on warmer ones. A peculiar trembling of the bee such as is seen in summer was not infrequently noticed. All of these activities are commonly observed in summer, but heretofore have not been thought to occur in winter and spring before the colony is able to fly forth.

It is probable that the heat of the sun has no slight influence on the cluster. At least in the check colony under observation it was evident that the cluster sought the sunny side of the hive, the front above the entrance, where from 10 or 11 o'clock in the morning until sundown the sun shone on the hive.

TEMPERATURE ACCOMPANYING THE LAYING OF THE FIRST EGGS.

With the laying of the first eggs in the spring, which marks the beginning of summer activity, striking changes occur in the behavior and temperature of the cluster. The central thermometers *b* and *c* were particularly affected. Upon opening the hive March 12 eggs less than three days old were discovered. Up to March 9 *c* had usually continued its winter course inversely to *o*, as is described and illustrated above by figure 8. But after March 9, when the first eggs were seen, the course of *c* changed and the inverse relationship was no longer apparent.

In order to explain the change in the course of *c* in relation to *o*, the behavior of the bees at egg-laying time must be considered. During the winter, while fresh air is necessary, there is no such need of it as when the eggs, or more particularly the brood, appear. Moreover, for incubation and for brood rearing a much higher and more constant temperature is needed. The effects of drops in the temperature of the outside air must be overcome. In preparing room for the laying of the queen, the zone for the brood nest is established, which is an important factor in the change in the course of curve *c*. All of these things appear immediately in the curve at the time of incubation. Formerly, when the bees went forth on a warm day there was a drop in *c*; now the trend of *c* is slightly upward during the warmth of the day corresponding somewhat with the warmth outside. Flight occurs nearly every day.

It is the belief of many beekeepers who winter their bees in cellars that too high a temperature is likely to cause uneasiness and brood rearing. Root (1908) calls attention to the necessity of maintaining a temperature of not more than 45° F. (7.22° C.) at the approach of spring. The writer is not aware that any systematic study of the temperatures of bees in cellars has ever been made, so that it is impossible to say how the temperature of the cluster would compare with that of the colony under experimentation. The prevailing outside temperature, however, in the present experiment was found to be about 45° F. (7.22° C.) for several days previous to the laying of the first eggs, March 9.

At any rate in this experiment it appears that a temperature of 45° F. (7.22 C.), with an occasional maximum outer temperature of 8° to 11° C., is closely associated with the beginning of egg laying. But there are probably other factors of importance, particularly the matter of food. In establishing the experimental colony late in the fall, it was impossible for the bees to store any pollen. In the spring, however, for a week previous to egg laying they were seen gathering it. This might be expected to be an important stimulus to egg laying, and the bees could not rear brood until some could be gathered. While there appears to be a close relation between stimuli, temperature out of doors, and pollen gathering to the laying of eggs, details of the phenomena can be worked out only on a larger number of colonies under experimental conditions.

Another noticeable phenomenon which occurred at this time was the equalization of the temperature throughout the cluster. This might occur earlier in colonies protected from the winds and in sunny locations and later in colonies less favorably situated. If, however, upon experimentation this should be found to be one of the fundamental stimuli to egg laying, it would in a measure explain the fact that eggs do not always appear at the same time in all of the colonies of a bee yard. Another factor would be the strength of the colony and the resulting heat which it could produce and conserve. These results of the present investigation suggest great possibilities for discovering the stimuli which regulate the beginning of egg laying in the spring and which might influence the periodicity of brood rearing during the summer.

So far the consideration has been largely of the period in which eggs were laid and which preceded directly the beginning of incubation or brood rearing. It will be seen, therefore, that this time is in a sense transitional from the winter condition to the summer season, the topic which will next be considered.

TRANSITION FROM WINTER TO SUMMER CONDITIONS.

The phenomena mentioned in the preceding caption which accompanied the laying of the first eggs marked the beginning of the transition from winter to summer conditions, but this transition was not completed until brood rearing was well established. With the establishment of brood rearing, the changes which manifested themselves with the first eggs became intensified. The course of the temperature recorded at *c* became unlike that which was observed in the winter and was influenced more directly by the outside temperature. The influence of the outside temperature became less and less marked, as is shown from the fact that the oscillation of *c* became less and less, the temperature in the center of the cluster became more constant, and the temperature throughout the hive became more equalized. As was stated, the turning point came on the 9th of March, but it was a little more than two weeks, about the 24th or 25th of March, before the colony really assumed normal summer temperature condition. Once this was gained, the temperature, particularly of the center of the cluster, remained relatively constant until fall. This transition period of two weeks was characterized by several features.

There was an increase of temperature both in the colony and out of doors. Out of doors the maximum ranged between 12° and 18° C. (53.6° to 64.4° F.), but even more favorable weather followed the establishment of brood rearing and the maximum ranged from 18° to 25° C. (64.4° to 73.4° F.). To a certain extent the temperature of the colony was raised like that of the outside temperature. The increase was general throughout the colony and must be attributed to the need of more heat for brood rearing, more ventilation, and the general increased activity of the bees. At this time *b* and *c* ranged constantly between 33° and 35° C. (91.4° to 95° F.), which will be seen to be practically the range throughout the summer.

In a word, the transition from winter to summer conditions was accomplished in a surprisingly short time. Accompanying incubation and brood rearing the temperature was gradually raised and became equalized through the hive, and once well established was maintained during the summer. Although the transition was relatively abrupt, it would be expected to vary with the colony and perhaps be prolonged in unfavorable weather.

GENERAL PHENOMENA OF THE SUMMER TEMPERATURE.

The constancy and equalization of the temperature and the range of 33° to 35° C. (91.4° to 95° F.), which characterized the close of the transition from winter to summer conditions, characterize equally well the prevailing summer phenomena. So constant were the temperatures in summer that their peculiarities may be briefly summarized. Few external factors influenced the hive temperature, and these affected it but slightly. In the original plan of the experiment it was hoped that it would be possible to discover whether there is any correlation between honey flows and temperatures; but inasmuch as the season was excessively dry and the flowers secreted no nectar for weeks at a time, this phase of the experiment could not be carried out.

RELATION OF C TO THE OUTSIDE TEMPERATURE.

Whatever is said of *c* in the following paragraphs applies equally to *b*, and practically as well to all the thermometers in the hive.

Although the temperature at *c* coursed constantly in the opposite direction to *o* during the winter, there is no appreciable correlation between the temperatures in the summer. It might be said of the hive that the temperature as a whole was independent of external conditions. A few exceptions to this will follow, however. During a period of stormy and cooler weather, for instance, although there were slight changes which will be discussed later, the temperatures were largely unaffected. Moreover, since the oscillation of *c* was slight, as will be explained, there was little relationship between the temperature of the center of the cluster and *o*.

THE MAXIMA AND MINIMA OF C IN RELATION TO O.

The daily oscillation between the maximum and minimum of *c* was usually less than 1° C. (1.8° F.), and in many instances it was but one or two tenths of a degree. On the whole the temperature in the brood nest is remarkably constant, ranging between 34° and 35° C· (93.2° to 95° F.).

Even with this slight fluctuation there was perceptible on many days a maximum and minimum for *c*, and particularly for the other hive thermometers which perhaps were the most influenced by external conditions. It may be said that, roughly, the maxima and minima occurred within two hours of the maxima and minima of *o*, but since in some instances this happened previous to the maximum and minimum out of doors, the warming up of the colony due to the increasing activity of the bees must have had its effect.

To show how closely the maxima of the thermometers in the outer parts of the cluster ultimately approached the readings of the central thermometers, it may be said that while in April the maximum of the outer thermometers in the hive was 19° C. (66.2 F.), in the following months it rarely fell below 34° C. (93.2° F.). In September, however, with the general cooling of the atmosphere, it fell to 28° C. (82.4° F.). This showed the tendency at the close of the experiment for the colony to approach winter conditions. The facts show again the unity or equalization of the temperature throughout the cluster, which in the brood-rearing season ranges between 34° and 35° C. (93.2° to 95° F.). The maxima and minima are shown in Table V. The range of the oscillation shows the constancy of the temperature during the height of the season and the greater fluctuations in spring and fall.

TABLE V.—*Maximum and minimum temperatures of the center of the cluster during summer. Thermometer C.*

Month.	Maximum.		Minimum.		Approximate range.	
	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*
April	35.4	95.7	31.6	88.9	4	7.2
May	36.0	96.8	33.8	92.9	2	3.6
June	35.5	95.9	33.6	92.5	2	3.6
July	35.0	95.0	33.2	91.8	2	3.6
August	35.8	96.4	33.8	92.9	2	3.6
September	34.8	94.6	28.0	82.4	7	12.6

FLUCTUATIONS IN THE HIVE TEMPERATURE AND THE CAUSES.

It has already been said that the fluctuations in the hive temperature were slight and that hot days and winds had very slight effect on the cluster temperature. There are some minor fluctuations due to internal and external disturbances which caused decrease or increase in the hive temperature.

THE EFFECT OF "ORIENTATION" OR "PLAY FLIGHTS."

Every beekeeper is familiar with the "play flights" of young bees about noon on warm sunny days. These are generally believed to be "orientation flights," in which the young bees fly forth in circles and with head toward the hive in order to learn its location. During the period of resumed brood rearing in August these flights occurred every few days in the experimental colony. At such times thermometer readings were taken at short intervals. Instead of causing the heat of the hive to increase these flights first caused a decrease, then a slight increase. Table VI presents figures for a typical observation, made after the bees had been confined to the hive by inclement weather for three days.

TABLE VI.—*Effects of "orientation flights" of bees on the temperature of the hive.*

Aug. 28.	Thermometer.													
	a.		*b.*		*c.*		*d.*		*e.*		*f.*		*o.*	
	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*
6 a. m.[1]	34.0	93.2	34.4	93.92	34.4	93.92	34.4	93.92	33.6	92.48	34.6	94.28	15.6	60.08
7 a. m.	34.0	93.2	34.4	93.92	34.4	93.92	34.0	93.2	33.4	92.12	34.4	93.92	16.4	61.52
8 a. m.[2]	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.4	92.12	34.6	94.28	16.8	62.24
9 a. m.	34.0	93.2	34.0	93.2	34.3	93.74	34.0	93.2	33.2	91.76	34.6	94.28	17.4	63.32
10 a. m.	34.0	93.2	34.2	93.56	34.3	93.74	34.0	93.2	33.2	91.76	34.8	94.64	18.0	64.40
11 a. m.[3]	33.8	92.84	33.8	92.84	33.8	92.84	33.8	92.84	33.2	91.76	34.2	93.56	19.4	66.92
11.30 a. m.[4]	33.8	92.84	34.0	93.2	34.0	93.2	34.0	93.2	33.8	92.84	34.4	93.92	20.0	68.0
12 m.	34.0	93.2	34.0	93.2	34.0	93.2	34.0	93.2	33.6	92.48	34.4	93.92	19.6	67.28
1 p. m.	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.6	92.48	34.8	94.64	20.2	68.36
2 p. m.[5]	33.8	92.84	34.0	93.2	34.0	93.2	33.8	92.84	33.6	92.48	34.4	93.92	20.2	68.36
2.15 p. m.	34.0	93.2	34.0	93.2	34.0	93.2	34.0	93.2	33.6	92.48	34.4	93.92	20.4	68.72
2.30 p. m.[6]	34.0	93.2	34.0	93.2	34.2	93.56	34.0	93.2	33.6	92.48	34.6	94.28	20.0	68.0
2.45 p. m.	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.8	92.84	34.8	94.64	20.4	68.72
3 p. m.	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.8	92.84	34.8	94.64	20.8	69.44
4 p. m.	34.0	93.2	34.4	93.92	34.4	93.92	34.2	93.56	33.8	92.84	34.8	94.64	20.2	68.36

[1] Cloudy.
[2] Bees fly slightly.
[3] First good fly for three days.
[4] Quieted flight.
[5] Bees fly freely again.
[6] Quiet again.

It will be noticed that short flights were taken at 8 o'clock in the morning when the thermometer *c* fell 0.2° C. At 11 o'clock the first flight of importance occurred. Then there was another slight drop in the temperature followed by a rise. At 2 o'clock there was a similar flight and change in the thermometer. In all cases within 15 to 30 minutes the thermometer had regained its normal temperature. While the drop was actually slight, when it is remembered that the daily fluctuation in the temperature was frequently but a fraction of a degree, the decrease was relatively considerable. The same effect was noticed in the spring and in the early part of the season, when the bees first commenced to take field trips. This cooling effect must be attributed to the rushing forth of the bees from the cluster; in so doing they liberate the confined heat of the cluster. Another factor is probably the excessive fanning at the entrance which usually accompanies these "play" flights. When the activities wane and the bees commence to return to the hive, the temperature resumes its normal condition.

A similar decrease in temperature was common in the early morning when the bees commenced to leave the hive for the field. For comparison with the foregoing, the readings taken in the early morning of August 3 and 4 are presented in Table VII.

TABLE VII.—*Effects of early morning flight of bees on temperature of the hive.*

Date.	Thermometer.											
	a		*b*		*c*		*d*		*e*		*o*	
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
Aug. 3.												
8 a. m.	34.0	93.2	34.2	93.56	34.6	94.28	34.2	93.56	34.0	93.2	22.6	72.68
9 a. m.	33.8	92.84	34.2	93.56	34.4	93.92	34.2	93.56	33.8	92.84	26.0	78.80
10 a. m.	33.9	93.02	34.4	93.92	34.8	94.64	34.2	93.56	34.0	93.2	26.8	80.24
11 a. m.	34.0	93.2	34.4	93.92	34.8	94.64	34.6	94.28	34.0	93.2	27.4	81.32
12 m.	34.0	93.2	34.6	94.28	34.8	94.64	34.6	94.28	34.0	93.2	28.0	82.40
Aug. 4.												
5 a. m.[1]	34.4	93.92	34.6	94.28	34.8	94.64	34.6	94.28	34.2	93.56	21.2	70.16
6 a. m.	34.4	93.92	34.6	94.28	34.6	94.28	34.6	94.28	34.4	93.92	21.0	69.80
7 a. m.[2]	34.0	93.2	34.4	93.92	34.6	94.28	34.2	93.56	34.0	93.2	22.6	72.68
8 a. m.	34.0	93.2	34.4	93.92	34.8	94.64	34.4	93.92	34.0	93.2	25.0	77.00
9 a. m.	34.0	93.2	34.8	94.64	34.8	94.64	34.4	93.92	34.0	93.2	27.0	80.60

[1] Fanning entrance. [2] Bees begin to fly freely.

EFFECTS OF CLUSTER HEAT ON THE TEMPERATURE BELOW THE FRAMES.

It was found that the heat from the cluster had no perceptible influence on the temperature of the air below the frames during the winter. Practically the air was at the outside temperature. But in summer totally different conditions prevail; the temperature within the hive becomes equalized. Furthermore, the crowding of the bees at certain seasons tends to force them to hang down from the bottoms of the frames or even out at the entrance. Consequently that space which was outside the frames assumes cluster conditions.

Early in the season *f* averaged 3° C. higher than *o* at all times; at the end of the season, September, it averaged from 5° to 6° C. higher. By the middle of May *f* stood only 1° or 2° C. lower than the thermometers in the cluster, although the thermometer in the outside air was much lower. Throughout the summer there was practically no difference between *c* and *f*. During the storm period, as will be seen in Table IX, which is discussed farther on, *f* ranged even higher than the prevailing cluster temperature. This was undoubtedly due to the massing of the bees below the frames as they were crowded in from the alighting board.

THE EFFECTS OF STORM.

Since the summer of 1908 was remarkably dry and free from storms, it is not possible to draw any definite conclusions upon the effects of storms, cold waves, and winds upon the cluster temperature. The only severe storm of the summer occurred in the latter part of August. The outside thermometer went as low as 14° C. (57.2° F.), while before and after this period there were frequent readings ranging from 20° to 30° C. (68° to 86° F.). During the storm there were several high winds. These, however, did not blow directly in at the entrance. The bees were thus confined for three days, and at times showed much evidence of shifting and massing at different parts of the hive. In a glass observatory hive the bees were actually seen to cluster now in one part of the hive and then in another. The wind and rain also drove the bees in off of the alighting board and forced them to hang from the bottoms of the frames. If the readings of the thermometers nearest the outside of the hive are rightly interpreted, the cluster withdrew from the walls of the hive, and this caused a decrease in the temperature at these points. While there is some evidence in the figures that the cold outside the hive had its effects on the center of the cluster, the temperature was not permitted to remain below 34° C. (93.2° F.). No fall was recorded lower than 33.8° C. (92.84° F.). Thus the bees appear to be able to control and conserve the temperature with remarkable constancy, even though there be high wind and relatively low temperature. Table IX, in comparison with the figures for a bright day in Table VIII, reveal these facts.

TABLE VIII.—*Temperatures of a bee colony on a normal day.*

Time.		Thermometer.											
Month and day.	Hour.	*a.*		*b.*		*c.*		*d.*		*e.*		*o.*	
		°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
Aug. 15	6 a. m.[1]	34.4	93.92	34.4	93.92	35.0	95.00	34.8	94.64	34.8	94.64	24.4	75.92
	7 a. m.	34.4	93.92	34.4	93.92	34.8	94.64	34.8	94.64	34.6	94.28	26.0	78.80
	8 a. m.	34.2	93.56	34.4	93.92	34.8	94.64	34.8	94.64	34.8	94.64	24.6	76.28
	9 a. m.[2]	34.2	93.56	34.4	93.92	34.8	94.64	34.8	94.64	34.8	94.64	25.8	78.44
	10 a. m.	34.6	94.28	34.6	94.28	34.8	94.64	34.6	94.28	34.6	94.28	27.6	81.68
	11 a. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	28.8	83.84
	12 m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	29.0	84.20
	1 p. m.	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	35.0	95.00	29.6	85.28
	2 p. m.	35.0	95.00	35.0	95.00	35.0	95.00	35.2	95.36	35.2	95.36	30.4	86.72
	4 p. m.	35.0	95.00	35.0	95.00	35.0	95.00	35.2	95.36	35.2	95.36	29.2	84.56
	6 p. m.	35.0	95.00	35.0	95.00	35.2	95.36	35.2	95.36	35.2	95.36	28.2	82.76
	7 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.2	95.36	35.0	95.00	27.6	81.68
	8 p. m.	35.0	95.00	35.0	95.00	35.0	95.00	35.0	95.00	35.0	95.00	26.6	79.88
Aug. 18	6 a. m.	34.0	93.2	34.2	93.56	34.0	93.2	34.0	93.2	34.2	93.56	21.8	71.24
	7 a. m.[3]	34.2	93.56	34.2	93.56	34.4	93.92	34.4	93.92	34.2	93.56	22.0	71.60
	8 a. m.	34.2	93.56	34.2	93.56	34.4	93.92	34.4	93.92	34.2	93.56	22.4	72.32
	9 a. m.[4]	34.4	93.92	34.4	93.92	34.6	94.28	34.6	94.28	34.4	93.92	25.0	77.00
	10 a. m.[5]	34.4	93.92	34.6	94.28	34.6	94.28	34.8	94.64	34.6	94.28	26.0	78.80
	11 a. m.	34.6	94.28	34.8	94.64	34.8	94.64	34.8	94.64	34.8	94.64	26.5	79.70
	12 m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	27.4	81.32
	1 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	28.6	83.48
	2 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	29.0	84.20
	3 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	28.0	82.40
	4 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.2	95.36	35.2	95.36	28.0	82.40
	6 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.2	95.36	27.4	81.32
	7 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	26.2	79.60
	8 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	25.6	78.08

[1] Cloudy and calm.
[2] Clearing, calm and close.
[3] Cloudy.
[4] Clearing and calm.
[5] Clear.

TABLE IX.—*The effects of storm and wind on the temperatures of the bee colony.*

Time.		Thermometer.													
		a.		*b.*		*c.*		*d.*		*e.*		*f.*		*o.*	
Month and day.	Hour.	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
Aug. 25	8 a. m.[1]	34.2	93.56	34.4	93.92	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	20.4	68.72
	8.30 a. m.	34.2	93.56	34.2	93.56	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	19.8	67.64
	9 a. m.[2]	34.4	93.92	34.4	93.92	34.2	93.56	34.2	93.56	33.8	92.84	34.6	94.28	19.8	67.64
	10 a. m.	34.0	93.20	34.2	93.56	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	20.8	69.44
	11 a. m.[3]	34.2	93.56	34.4	93.92	34.4	93.92	34.2	93.56	34.0	93.20	34.6	94.28	20.2	68.36
	12 m.	34.0	93.20	34.8	94.64	24.2	93.56	34.4	93.92	34.0	93.20	34.6	94.28	20.6	69.08
	1 p. m.[4]	34.2	93.56	34.4	93.92	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	18.4	65.12
	2 p. m.	34.0	93.20	34.6	94.28	34.0	93.20	34.0	93.20	34.4	93.92	34.6	94.28	17.8	64.04
	3 p. m.	34.0	93.20	34.4	93.92	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	17.6	63.68
	4 p. m.	34.0	93.20	34.8	94.64	34.2	93.56	34.0	93.20	34.0	93.20	34.6	94.28	17.0	62.60
	5 p. m.	34.0	93.20	34.0	93.20	34.2	93.56	34.0	93.20	34.0	93.20	34.6	94.28	16.2	61.16
	6 p. m.[4]	34.0	93.20	34.2	93.56	34.0	93.20	34.0	93.20	33.6	92.48	34.6	94.28	18.2	64.76
	7 p. m.	34.0	93.20	34.4	93.92	34.2	93.56	34.2	93.56	33.6	92.48	34.6	94.28	16.4	61.52
	8 p. m.	33.8	92.84	34.2	93.56	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	16.2	61.16
	9 p. m.	34.0	93.20	34.2	93.56	34.2	93.56	34.0	93.20	33.6	92.48	34.6	94.28	15.0	59.00
	10 p. m.	34.0	93.20	34.4	93.92	34.4	93.92	34.4	93.92	33.0	91.40	34.6	94.28	15.0	59.00
	11 p. m.	34.0	93.20	34.2	93.56	34.4	93.92	34.2	93.56	33.2	91.76	34.6	94.28	14.6	58.28
	12 p. m.	33.8	92.84	34.0	93.20	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	15.4	59.72
Aug. 26	1 a. m.	33.8	92.84	34.2	93.56	31.0	93.20	34.0	93.20	33.4	92.12	34.6	94.28	15.6	60.08
	2 a. m.	33.6	92.48	34.0	93.20	34.0	93.20	34.2	93.56	33.0	91.40	34.6	94.28	14.8	58.64
	3 a. m.[5]	33.6	92.48	34.2	93.56	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	17.4	63.32
	4 a. m.[6]	33.6	92.48	34.2	93.56	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	16.2	61.16
	5 a. m.[6]	33.6	92.48	34.0	93.20	34.2	93.56	34.0	93.20	33.2	91.76	34.6	94.28	17.0	62.60
	6 a. m.[6]	33.6	92.48	34.2	93.56	34.2	93.56	34.0	93.20	33.2	91.76	34.6	94.28	16.6	61.88
	7 a. m.[6]	33.6	92.48	34.4	93.92	34.2	93.56	33.6	92.48	33.4	92.12	34.6	94.28	17.0	62.60

[1] Cloudy.
[2] Breeze from north.
[3] Raining a little.
[4] Rain.
[5] High wind from east.
[6] High wind from east, no rain.

Another fact to which reference has been made under the caption, "Effects of cluster heat on the temperature below the frames," should be mentioned here. During this period of storm, *f* frequently recorded a higher temperature than the thermometers above it. This was undoubtedly due to the crowding of the bees in off of the alighting board, forming a curtain below the frames. This is an advantage in helping to conserve the heat and in preventing the cold, inward draft through the entrance from striking directly on the brood.

THE EFFECTS OF TRANSPORTATION ON THE TEMPERATURE OF THE COLONY.

Not infrequently beekeepers sustain heavy losses in moving their bees, although it is not usually done in extremely hot weather. Since the moving of the experimental colony to College Park, Md., a distance of about 11 miles, was unavoidable, the writer decided to make the most of the necessity and determine in so far as possible the effects of transportation on the colony. Even with precautions, strong and populous colonies sometimes smother. Brood is often killed, supposedly from excessive heat. With these points in mind every precaution was taken to protect the colony from harm; and since no damage resulted, the experiment reveals the temperature conditions in a successful transportation of a strong colony under most adverse circumstances—extreme heat and humidity and bad roads.

The trip was commenced at 10.30 a. m. on July 2. The day was humid, with intermittent sunshine and clouds, and no breeze. In Washington the mercury rose to 32.33° C. (90° F.) at 2 o'clock. The road was through the city of Washington over asphalt and stone pavements for several miles and then over rough country roads, which had scarcely any shade. The colony was moved on a spring express wagon with cover, the curtains of which were kept down on the sunny side so as to prevent the sun from striking directly on the hive. The other curtains were rolled up in order to allow all the ventilation possible, but since there was no breeze all the draft which the bees got must have been procured by fanning and by the movement of the wagon.

The colony was crowded into a 10-frame Langstroth hive and the entrance was screened the night previous. All of the thermometers remained in position. This, of course, prevented giving ventilation through the top of the hive, which is the common practice in moving bees. In order to give room for expansion of the cluster and to confine the air as little as possible, the hive was set over an empty body, on the bottom of which wire cloth was tacked. In order to allow the air to circulate freely beneath the hive, it was supported above the bottom of the wagon on $\frac{7}{8}$-inch strips of wood, the spring of which relieved to some extent the jolt of the wagon. In the morning, before the colony was disturbed and just after it was loaded, thermometer readings were taken. On the road readings were also made at short intervals. In this way the result of every successive event in the trip was known.

The first disturbance, carrying the hive downstairs and loading, was immediately responded to by the bees. The first 15 minutes on the road were but slightly more disturbing. Gradually, however, the temperature increased until 1.30 o'clock in the afternoon and an hour previous to releasing, when practically the maximum was reached, 36.0° C. (96.8° F.). It should be mentioned, however, that during the next few hours and even after the bees had their liberty the thermometers in the distant parts of the hive, *a* and *e*, registered 36.2° C. (97.16° F.). But it is probable that the bees clustered more densely at these points than they did in the center of the hive. This temperature can not be considered particularly abnormal, although it is higher than any temperature registered immediately before or after the transportation. On several occasions during the summer and even in May, practically the same degree was reached; but since in normal circumstances it never went higher than 36° C. (96.8° F.), the temperature observed is probably nearly as high as can be reached by bees without damage. It would not have taken many degrees more than this to have softened the combs and to have caused them to sag and break. The melting point of pure wax is 62° to 64° C. (143° to 145° F.), but the difference between the melting point and the point at which combs become soft enough to sag must be considerable, perhaps 20° C. (36° F.).

It can not be said that the temperature was higher at any one part of the hive than at another, unless possibly there was a slight tendency for the brood cluster to be maintained cooler. This would naturally be expected, but under such trying circumstances the phenomenon could not be measured satisfactorily. At no time on the trip did the bees hang down from their combs into the lower body, and upon releasing them there was no evidence of condensation. At all times, as would have been expected, there was considerable fanning. Furthermore, the bees were not made cross by their confinement, as was the case when the rest of the colonies of the apiary were moved, which was done under much more favorable circumstances except for ventilation. That no brood died in the experimental colony is further evidence that 36° C. (96.8° F.) is not abnormal.

The colony was placed in its new position at 2.30 o'clock and the bees liberated. The effects of their liberty on the temperatures were not apparent, however, as will be seen in Table XI, for more than an hour, when the temperatures began gradually to fall. Finally, when the bees had orientated themselves and had commenced to return to the hive, there was a noticeable quieting and a perceptible drop in the mercury. At 7.30 o'clock, after all the bees had returned to the hive, conditions were practically normal.

In conclusion it may be said that the conditions under which the bees were moved, although trying and about as adverse as possibly could be encountered, did not produce abnormal heat in the hive. The temperature increased only 2°, from 34° to 36°+C. (93.2 to 96.8° F.). While it is generally admitted that ventilation from the top is preferable in moving bees, on the hypothesis that warm air rises, ventilation from the bottom was a success in the case under discussion. In moving the rest of the department apiary to College Park earlier in the season, when the weather was more favorable, the day being cloudy with showers, three colonies suffered severely from overheating and condensation. These colonies were screened at the entrance and over the top of the hive; but apparently the screening of the top was not sufficient, because when the bees became excited and expanded as a result of the heat, they packed so tightly against the top screen as to shut out all ventilation. The tendency of bees is upward and toward the light. On the contrary, if ventilation is given from below, there is less tendency for them to pack against the screen. While it is generally maintained that for moving colonies top ventilation is preferable, the present experiment would indicate that bottom ventilation is practical and advantageous.

For comparison, figures taken the day previous (Table X) and the day after the transportation (Table XII), as well as on that day (Table XI), are presented.

TABLE X.—*Readings of thermometers, July 1, on day previous to transportation of bee colony.*

Hour.	Thermometer.											
	a.		*b.*		*c.*		*d*		*e.*		*o.*	
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
9 a. m.	33.4	92.12	34.0	93.20	34.0	93.20	33.8	92.84	33.8	92.84	25.8	78.44
10 a. m.	33.6	92.48	34.0	93.20	34.2	93.56	33.6	92.48	33.6	92.48	27.0	80.60
11 a. m.	33.8	92.84	34.2	93.56	34.2	93.56	33.8	92.84	33.6	92.48	28.5	83.30
12 m.	33.9	93.02	34.5	94.10	34.5	94.10	33.9	93.02	33.9	93.02	29.0	84.20
1 p. m.	34.0	93.20	34.5	94.10	34.5	94.10	34.0	93.20	34.0	93.20	29.8	85.64
2 p. m.	34.4	93.92	34.8	94.64	34.8	94.64	34.0	93.20	34.0	93.20	31.5	88.70
3 p. m.	34.4	93.92	34.8	94.64	34.8	94.64	34.0	93.20	34.0	93.20	31.5	88.70
4 p. m.	34.6	94.28	34.8	94.64	34.8	94.64	34.2	93.56	34.2	93.56	32.2	89.96
8 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	34.8	94.64	35.0	95.00	29.0	84.20

TABLE XI.—*Readings of thermometers during transportation of bees, July 2. Day extremely warm and sultry.*

Hour.	Thermometer.										Observations.
	a		*b*		*c*		*d*		*e*		
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	
9 a. m.	34.4	93.92	34.4	93.92	34.4	93.92	34.0	93.20	34.0	93.20	Hive closed but unmoved.
10.15 a. m.	35.0	95.00	35.0	95.00	35.0	95.00	34.8	94.64	34.8	94.64	Hive loaded on wagon.
10.30 a. m.	35.0	95.00	35.0	95.00	35.0	95.00	34.8	94.64	34.8	94.64	Drive to College Park started.
10.45 a. m.	35.2	95.36	35.0	95.00	35.1	95.18	34.9	94.82	35.0	95.00	
11 a. m.	35.4	95.72	35.2	95.36	35.2	95.36	35.0	95.00	35.0	95.00	
11.15 a. m.	35.4	95.72	35.0	95.00	35.1	95.18	35.0	95.00	35.0	95.00	Sun and clouds.
11.30 a. m.	35.6	96.08	35.2	95.36	35.2	95.36	35.0	95.00	35.0	95.00	Do.
11.45 a. m.	35.8	96.44	35.4	95.72	35.6	96.08	35.1	95.18	35.2	95.36	Do.
12 m.	35.8	96.44	35.6	96.08	35.6	96.08	35.3	95.54	35.4	95.72	Do.
12.15 p. m.	35.8	96.44	35.8	96.44	35.6	96.08	35.4	95.72	35.6	96.08	Do.
12.45 p. m.	35.8	96.44	35.6	96.08	35.6	96.08	35.4	95.72	35.6	96.08	Stopped 30 minutes for lunch.
1 p. m.	35.8	96.44	35.6	96.08	35.6	96.08	35.6	96.08	35.6	96.08	
1.15 p. m.	36.0	96.80	35.8	96.44	35.8	96.44	35.8	96.44	35.8	96.44	
1.30 p. m.	36.0	96.80	36.0	96.80	35.9	96.62	35.8	96.44	36.0	96.80	
2 p. m.	36.0	96.80	36.0	96.80	36.0	96.80	35.9	96.62	36.0	96.80	
2.30 p. m.	36.2	97.16	36.0	96.80	36.0	96.80	36.0	96.80	36.1	96.98	Hive set on stand and opened.
3 p. m.	36.2	97.16	36.0	96.80	36.0	96.80	36.0	96.80	36.2	97.16	
3.30 p. m.	36.2	97.16	35.8	96.44	35.8	96.44	36.0	96.80	36.0	96.80	
4 p. m.	36.1	96.98	35.4	95.72	35.8	96.44	36.0	96.80	36.0	96.80	
4.30 p. m.	35.4	95.72	34.1	93.38	34.8	94.64	35.1	95.18	35.4	95.72	
5 p. m.	35.0	95.00	34.0	93.20	34.6	94.28	34.9	94.82	35.0	95.00	
6.30 p. m.	34.6	94.28	34.2	93.56	34.2	93.56	34.4	93.92	34.4	93.92	Bees all returned to hive.
7 p. m.	34.4	93.92	34.2	93.56	34.2	93.56	34.2	93.56	34.2	93.56	
7.30 p. m.	34.4	93.92	34.0	93.20	34.0	93.20	34.2	93.56	34.2	93.56	Quiet and normal.

TABLE XII.—*Readings of thermometers, July 3. Day after transportation of bees.*

Hour.	Thermometer.										Observations.
	a		*b*		*c*		*d*		*e*		
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	
7.30 a. m.	33.8	92.84	34.0	93.20	34.0	93.20	33.6	92.48	33.0	91.40	
8.30 a. m.	33.8	92.84	33.8	92.84	34.0	93.20	33.4	92.12	33.0	91.40	Cloudy.
10 a. m.	33.8	92.84	34.0	93.20	34.0	93.20	33.4	92.12	33.6	92.48	Breeze.
11 a. m.	34.0	93.20	34.0	93.20	34.0	93.20	33.4	92.12	33.4	92.12	
12 m.	34.0	93.20	34.2	93.56	34.2	93.56	33.6	92.48	33.4	92.12	
7 p. m.	34.8	94.64	34.8	94.64	34.6	94.28	34.2	93.56	34.0	93.20	Bees returned.
8 p. m.	34.8	94.64	34.6	94.28	34.6	94.28	34.0	93.20	34.0	93.20	

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

DIV. INSECTS.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 100

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
August 31, 1914.

(PROFESSIONAL PAPER.)

WALNUT APHIDES IN CALIFORNIA.

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INTRODUCTION.

The study of walnut aphides dealt with in the following pages was begun early in the year 1911 and continued until the summer of 1913. The observations were at first made at San Jose, Cal., but after September, 1912, the work was done chiefly at Walnut Creek, Cal. Practically all the life-history observations were made at the former locality, and much of the control work was done at Walnut Creek. The habits of the aphides do not vary materially throughout California. It was at first the writer's intention to confine his studies to the European walnut aphis (*Chromaphis juglandicola* Kalt.), as this species alone infests walnuts of commercial value grown in California, but latterly two native species of Aphididæ were found to be pests on native walnuts much used for stock on which to graft the European or Persian nut, and thus the studies were extended so as to include all three species. The two native aphides above mentioned are *Monellia caryæ* Monell, the American walnut aphis, which affects the eastern black walnut (*Juglans nigra*) and *Monellia caryella* Fitch, the little hickory aphis,[1] which affects the California black walnut (*Juglans californica*). Both of these species infest the Royal Hybrid walnut (a cross between the eastern black walnut and the California black walnut), while the Paradox Hybrid walnut (a cross between the European walnut and the California black walnut) is attacked by the European walnut aphis and to a lesser extent by the little hickory aphis. Both of these hybrids are rapid growers, and a certain percentage of the seedlings obtained from the crossings makes good stock on which to graft the commercial varieties of nuts. The great majority of European nuts and their varieties are grown in California

[1] This is the name Fitch gave to species which he found on hickory, and it seems best to retain it, although rather an unfortunate title in so far as California is concerned, as the only wild member of the Juglandaceæ in that State is *Juglans californica*.

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on roots of either the California black walnut straight or on roots of one or the other of these two hybrids. When a graft has been made and both stock and scion are putting out leaves simultaneously, more than one species of aphis will usually occur on the same tree. In such a case the two species feed on their own particular host, but the migrant forms of either may be found resting on foliage of the opposite host. The Paradox and Royal hybrids are used in various parts of California as shade trees and will furnish a fine grade of wood, which will take on a high polish.

THE EUROPEAN WALNUT APHIS (Chromaphis juglandicola Kaltenbach).

Lachnus juglandicola Kaltenbach, Monographie der Familien der Pflanzenlause, Aachen, 1843.

Callipterus juglandicola Koch, Die Pflanzenläuse Aphiden, Nürnberg, p. 224, 1857.

Callipterus juglandicola Passerini, Gli Afidi, Parma, 1860.

Callipterus juglandis Walker, The Zoologist, ser. 2, v. 5, p. 2000, Feb., 1870.

Pterocallis juglandicola Buckton, Monograph of the British Aphides, v. 3, London, 1881, p. 32–34.

Callipterus juglandicola Schouteden, Mem. Soc. Ent. Belg., v. 12, p. 209–210.

Chromaphis juglandicola Essig, Mo. Bul. Cal. State Com. Hort., v. 1, no. 5, p. 190–194, figs. 72–73, April, 1912.

In 1870 Walker erected the genus *Chromaphis* and designated *Callipterus juglandicola* Kaltenbach as the type species. Reference to this is made by H. F. Wilson in his paper "A Key to the Genera and Notes on the Synonymy of the Tribe Callipterini, Family Aphididae," Canad. Ent., v. 42, no. 8, p. 253–259, Aug., 1910.

HISTORY OF THE SPECIES.

The species was described originally by J. H. Kaltenbach in his "Monographie der Familien der Pflanzenläuse" as *Lachnus juglandicola*. A somewhat free translation of this description is as follows:

Wingless: Pale yellow, egg-shaped, flat, square, incised, and armed with glandular hairs on the margins; legs whitish-yellow, a black spot on the apex of the hind femora. Length, $\frac{1}{2}''$.

Winged: Yellow; eyes red; antennæ whitish, with black rings; cornicles yellow, hardly noticeable; tail lacking.

This tree louse occurs sporadically in June and July in numbers under the leaves of the walnut tree (*Juglans regia*).

Wingless: Antennæ shorter than the head and thorax combined, not markedly jointed, whitish-yellow. Apex of antennæ black, of third joint ringed black. Eyes light red; beak short, scarcely reaching to the first coxæ. On the dorsum occur two longitudinal rows of black spots, which are absent on younger individuals. Cornicles and tail lacking. Legs hyaline whitish-yellow; a black spot is found on the upper side of the hind femora at their apices.

Winged: Antennæ noticeably shorter than the body, pale, the four major joints black at their apices; third joint distally enlarged; sixth joint with a gradually tapering thin apex. The body is yellow; in many cases the black dorsal spots of the abdomen are absent; in other cases but two to six are present; cornicles scarcely perceptible, yellow; tail not present. Legs pale; the spots on the apex of the hind femora are larger than those of the wingless. In well-colored examples such spots occur on the middle femora and those on the hind femora are enlarged into a ring. The wings are transparent; the stigma yellow, cubitus and the two inner veins brown and markedly stouter at the base, then gradually becoming finer and paler; veins of lower wing and wing margin pale yellow; stigmatic or fourth vein very fine and strongly curved.

There is no doubt that Kaltenbach's species is the same that occurs commonly all over California on the European walnut. The black femoral spot, together with the antennæ as described, establishes its identity. Kaltenbach's wingless form appears to be the oviparous female in her penultimate molt, for the true apterous viviparous female—a common form in the majority of plant lice—does not exist, or, if it does, is extremely rare, the author in two years of close observation having failed to observe it. Buckton (1872)[1] gives a description of the apterous viviparous form, but he also seems to have had before him the immature oviparous form.

The insect probably occurs wherever the European walnut is grown. It has been reported from all over Europe, as well as from the States of Colorado (Gillette, 1910), Oregon (Wilson and Lovett, 1911–12), and California (Essig, 1909).

GENERAL DESCRIPTION; CHARACTER AND EXTENT OF INJURY.

This aphidid is a small, lemon-yellow insect, about one-sixteenth of an inch in length. It occurs sporadically on the underside of the leaves and on the young fruit of the European walnut (*Juglans regia*) and its cultivated forms and hybrids. It appears on the upper surface of the leaf only at times of very severe infestation. It is to be found from late February or early March until December, persisting as long as the leaves remain on the tree, but is present in greatest numbers during the months of July and August. As many as 200 individuals may occur on a single large leaflet if infestation be severe, while the author has observed over 30 aphides on a single young nut. Nuts badly infested while young never attain their normal size. Many of them mature half-sized, covered on the upper surface with the black sooty fungus which thrives on the sticky exudations of the aphides. Attacks on the tree year by year also materially reduce its vitality, since the aphides will be present in the spring even before the leaves have opened and will remain until these drop.

Plate I, figure 1, shows the difference in size between infested and uninfested nuts of one variety of European walnut, while Plate I, figure 2, demonstrates the appearance of the sooty fungus on a walnut leaf.

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[1] Dates in parentheses refer to the Bibliography, p. 47.

LIFE HISTORY AND TECHNICAL DESCRIPTIONS.

The Viviparous or Asexual Forms.

When the young stem-mother is ready to emerge in the spring she causes the shell of the winter egg to burst with a longitudinal slit on the dorsal surface from the micropylar end. (See fig. 1.) Egress is performed head first, and antennæ and legs are requisitioned by the young larva in worming its way out of the shell. While the process of emerging, which occupies half an hour or more, is taking place, the aphis assumes an erect position at right angles to the long axis of the egg. After the exit of the young the eggshell has a large triangular hole at the micropylar end.

As soon as the buds begin to swell in early spring these stem-mothers hatch and continue hatching until the leaves have fully opened out, at which time all will have issued from the egg. The earliest plant-lice to emerge may be seen wandering over the bare twigs and buds, apparently feeding a little upon the scales protecting the unopened buds, but not showing much growth until the buds have opened and can afford nourishment.

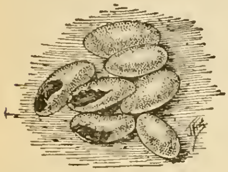


Fig. 1.—*Chromaphis juglandicola:* Group of eggs, three lowest hatched. Twenty times natural size. (Original.)

Undoubtedly many of the aphides that hatch early die of ill nourishment, and some of these do not attain their full development for six or seven weeks, while those hatching later and finding tender food in abundance become full grown at the end of five weeks. Certain it is that on a particular tree the stem-mothers all became winged almost simultaneously. On trees which leaf early the stem-mothers will begin emerging from the egg as early as February 15, but on the Franquette and such late varieties no aphides will be found until in April. Immediately after hatching the lice seek the buds or young leaves. In the former case the aphides crawl in between the scales, but on the leaves they appear on the lower or exposed side, notwithstanding the fact that much better protection is afforded by the upper, as yet unfolded, surface which at that time is almost entirely hidden from view. Possibly the sticky character of the upper surface of the leaves repels them. Table I indicates the life cycle of four stem-mothers which hatched after the buds had opened.

Table I.—*Period of development of the stem-mother of Chromaphis juglandicola, San Jose, Cal., 1912.*

No. of individual.	Date of hatching.	Date of acquiring wings.	Period from hatching to maturity.
			Days.
1	Mar. 24	Apr. 28	35
2	24	28	35
3	24	28	35
4	24	29	36
Average period			35.25

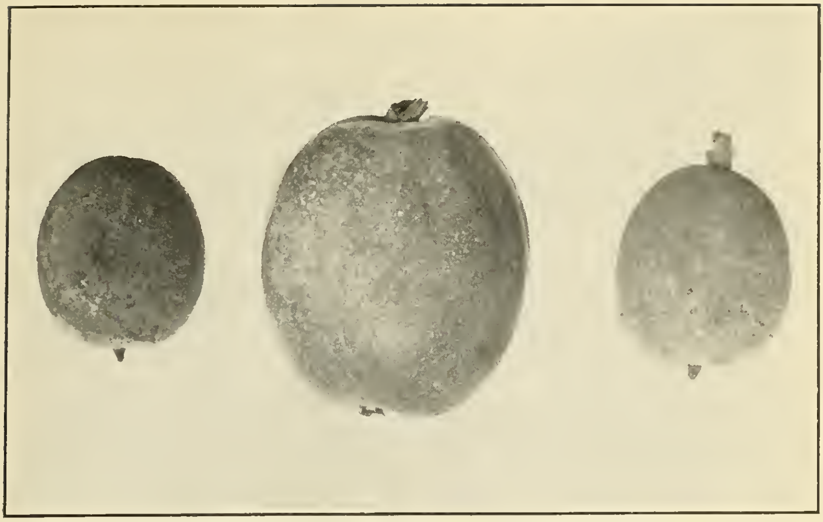


FIG. 1.—THREE MATURED NUTS OF EUROPEAN WALNUT SEEDLING.

[Middle nut natural size, other two undersized from attack by aphides.]

FIG. 2.—UPPER SIDE OF THREE LEAFLETS OF EUROPEAN WALNUT SEEDLING.

[The central leaflet shows growth of fungus thriving upon the exudation of aphides above. Two-thirds natural size.]

THE STEM-MOTHER; NEWLY HATCHED YOUNG (FIG. 2).

Oval, lemon yellow. Eyes red, of moderate size. Antennæ 3-jointed, not quite reaching to base of second coxæ; joint III nearly three times as long as joints I and II together. Legs comparatively long, entirely pale. Body covered with capitate hairs. Cornicles very small, pale whitish-yellow, hardly raised above the surface of the body. Cauda small, pale, bluntly conical. Beak entirely pale, reaching second coxæ. Black knee spots characteristic of this species absent. Measurements: Length of body, 0.72 mm.; width, 0.30 mm.; antenna, joint I, 0.04 mm.; joint II, 0.035 mm.; joint III, 0.145 mm. Almost immediately after birth the legs and antennæ turn dusky gray and the dark abdominal spots appear. In this respect the young of the stem-mothers differ from those of all other generations, for the appendages of the young aphides of subsequent broods never turn entirely dusky nor do the abdominal spots appear so early.

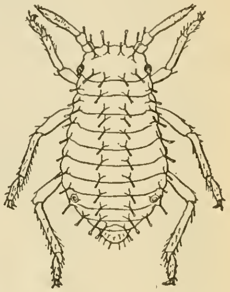


FIG. 2.—*Chromaphis juglandicola:* Stem-mother, newly hatched. (Original.)

THE STEM-MOTHER; 4 DAYS OLD.

Yellowish-green, flatly oval, closely appressed to the surface of the leaflet or bud scale. Antennæ and legs dusky gray. Eyes circular, red, small. Head, thorax, two proximal antennal joints, and abdomen bearing capitate hairs which arise (those of the antennæ excepted) from small tubercules situated in the middle of a small, circular, dusky area. Antennæ 3-jointed, the distal joint the largest. Cornicles very small, erect. Cauda almost as long as the hind tarsus, its apex blunt. Cornicles and cauda concolorous with the abdomen. Beak very pale, reaching second coxæ, its extreme apex brown. Underside of the head very pale yellow; of the abdomen greenish-yellow.

THE STEM-MOTHER; AFTER FIRST MOLT AND JUST PREVIOUS TO SECOND MOLT.

Pale lemon-yellow or yellowish green, flatly oval, closely appressed to the plant surface, occurring on the underside of the expanding leaves, between the ribs. Antennæ and legs very pale yellow, almost hyaline. Antennæ short, reaching slightly beyond the posterior margin of the prothorax, 3-jointed, with a rudimentary suture on the distal half of joint III. This joint is about three times as long as the two proximal joints together. Eyes crimson, not fully developed. Legs entirely pale, without any trace of dark knee spots. Thorax and segments 1 to 6 of the abdomen with two longitudinal rows of black or brown spots, on each of which occurs a small pale tubercle bearing two capitate hairs, one larger than the other. On the thoracic segments and on abdominal segments 1 to 7 occur two rows of pale lateral tubercles, each of which bears three capitate hairs. The frontal margin of the head bears six such hairs on tubercles. Antennal joints I and II with a capitate hair on their inner margins near the middle, and joint III with one such hair on the inner margin near the base. The eighth abdominal segment bears a dorsal fringe of six capitate hairs, those on either end being smaller than the four inner ones. Cornicles situated on segment 6, as broad as long, erect, concolorous with the abdomen. Cauda without armature, bluntly conical, almost hyaline, about as long as the hind tarsus. Beak barely reaching second coxæ, pale yellow, the extreme tip brown. Measurements: Length of body, 1.55 mm.; width, 0.775 mm.; antenna, joint I, 0. 053 mm.; joint II, 0.048 mm.; joint III, 0.304 mm.

Described from specimens collected at San Jose, Cal., March 28, 1912.

After the second molt the spines on the dorsum of the body disappear. (See fig. 3.)

The pupal and imaginal stages of the stem-mother show no apparent difference in respect to size, color, or structure from those of the later viviparous generations, and thus one description of these forms will suffice for all the winged viviparous generations.

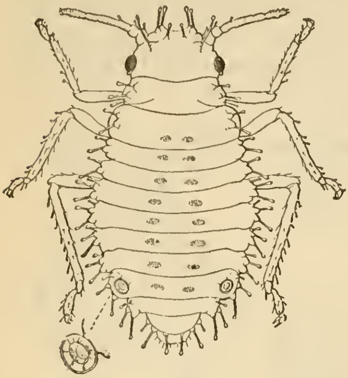


FIG. 3.—*Chromaphis juglandicola:* Larva of stem-mother after second molt. (Original.)

THE PUPA OF THE WINGED VIVIPAROUS FEMALE (FIG. 4).

General color pale lemon-yellow. Eyes red, fully formed. Antennæ reaching a little beyond the base of the wing-pads, pale, joint III the longest, joints IV and V subequal. Ocelli present. Anterior margin of the head bearing six capitate spines. Thoracic segments pale yellow. Wing-pads pale yellow, closely appressed to the sides of the body. Legs pale yellow, with the dark knee spot on the hind femora only; tarsi dusky. Abdomen oval, pale lemon-yellow, with a varying number of dark spots on the dorsum, which spots are always present on segment 5 but often lacking on the other segments. Head, thorax, and abdomen furnished with lateral rows of capitate hairs which stand on small pale tubercles. Cornicles small, as wide as long, slightly constricted in the middle, situated on the sixth abdominal segment. Cauda short, about as long as the cornicles, bluntly rounded at the apex. Cornicles and cauda concolorous with the body. Beak short, pale, stout, reaching to the first pair of coxæ. The pupa has the legs relatively a little shorter than those of the adult and is thus more closely appressed to the leaf surface. The body is quite flat. Measurements: Length of body, 1.87 mm. (average); width, 0.85 mm. (average maximum); antenna, joint I, 0.050 mm.; joint II, 0.042 mm.; joint III, 0.183 mm.; joint IV, 0.081 mm.; joint V, 0.076 mm.; joint VI, 0.065 mm.; filament, 0.034 mm. Cornicles, 0.04 mm.

The stem-mothers pass through the pupal molt about one week before the final molt takes place, and after the latter they acquire their full development as winged adults. In the latter generations the pupal instar occupies from three to six days.

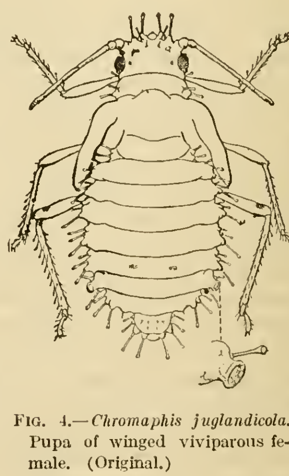


FIG. 4.—*Chromaphis juglandicola:* Pupa of winged viviparous female. (Original.)

THE WINGED VIVIPAROUS FEMALE (FIG. 5).

General color pale lemon-yellow; many individuals are darker yellow, yellowish-brown, or salmon-pink. Antennæ on very small frontal tubercles, about one-half the length of the body, yellow, with the inner lateral margins of the first two joints dusky; articulations of joints III to VI and the whole filament dusky to black. Eyes red. Ocelli present. Prothorax yellow. Thoracic lobes and scutellum light brown, sometimes greenish-yellow, pale yellow in newly-molted individuals. Wings of medium size; subcosta and wing insertions pale yellow; stigma pale gray, with a darker area at the confluence of the third discoidal vein, and another such though smaller area at the apex; veins rather heavy, dark brown, all three discoidals arising from the subcosta and thickened at their bases; second branch of third discoidal nearer the wing apex than the first fork; third discoidal describing a regular gentle curve for its entire length; stigmatic vein entire, the depth of its curve varying in different examples, generally reaching the wing margin midway between the apex of the stigma and the the end of the third discoidal (often it touches the margin considerably nearer the stigma, but rarely nearer the third discoidal). Legs rather short, but a little longer than those of the pupa; front pair yellow with the tarsi and apical third of the tibiæ dusky

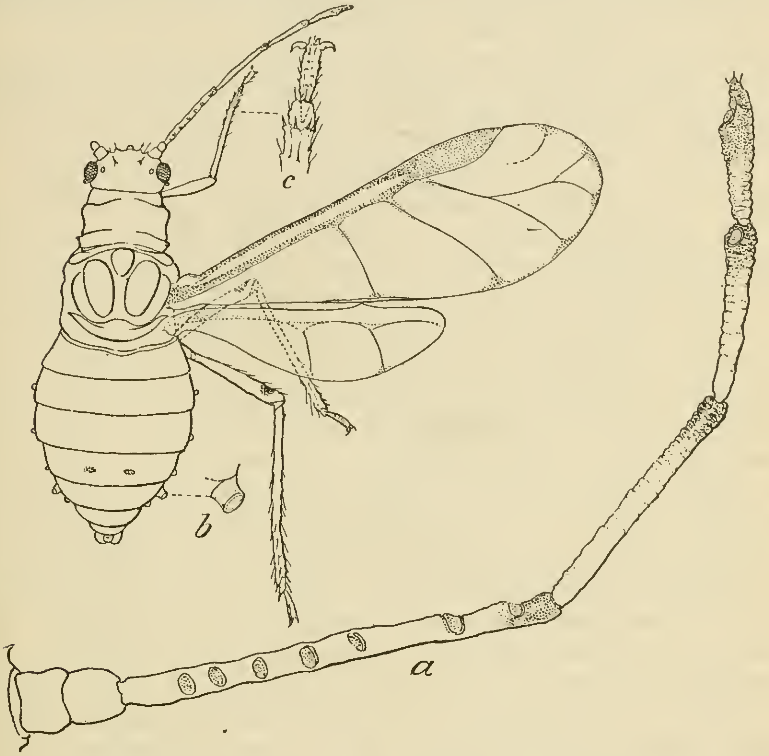


FIG. 5.—*Chromaphis juglandicola:* Winged viviparous female (appendages of left side removed). *a*, Left antenna; *b*, right cornicle; *c*, front tarsus. (Original.)

gray and the knee spot rarely present (gray when present); middle pair yellow, with an indefinite gray spot on the upper side of the femur above the knee and with the tarsi dusky gray; hind pair yellow, with a coal-black spot (sometimes produced into an annulation) on the upper side of the femur above the knee joint and with the tarsi dusky gray as in the other pairs. The knee spots are always present on the hind femora, while they occur in about 80 per cent of individuals on the middle femora. In 35 individuals examined throughout the year all had the spots on the hind femora, 28 had spots on the middle femora, and only 1 had spots on the fore femora. Abdomen pale lemon-yellow, widest at segment 3, considerably wider than the thorax, generally bearing two oval brown spots on segment 5 and more rarely with two similar but smaller spots on segment 4; occasionally immaculate. These spots are sometimes grayish, varying in intensity, and appear to be the pupal markings retained in the adult form.

Cornicles (fig. 5, *b*) pale yellow, constricted in the middle, barely as long as broad. Abdominal segments 3 to 6 inclusive bearing pale lateral tubercles. Body without hairs. Cauda very pale, globular, about as long as the cornicles. Beak pale yellow, the extreme tip black, reaching a little beyond the first coxæ. Sternum pale brown. Measurements: Length of body, 1.62–2.55 mm., average 2.08 mm.; width of body at segment 3 of abdomen, 0.71–1.06 mm., average 0.88 mm.; wing expanse, 4.42–5.21 mm., average 4.77 mm.; antenna, joint I, 0.046–0.067 mm., average 0.055 mm.; joint II, 0.039–0.055 mm., average 0.043 mm.; joint III, 0.267–0.408 mm., average 0.337 mm.; joint IV, 0.153–0.233 mm., average 0.196.mm.; joint V, 0.133–0.191 mm., average 0.162 mm.; joint VI, 0.079–0.094 mm., average 0.083 mm.; antennal filament, 0.038–0.043 mm., average 0.040 mm.; total length of antenna, 0.775–1.060 mm., average 0.916 mm.; cornicles, 0.05 mm.; cauda, 0.056 mm.

There are from 6 to 8 transverse oval sensoria on antennal joint III, 1 terminal sensorium on joint V, and three terminal ones on joint VI. Buckton's measurements (Buckton, 1872) seem to have been taken from small examples for, with the exception of those of the antennal joints, his measurements are all smaller than the average found by the writer. It may be that California examples are larger than the European.

Within a few hours after the last molt the wings harden and the chitin stiffens. The stem-mothers then begin to deposit the young that have been visible as pseudova for a week or longer inside their bodies. In the life-history experiments the greatest number of young produced by one viviparous female was 44. These were extruded from the body in 20 days, 30 in the first half and 14 in the last half of that period. Several adults under observation deposited 11 or 12 young within 12 hours after reaching maturity, and no more after that, dying with many unborn pseudova in their bodies. In the field the aphides deposit all their young on one leaf or on several leaves near one another. The average number of young deposited by a single adult ranges between 25 and 35. This seems to be about the same as in other closely related Callipterini, but is a much smaller number than that occurring in members of other tribes of Aphididæ. The aphides of the fall viviparous generation produce fewer young, those which develop in November depositing only 6 or 8. As many as 30 oval unborn aphides may be seen in the body of one recently molted female. These embryos vary in size, only those to be deposited immediately being fully grown. Each is inclosed in a very thin hyaline sac in which they are contained at birth.

The newly deposited young of the second and subsequent generations, both viviparous and oviparous, differ from the infant stem-mothers in that they are entirely pale yellow (rarely suffused with a faint pink) and remain thus until the first molt, while the young stem-mothers have dusky appendages and abdominal spots. The young deposited by the stem-mothers pass through their first molt in from three to six days. After this molt there appear brown or black dorsal spots in the majority of the individuals, and these markings persist through the succeeding molts. A small percentage of examples remain immaculate throughout development. The "lice" of the second generation develop more quickly than the stem-mothers or first generation, owing to greater abundance of food supply and to the higher temperature existing at that later period. In 1911 second-generation young were deposited in the field on early varieties of walnuts a little before April 23, while in the following year these were deposited as early as April 6. This is to be expected, since in 1912 the trees came out in leaf two weeks earlier than in the previous year. Table II shows the life cycle of 41 individuals of the second generation at San Jose, Cal., in 1911.

TABLE II.—*Life cycle of the second generation of Chromaphis juglandicola, San Jose, Cal., 1911.*

No. of individual.	Date of—		Life cycle.	No. of individual.	Date of—		Life cycle.
	Deposition.	Acquiring wings.			Deposition.	Acquiring wings.	
			Days.				*Days.*
1	Apr. 23	May 12	19	22	May 2	May 22	20
2	23	12	19	23	2	22	20
3	23	14	21	24	3	22	19
4	23	16	23	25	3	22	19
5	23	18	25	26	3	22	19
6	24	18	24	27	3	22	19
7	24	18	24	28	3	22	19
8	24	18	24	29	4	23	19
9	24	18	24	30	4	23	19
10	24	18	24	31	5	25	20
11	25	20	25	32	5	25	20
12	26	21	25	33	5	25	20
13	May 1	21	20	34	6	26	20
14	1	21	20	35	6	26	20
15	1	21	20	36	6	27	21
16	1	21	20	37	6	27	21
17	1	21	20	38	6	27	21
18	2	21	19	39	7	27	20
19	2	21	19	40	8	28	20
20	2	22	20	41	9	27	18
21	2	22	20				

Life cycle:	Days.
Maximum	25
Minimum	18
Average	20.7

The aphides of the third generation appear on the earliest varieties of walnuts about the middle of May, but on the late varieties such as the Franquette this brood appears as much as a month later. The individuals of this generation are on the average slightly larger than those of other generations. In a large series of adult viviparous females taken throughout the year of 1911 the largest example was of the third generation. Its body was 2.55 mm. in length and 1.06 mm. in width, and both of its antennæ measured 1.06 mm., or 0.02 mm. in excess of the next longest antenna in the series. Table III indicates the life cycle of 97 individuals of the third generation.

TABLE III.—*Life cycle of the third generation of Chromaphis juglandicola, San Jose, Cal., 1911.*

No. of individual.	Date of—		Life cycle.	No. of individual.	Date of—		Life cycle.
	Deposition.	Acquiring wings.			Deposition.	Acquiring wings.	
			Days.				*Days.*
1	May 19	June 4	16	50	May 19	June 7	19
2	19	4	16	51	19	7	19
3	19	4	16	52	19	7	19
4	19	4	16	53	19	7	19
5	19	5	17	54	19	7	19
6	19	5	17	55	19	7	19
7	19	5	17	56	19	7	19
8	19	5	17	57	19	8	20
9	19	5	17	58	19	8	20
10	19	5	17	59	19	8	20
11	19	5	17	60	19	8	20
12	19	5	17	61	19	8	20
13	19	5	17	62	19	8	20
14	19	5	17	63	19	8	20
15	19	5	17	64	19	8	20
16	19	5	17	65	19	9	21
17	19	5	17	66	19	9	21
18	19	6	18	67	22	10	19
19	19	6	18	68	22	11	20
20	19	6	18	69	22	11	20
21	19	6	18	70	22	11	20
22	19	6	18	71	22	11	20
23	19	6	18	72	22	11	20
24	19	6	18	73	22	11	20
25	19	6	18	74	22	11	20
26	19	6	18	75	22	11	20
27	19	6	18	76	22	11	20
28	19	6	18	77	22	11	20
29	19	6	18	78	22	11	20
30	19	6	18	79	22	11	20
31	19	6	18	80	22	11	20
32	19	6	18	81	22	11	20
33	19	6	18	82	22	11	20
34	19	6	18	83	22	11	20
35	19	6	18	84	22	12	21
36	19	6	18	85	22	12	21
37	19	6	18	86	22	12	21
38	19	6	18	87	22	12	21
39	19	6	18	88	22	12	21
40	19	6	18	89	22	12	21
41	19	6	18	90	22	13	22
42	19	6	18	91	22	13	22
43	19	7	19	92	22	13	22
44	19	7	19	93	22	14	23
45	19	7	19	94	22	14	23
46	19	7	19	95	22	14	23
47	19	7	19	96	22	15	24
48	19	7	19	97	22	15	24
49	19	7	19				

Life cycle:	Days.
Maximum	24
Minimum	16
Average	19.1

Generations IV to VIII inclusive occupy roughly 16 days apiece for development, and this period is the average life cycle during the summer months. Some aphides will develop in 14 days and others in 19 or 20. Table IV gives the life-cycle records of these five generations and also that of the ninth. The records in some instances are small, but the fact that in the first five of these generations there is practically no difference in the duration of the life cycle was corroborated by a larger series of experiments during the summer months with individuals of which the respective generations were unknown.

TABLE IV.—*Life cycle of the summer generations of Chromaphis juglandicola, San Jose, Cal., 1911.*

Generation No.	No. individual.	Date of— Deposition.	Date of— Reaching adult state.	Life cycle.	Form of individual.
				Days.	
	1	June 8	June 28	20	Viviparous.
	2	16	July 1	15	Do.
	3	16	1	15	Do.
IV	4	16	1	15	Do.
	5	16	2	16	Do.
	6	16	2	16	Do.
	7	16	2	16	Do.
	1	July 1	15	14	Do.
V	2	1	15	14	Do.
	3	1	17	16	Do.
	4	1	18	17	Do.
	1	15	31	16	Do.
	2	15	31	16	Do.
	3	15	31	16	Do.
	4	15	31	16	Do.
	5	15	31	16	Do.
	6	15	31	16	Do.
	7	15	31	16	Do.
	8	16	Aug. 1	16	Do.
	9	16	1	16	Do.
	10	16	1	16	Do.
VI	11	16	2	17	Do.
	12	16	2	17	Do.
	13	16	2	17	Do.
	14	16	2	17	Do.
	15	17	2	16	Do.
	16	17	2	16	Do.
	17	17	2	16	Do.
	18	17	3	17	Do.
	19	17	4	18	Do.
	20	18	5	18	Do.
	21	18	6	19	Do.
	22	18	6	19	Do.
	1	Aug. 2	17	15	Do.
	2	2	17	15	Do.
VII	3	2	17	15	Do.
	4	2	19	17	Do.
	5	3	20	17	Do.
	6	3	20	17	Do.
	7	3	20	17	Do.
	1	18	Sept. 1	14	Do.
	2	19	2	14	Oviparous.
	3	19	2	14	Do.
	4	19	3	15	Do.
	5	19	3	15	Do.
	6	19	3	15	Do.
	7	19	3	15	Do.
	8	19	3	15	Do.
VIII	9	19	3	15	Do.
	10	20	4	15	Do.
	11	20	4	15	Do.
	12	20	4	15	Do.
	13	20	6	17	Viviparous.
	14	20	6	17	Oviparous.
	15	20	6	17	Do.
	16	20	7	18	Viviparous.
	1	Sept. 5	30	25	Oviparous.
	2	5	Oct. 1	26	Do.
	3	5	6	31	Viviparous.
	4	5	6	31	Do.
	5	5	8	33	Do.
	6	5	8	33	Do.
	7	7	9	32	Do.
IX	8	7	11	34	Do.
	9	7	13	36	Do.
	10	7	14	37	Do.
	11	7	14	37	Do.
	12	8	12	34	Do.
	13	8	17	39	Do.
	14	8	17	39	Do.

An inspection of Table IV shows that the length of the life cycle of Generations IV to VII was almost the same. This is to be expected, since in 1911 the months of June, July, and August had almost identical temperatures both day and night. It will also be observed that there was a very noticeable difference between the life-cycle periods of Generations VIII and IX, 16 individuals of the eighth generation averaging 15.4 days and 14 individuals of the ninth generation averaging 33.4 days. The ninth generation thus required for development a period over twice as long as that required by the preceding generation, developing almost as slowly as the stem mother generation (see Table I). Yet the temperature during the daytime influencing the ninth generation differed but little from those which obtained during the development of the eighth. The probable causes of the slow development of the ninth generation lice is to be found in the colder night temperatures to which they were subjected and in the fact that the leaves at this time are becoming less vigorous and consequently afford poorer nourishment for the aphides than earlier in the season. There is a tenth generation, and in warm early seasons probably an eleventh, but in these generations the brood is small and the "lice" grow slowly. Plant lice may be found in early December giving birth to young, which are destined to perish either when the leaves drop or through exposure to hard frost. The author has observed dead aphides of all sizes on the brown frosted leaves during early winter.

All the plant lice used for the life-history experiments were reared out of doors on young seedling walnut trees planted in pots and inclosed with glass cylinders. In 1911 the stock was procured from stem mothers collected on the earliest varieties of walnuts. When the work was started in 1911 it was too late to procure eggs, and so the data on the stem-mother cycle was acquired in 1912.

After the ninth generation no more life-history experiments were carried on in the rearing cages, but a weekly examination was made of infested leaves in the field to determine the proportions of the different forms, sexual and asexual, during the fall months.

THE OVIPAROUS OR SEXUAL FORMS.

The oviparous forms are the true sexes, comprising the winged male and the wingless oviparous, or egg-producing, female. The female aphis, after fertilization by the male, deposits true eggs, in which form alone the insect can tide over the winter months when no food supply is procurable.

As is shown in Table IV, there is no real oviparous generation, for in all the later or fall generations a certain percentage of the young will develop either into the sexed males or the sexed females. On heavily infested trees oviparous aphides appear as early in the season as July, while on trees attacked by few lice these forms will not occur until September or October. It therefore seems that the more heavily a tree is infested the earlier will the sexed forms be produced.

A glance at Table IV demonstrates that the first oviparous form of the life-cycle material became adult September 2, and was a member of the eighth generation. In the field the first oviparous form was observed in 1911 on July 7, and in 1912 on July 9. Both of these occurred on early-leafing trees and probably belonged to the fifth or sixth generation. As the growth of the aphis colony may be said to have reached its zenith about the middle of July, it is at the time of its greatest abundance that the sexed individuals begin to appear. And, indeed, for the welfare of the species they appear none too soon, for it is in July and August that the hordes of natural enemies work tremendous havoc, frequently cleaning up a bad infestation on a tree within three weeks. Those sexual females that have gone to the trunk and limbs to deposit their eggs very often escape destruction while the others remaining on the foliage are devoured. Until the middle of August the sexual forms are comparatively rare and comprise less than 5 per cent of the whole, but after that time they become more and more abundant. The sexed females always greatly outnumber the males. Table V indicates the advance and decline of the sexual forms in the late summer and fall. The data were obtained by weekly visits to badly infested trees, during which the lice on a certain number (50) of leaflets picked out at random were counted. It must be borne in mind that as the fall advances more and more sexual females repair to the limbs for the purpose of depositing their eggs, and that therefore in the case of the later counts a really greater proportion of these were present on the trees than would appear from the records.

TABLE V.—*Comparative numbers of sexual and asexual forms of Chromaphis juglandicola observed on the foliage at different dates, San Jose, Cal., 1911.*

Date of collection.	Number of—			Percentage of—
	Viviparous forms.	Oviparous forms.	Males.	Viviparous forms.
September 15	241	247	4	49
23	258	355	5	42
30	203	143	6	58
October 7	171	66	9	70
14	166	74	14	65
24	207	117	9	62
November 2	172	111	4	60
9	420	80	11	82
16	233	36	7	84
23	10	0	0	100
Total	2,081	1,229	69	
Average				61.6

The maximum number of aphides found on a single leaflet throughout the counts was 90, of which 64 were sexual females. This occurred on the first date of collection.

It will be noticed from Table V that on the first two dates the oviparous forms were predominant but that on all later dates these were outnumbered by the viviparous individuals. On the date of the fourth collection (October 7) numerous sexual females were found on the limbs of the tree, and their number was more and more augmented each succeeding week. About October 1 the males appeared in numbers, very few of them having been in evidence previous to this time, although the first male of the season was noticed July 10. Table VI indicates the preponderance in numbers of the sexual female over the male.

TABLE VI.—*Preponderance of the sexual female of Chromaphis juglandicola over the male.*

Date of collection or count.	Number of sexual females to each male.	Date of collection or count.	Number of sexual females to each male.
September 15	62	October 24	13
23	71	November 2	28
30	24	9	7
October 7	7.3	16	5
14	5.3	23	[1]

[1] None of either sex seen on leaves.

Table VI was compiled from the same material as that used for Table V. On November 9 nearly all the sexual females were clustered on the limbs, and two weeks later they and all other plant lice at the experimental trees succumbed to a severe frost, which had at the same time withered all the leaves. This clustering of the sexual females or sexuparæ about the limbs explains the small percentage of this form as compared with the males on November 9 and 16.

Copulation seems to occur only on the leaf, and the females are not fertilized until they have passed through the last molt. A single male may fertilize several females—probably quite a large number when it is considered that the latter sex so greatly outnumbers the former and that very few eggs prove infertile. Copulation in all instances observed by the writer occupied some 30 seconds of time—a very short period for an aphis. If the male be disturbed, he will immediately retract his genital organ and move off. In 1912 the males appeared in comparative abundance in the vicinity of San Jose as early as August 26.

In general appearance the adult oviparous female differs from the viviparous form in that it is wingless, has a wider body, and bears three conspicuous transverse brown or black bands on the dorsum of the abdomen. The male is greenish-yellow, winged, with black or dusky gray legs and antennæ. The oviparous or sexual female molts four times but does not differ in appearance from the viviparous form until the third molt is passed.

THE OVIPAROUS FEMALE, AFTER THE THIRD MOLT (FIG. 6).

Rather smaller and narrower than the full-grown form. General color pale gamboge-yellow, sometimes lemon yellow. Body twice as long as wide. Eyes bright red. Head with six erect, capitate spines on the anterior margin. Antennæ short, reaching barely to the middle of the mesothorax; 7-jointed, joint III the longest, joints IV and V subequal, joint VI longer than its spur or filament. Spur dusky, rest of antennæ pale lemon yellow. Head, thorax, and abdomen with two longitudinal rows of oval black spots on the dorsum. Thorax and abdominal segments 1–5 with two lateral longitudinal rows of circular black spots, on which are situated small tubercles bearing capitate hairs. Such tubercles also occur on the black dorsal spots. Eighth segment of the abdomen unmarked, bearing on its posterior margin a fringe of six capitate hairs. Legs pale greenish-yellow with the characteristic knee spot on the hind femora only; tarsi gray. Cornicles on the sixth segment, quite small, wider than long, pale lemon-yellow. Cauda equal in length to the hind tarsus, pale yellow, rounded. Beak very pale, almost white, reaching to the anterior coxæ. Measurements: Length of body, 1.51 mm.; width of body, 0.76 mm.; antennæ, joint I, 0.063 mm.; joint II, 0.048 mm.; joint III, 0.136 mm.; joint IV, 0.083 mm.; joint V, 0.085 mm.; joint VI, 0.086 mm.; filament, 0.021 mm.

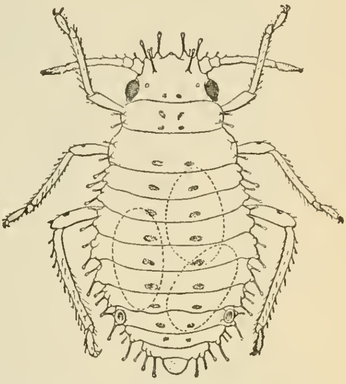


FIG. 6.—*Chromaphis juglandicola:* Oviparous female, penultimate instar. (Original.)

Described from specimens collected at Walnut Creek, Cal., and San Jose, Cal., October 16 to 26, 1912.

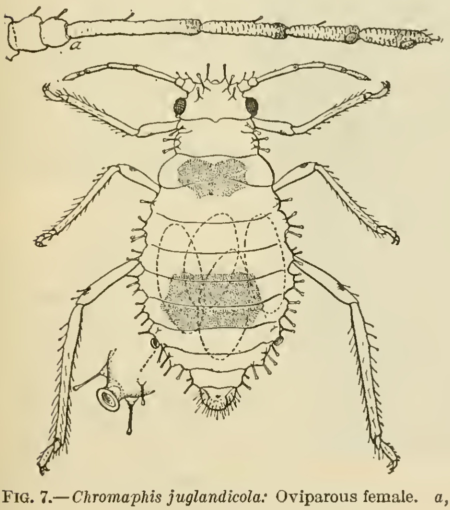


FIG. 7.—*Chromaphis juglandicola:* Oviparous female. *a*, Right antenna. (Original.)

THE OVIPAROUS FEMALE, ADULT STAGE (FIG. 7).

General color gamboge, varying in newly molted examples to lemon yellow and in older individuals to salmon pink or with a distinct brownish tint. Eyes crimson. Head and prothorax with indefinite dusky brown markings. Ocular tubercles small. Anterior margin of the head with six capitate hairs projecting forward. Thorax mottled all over with shades of brown, its lateral margins lighter. Prothorax with two capitate hairs on either side of its posterior portion. Abdomen with two or three hairs on the lateral margins of each segment. Segments 4 and 5 and posterior half of 3 with dark brown or black markings which generally coalesce to form three transverse bars or bands, of which those on segments 4 and 5 do not quite reach the lateral margins of the segments, while that on the third segment is slightly shorter and but half as broad as the others. Wings absent. Cornicles quite similar to those of the winged viviparous female. Cauda globular, concolorous with the abdomen, larger than that of the winged viviparous female. Anal plate large, U-shaped, extending beyond the cauda when viewed from above. In reality it has a shallow incision at the apex. Antennæ on slight frontal tubercles, reaching to the middle of the metathoracic segment, white, with the apices of joints 3 to 6 black. Legs very pale yellow, almost hyaline; tarsi dusky gray at their apices. All six femora have the characteristic black or brown knee spot. Beak yellow, the extreme tip black, reaching to the second coxæ. Hind tibiæ not much swollen, bearing about 35 circular sensoria occurring evenly on the middle two-thirds of the tibia and arranged in an irregular spiral. Measurements: Length of body, 1.60 mm.; width of body, 0.81 mm.; antenna, joint I, 0.06 mm.; joint II, 0.04 mm.; joint III, 0.22 mm.; joint IV, 0.125 mm.; joint V, 0.109 mm.; joint VI, 0.081 mm.; filament, 0.023 mm. Cornicles, 0.06 mm. Cauda, 0.085 mm.

Described from specimens collected in the fall of 1911 at San Jose, Cal.

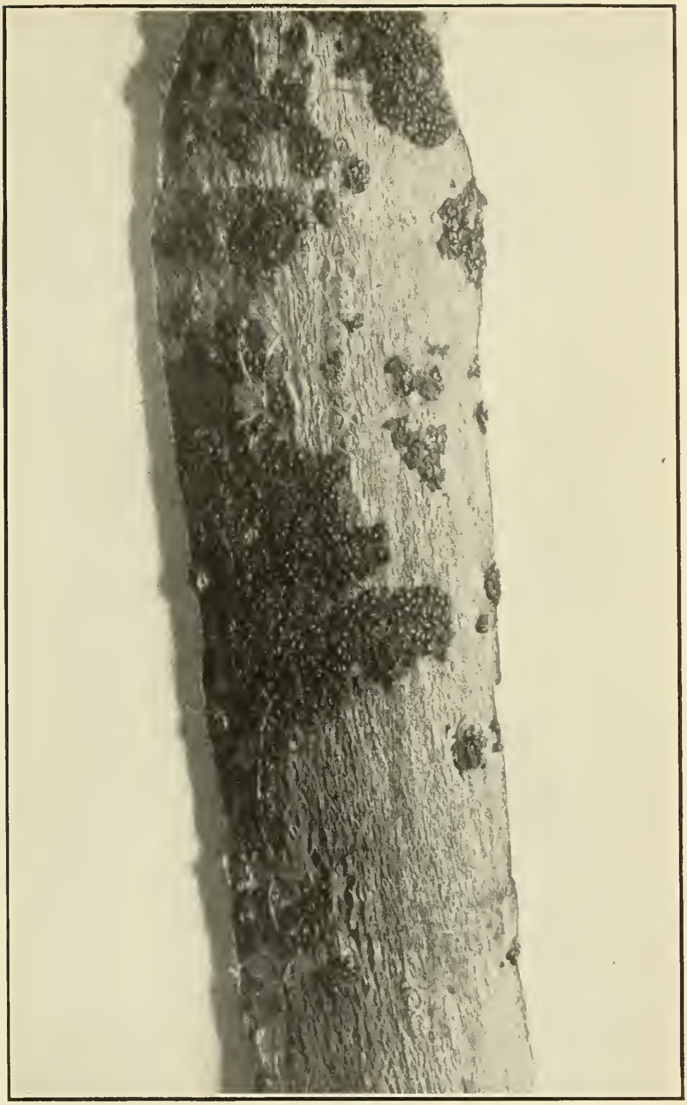
THE FULL-GROWN MALE PUPA.

In its immature stages the male pupa resembles the oviparous female. A description of a single full-grown male pupa taken at San Jose, Cal., October 27, 1912, is as follows:

General color pale lemon yellow. Antennæ pale, whitish, reaching to the anterior margin of the metathorax; last three joints black or dusky. Head and prothorax brownish. Eyes bright red. Wing pads very pale. Legs entirely whitish, only the hind femora bearing the characteristic knee spot; tarsi dusky gray. Cornicles as broad as long. Cauda very small, rounded. Cornicles and cauda pale yellow. Head, thorax, and abdomen with two longitudinal dorsal rows of oval black spots and with two such lateral rows of circular black spots. On each of these spots is situated a tubercle having a single capitate hair. Excluding the wing pads the body resembles that of the immature sexual female. Measurements: Length of body, 1.01 mm.; width of body, 0.50 mm.; antenna, joint I, 0.049 mm.; joint II, 0.035 mm.; joint III, 0.121 mm.; joint IV, 0.081 mm.; joint V, 0.087 mm.; joint VI, 0.063 mm.; filament, 0.023 mm.

THE WINGED MALE, ADULT STAGE (FIG. 8).

General color of the body pale yellow or greenish yellow. Head, prothorax, and thorax grayish black. Scutellum black. Eyes bright red. Antennæ not on frontal tubercles, reaching to the posterior margin of the first abdominal segment, pale yellow; joints I and II, the filament or spur, and the articulations of joints III to VI dusky gray. These dark articular annulations are less pronounced than in the viviparous female. Wings of medium size; costa, subcosta, and insertions pale yellowish gray; stigma short and gray, with its central area paler; veins gray, second fork of third discoidal nearer to the wing apex than to the first fork and arising beyond the apex of the stigmatic vein; stigmatic vein evenly and gently curved, absent in the middle for a space equal to one-third of its length. Legs longer in proportion to the body than those of the other forms; front legs and middle tibiæ very pale yellow or yellowish green; distal two-thirds of the middle and hind femora shaded gray, the black knee spot being present on these four femora; hind tibiæ shaded gray for its proximal three-fourths, its apical fourth pale yellow; all tarsi light gray. Abdomen barely as long as the head and thorax combined, widest at the fourth segment, and with a pair of



EGGS OF EUROPEAN WALNUT APHIS (CHROMAPHIS JUGLANDICOLA) ON PIECE OF BARK OF EUROPEAN SEEDLING WALNUT. TWICE NATURAL SIZE.

oval gray transverse spots on the fifth segment, which are separated by a space equal to their length. Cornicles pale yellow, about as broad at the base as long, very much as in the winged female. Cauda pale yellow, globular, not quite as long as the hind tarsus. Sexual organ pale yellow. Beak pale yellow, slightly exceeding the fore coxæ. Sterna black. Sensoria transversely oval, situated in an irregular row as follows; joint III, 11 to 16; joint IV, 5 to 7; joint V, 4 to 5; joint VI, 2 besides usual terminal.

Measurements: Length of body (average), 1.47 mm.; width of body (maximum), 0.48 mm.; expanse of wings (average), 4.20 mm; antenna, joint I, 0.05 mm.; joint II, 0.04 mm.; joint III, 0.34 mm.; joint IV, 0.12 mm.; joint V, 0.12 mm.; joint VI, 0.08 mm.; filament, 0.03 mm.; cornicles, 0.05 mm.

FIG. 8.—*Chromaphis juglandicola:* Winged male (appendages of left side removed). *a*, Left antenna. (Original.)

Described from many individuals collected in 1911 and 1912 at San Jose, Cal.

Both the male and the winged viviparous female when disturbed have a habit if jumping psyllid-like into the air. Their flight is generally in the form of a long spiral, and when disturbed they fly in an upward direction.

EGG DEPOSITION.

As mentioned before, the first sexual females of the year remain longer on the leaves after they have reached the adult state than those developing later. In 1911 eggs were not observed in the field until September, or seven weeks after the first appearance of sexual females. In 1912 some eggs appeared in August. This long period between the first appearance of the sexed females and the earliest egg deposition may be explained by the fact that until late in August males are quite scarce and so the females must wait on the leaves until the males are developed. Directly after mating the female repairs to the branches and limbs to deposit her eggs. Although eggs may be deposited anywhere along the limbs, and more rarely on the newer growth, the locations most preferred are the old scars of fallen leaves and the surface of the larger limbs near their bases. Another favored location is that in the crotches of the smaller limbs. Eggs are rarely laid along the stalk of the leaf or at the base of the leaflets, and if placed in those positions they fall to the ground when the leaf drops. Cavities and interstices in the bark are also chosen, but when infestation is very severe the eggs are laid in the open on the larger limbs (see Pl. II). In such a case large groups of eggs are massed together by many females, but a single female lays not more than three or four in a group. The eggs are fastened together and to the plant surface by a thin, transparent, gluey substance. No accurate information was obtained as to the number of eggs a single aphis produced, but from general field observations together with dissections of gravid females the writer arrived at the conclusion that not more than 30 eggs fell to the share of each adult, and probably not over half that number. On July 20, 1911, five gravid females were dissected. These contained respectively 5, 3, 3, 4, and 4 well-developed ova, besides about a dozen much smaller ones. On August 28, 1912, four oviparous females dissected contained respectively 2, 2, 4, and 2 full-grown ova besides about 20 much smaller ones. All these individuals were taken on the leaves and had not oviposited. The largest eggs dissected were lozenge-shaped and measured 0.37 mm. in length by 0.14 mm. in width.

THE EGG (FIG. 1; PL. II).

When first laid, the egg is pale lemon-yellow or whitish yellow, oval, almost twice as long as broad, flatter than most eggs of Aphididæ, and slightly broader at the micropylar end. After two or three days it turns black and shines obscurely when placed under a strong light. The surface is beautifully sculptured with granular hexagonal markings. These markings are thickened portions of the shell. The narrow intermediate portions of the shell are extremely thin, so much so that four months after the egg has been laid the yellow interior substance is plainly visible through them if subjected to a high power of magnification. It appears that about 85 per cent of the eggs are fertile. The average size is 0.50 mm. by 0.28 mm. The egg stage may be said to occupy, on the average, five months in California.

ANT ATTENDANTS.

The sweet juices excreted by the European walnut aphis attract large numbers of ants, of which a large black species, *Formica subsericea* Say, is the most abundant. The author is indebted to Mr. Theo. Pergande, of the Bureau of Entomology, Washington, D. C., for the determination of this species.

THE AMERICAN WALNUT APHIS (Monellia caryae Monell).[1]

Callipterus[2] *caryae* Monell, U. S. Geol. & Geog. Survey Bul. 5, No. 1, p. 31, Jan. 22, 1879.

Monellia[3] *caryae* Gillette, Jour. Econ. Ent., v. 3, No. 4, p. 367, fig. 6, Aug., 1910.

HISTORY OF THE SPECIES.

This plant-louse was first collected in Missouri by Mr. J. T. Monell in 1879. His original description is as follows:

Winged form; general color pale yellow; tips of antennal joints black; legs entirely pale whitish. Antennæ a little shorter than the body; seventh joint equal to or one-third longer than the preceding; fifth joint as long as the two following taken together. Nectaries not perceptible. Rostrum not reaching to the middle coxæ. Wings hyaline, veins pale; stigma rather short and blunt at the apex. Stigmal vein subobsolete, its course being only traced with difficulty. The distance between the apex of the lower cubital branch and that of the second discoidal equal to about one-half the distance between the apices of the first and second discoidals. Apterous viviparous females and pupæ with four rows of tubercles, each mounted with a capitate bristle.

Leaves of walnut, hickory and pecan. June–July, St. Louis, Mo.

This aphis has been reported from Illinois (Thomas, 1880; Davis, 1910), Nebraska (Williams, 1910), Oregon (Gillette, 1910), and Michigan (Gillette, 1910), and doubtless occurs in America wherever its food plants grow.

GENERAL DESCRIPTION; CHARACTER AND EXTENT OF INJURY.

This aphis is about one-sixteenth of an inch long and about one-third as wide and is generally of a pale lemon-yellow color. It occurs on the lower surface of the leaf and on the nutlets of the eastern black walnut tree and crosses derived from it. When infestation is severe, the aphides will also be found on the upper surface of the leaves. The species, according to Mr. Monell and other writers, feeds also on hickories and pecan. The character and extent of its injury is altogether similar to that of the European walnut aphis (*Chromaphis juglandicola* Kalt.). This plant-louse does not lie so flatly appressed to the plant surface as the European species and is much more active, bearing longer legs and antennæ in proportion

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[1] Mr. J. T. Monell, of the Bureau of Entomology, has kindly identified the specimens sent to him by the author as *Monellia caryae* Monell.

[2] The genus Callipterus ("beautiful-winged") was erected by Koch (1855).

[3] The genus Monellia was erected by Oestlund (1887), with *caryella* Fitch as the type species.

to the size of the body. When on the lower surface of the leaflet it has the habit of resting with the head directed straight toward the peduncle of the leaflet. In July and August, in which months this insect is most abundant, as many as 400 individuals may be found on one leaflet, 5 per cent of which will be resting on the upper side. At this time it is much sought after by ants, which feed on the liquid excreted by it. A large red and black species, determined by Mr. Theodore Pergande as *Formica obscuriventris* Mayr, is a very common attendant. *Formica subsericea* Say also attends it. The sweet excretions of the aphis attract many flies of the families Muscidæ, Anthomyiidæ, Oscinidæ, and Syrphidæ, many large bees including the honeybee, wasps of the family Pompilidæ, and parasitic wasps of the families Ichneumonidæ and Braconidæ, and numerous smaller forms of insect life. The author first observed this aphis on July 20, 1911, at San Jose, Cal.

LIFE HISTORY AND TECHNICAL DESCRIPTIONS.

The Viviparous or Asexual Forms.

The stem-mothers hatch as soon as the buds start to swell, about the 1st of April. These develop into winged aphides and pass their life cycle in from 25 to 30 days, according to temperature and the amount of food supply. The viviparous aphis passes through four molts, becoming winged after the final one. Table VII indicates the life cycle of 38 individuals of the summer generations.

Table VII.—*Life-cycle of viviparous females of Monellia caryae, summer generations, San Jose, Cal., 1912.*

No. of individual.	Generation.	Date of deposition.	Date of acquiring wings.	Life cycle.	No. of individual.	Generation.	Date of deposition.	Date of reaching maturity.	Life cycle.
				Days.					Days.
1	II	Apr. 22	May 12	20	20	V	June 22	July 7	15
2	II	22	12	20	21	V	23	7	14
3	II	22	12	20	22	V	23	7	14
4	II	May 1	20	19	23	V	24	7	13
5	II	1	22	21	24	V	24	7	13
6	II	1	23	22	25	V	24	7	13
7	II	1	23	22	26	V	24	8	14
8	III	13	29	16	27	V	24	8	14
9	III	13	29	16	28	V	24	8	14
10	III	13	29	16	29	V	25	8	13
11	III	13	29	16	30	V	25	8	13
12	III	13	29	16	31	V	25	8	13
13	III	13	30	17	32	V	25	8	13
14	III	13	30	17	33	V	25	9	14
15	III	13	30	17	34	V	27	10	13
16	III	13	30	17	35	V	27	10	13
17	III	13	30	17	36	V	27	10	13
18	V	June 22	July 4	12	37	V	27	10	13
19	V	22	7	15	38	VI	July 13	Aug. 1	19

Thus, the second generation requires 20 days, the third 16 or 17, and the fifth 15, in which to complete the life cycle. Records of the fourth generation were not obtained owing to premature death of all individuals of this generation of which the date of deposition had been ascertained. Individuals of the fourth generation probably mature in an average of 16 days. The leaves of the Eastern black walnut fall earlier than those of the European or California black types, and consequently the viviparous aphides are not found so late on the trees. There are probably not more than nine generations of these in a year.

Immediately after passing the final molt the aphides begin depositing young. These are entirely pale lemon-yellow with red eyes and four longitudinal rows of capitate hairs and do not exceed 0.70 mm. in length. From 10 to 20 young are produced by a single female, dependent on the season of the year. The earlier generations are more prolific. After midsummer the progeny becomes smaller and smaller with successive broods.

THE PUPA OF THE WINGED VIVIPAROUS FEMALE (FIG. 9).

After the second molt the pupal wing pads are apparent as small emarginations on the sides of the thorax, but after the following molt they are much more readily seen. The pupa of the winged viviparous female may be described as follows:

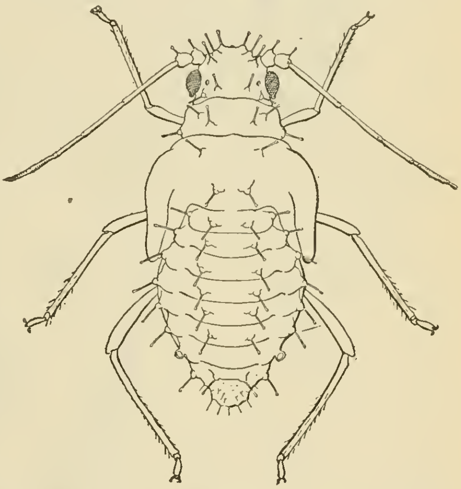

FIG. 9.—*Monellia caryæ:* Pupa of winged viviparous female. (Original.)

Color generally pale lemon-yellow, sometimes white; head often with a reddish tinge. Antennæ on small frontal tubercles, pale yellow, with the filament and articulations of joints 3 to 6 dusky black. Eyes bright red. Thoracic segments and wing pads light yellow, wing pads projecting out from the body at a very acute angle. Legs pale, tarsal apices dusky. Body beset with long capitate spines in four rows. Cornicles on segment 6 of the abdomen, hardly perceptible, broader than long. Cauda blunt, conical, and short. Cornicles and cauda concolorous with the abdomen. Beak pale, reaching to the middle coxæ. Measurements: Length of body (average), 1.87 mm.; width of body (average), 0.71 mm.; antenna, joint I, 0.058 mm.; joint II, 0.050 mm.; joint III, 0.287 mm.; joint IV, 0.207 mm.; joint V, 0.201 mm.; joint VI, 0.128 mm.; filament, 0.136 mm.

This pupa is distinguishable from that of Chromaphis by the presence of the dorsal rows of spines and by the absence of the black femoral spots. The penultimate instar occupies on the average four or five days. At its termination the final molt occurs, and after this the insect has acquired its full development.

THE WINGED VIVIPAROUS FEMALE (FIG. 10).

General color pale lemon-yellow; many examples are greenish yellow and others decidedly pinkish. Head, thoracic lobes, and scutellum pale brown or yellowish brown. Eyes pink. Antennæ on small frontal tubercles, about half as long as the body, pale yellow, with articulations of joints III to VI black; joint III the longest, not noticeably thickened basally; joint IV slightly longer than V and barely as long as joint VI, together with its spur or filament. Bases of antennæ encircled, in the majority of individuals, with a narrow dusky ring. Close to the lateral margins of the prothorax and roughly parallel to them occur two narrow black lines. (These are sometimes absent.) Wings of moderate size; costa, subcosta, and stigma pale yellowish green, other veins light brown, of medium thickness. Stigmatic vein entirely subobsolete, its course not easily made out. Legs very pale, whitish, tarsi and apex

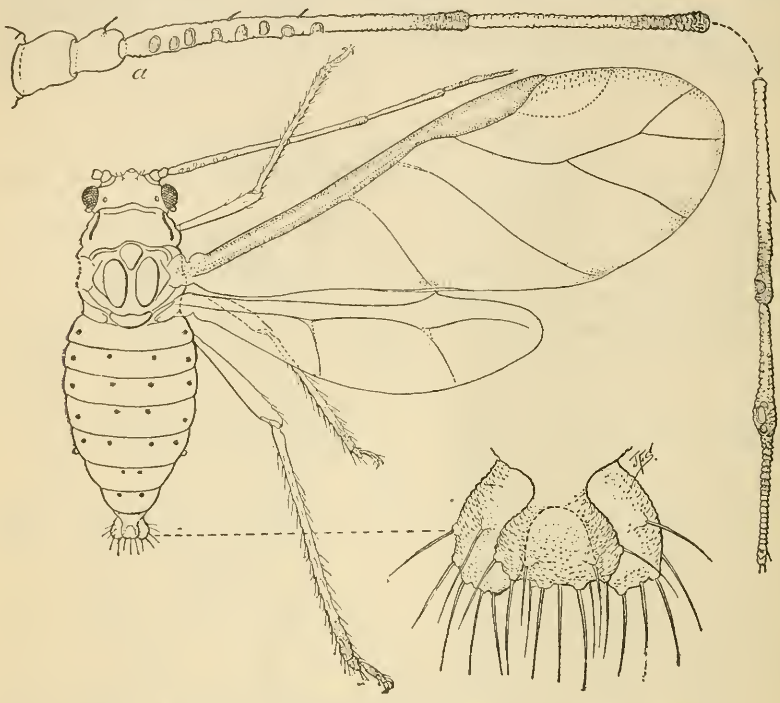

FIG. 10.—*Monellia caryæ:* Winged viviparous female. *a*, Antenna. (Original.)

of tibiae dusky grey; anterior and posterior femora in about half of the individuals bear a grey knee spot quite like that of *Chromaphis juglandicola* Kalt. but smaller. This spot never occurs on the middle femora. Abdomen pale yellow, sometimes greenish and at other times reddish, with four rows of small black spots, which are very variable and often wholly absent. The two lateral rows have larger spots and these are found on segments 2–6; the two median rows are smaller and their spots exist on segments 2–8. Cornicles on segment 6, hardly perceptible, more than twice as broad as long, about 0.008 mm. long. Cauda globular, shorter than the hind tarsus. Cornicles and cauda concolorous with the abdomen. Anal plate bifid, armed with spines. Beak pale, extreme tip brown and not quite extending to the second pair of coxæ. Sensoria occur on the antennæ as follows: Joint III, 6–9 transversely oval on basal half or two-thirds of joint; in an equally spaced row; joint V, 1 terminal; joint VI, 4 terminal (1 large, 3 small). Measurements: Length of body, 2.16 mm.; width of body, 0.754 mm.; wing expanse, 4.44 mm. Antenna, joint I, 0.076 mm.; joint II 0.060 mm.; joint III, 0.416 mm.; joint IV, 0.273 mm.; joint V, 0.273 mm.; joint VI, 0.143 mm.; filament, 0.164 mm.

Described from many specimens taken at San Jose, Cal., during 1911 and 1912.

The complete absence of the stigmatic vein and the relatively longer antennæ, together with the diminutive cornicles, will readily distinguish this species from the European walnut aphid.

In 18 months' study of this plant-louse the author has failed to find any trace of the existence of a wingless viviparous form.

The Oviparous or Sexual Forms.

If a tree be heavily infested, the sexual forms appear first about the middle of July and probably belong to the fifth and sixth generations. If infestation be only moderate or slight, these forms are not produced until several weeks later and will be members of the seventh and following generations. The sexed forms from the beginning are produced in comparative abundance and comprise from 30 to 50 per cent of the whole. The young sexed females are paler and more spindle-shaped than the young of the viviparous individuals, while the male larvæ and pupæ are conspicuously brick-red in color. The male is not so greatly outnumbered by the female as in the European walnut aphis, and from the first comprises from 20 to 30 per cent of the sexed insects. On August 26 and 27 and September 5, 1912, a count of the forms on 34 leaflets taken at random from an Eastern black walnut tree showed 177 viviparous females, 14 males, and 26 sexed females. Probably as many again of the sexed females in proportion to the leaflets counted could be found on the twigs ovipositing. Copulation takes place on the leaf and occupies half a minute. All through August and September, 1912, the oviparous females were observed on the twigs, but few eggs were found until September. After the middle of September few aphides were found, the great majority having been destroyed by their natural enemies, but those that escape perpetuate the species until the leaves fall in November. The majority of aphides born in the late fall are sexual. The sexed female shortly after mating becomes much swollen by reason of the growing ova in her body, and the last four abdominal segments become orange colored. She repairs to the twigs and limbs and wanders around searching for locations wherein to oviposit. Occasionally immature females wander off to the twigs, but later return to the leaves to resume feeding. The fully mature fertilized oviparous female once she has forsaken the leaf rarely if ever returns, and thus escapes many predatory foes. Having found a crevice or crack in the cortex suitable for her purpose she grips the limb with her six legs and bends the hind part of the abdomen at a right angle to the rest of the body and then gives her abdomen a succession of jerks to get it into place. This performed to her satisfaction, she remains motionless for 60 seconds while the egg is being extruded, and after depositing it walks off. The writer has never seen the eggs of this species placed in an open situation, but always in some protected position in the bark. On August 28, 1912, four gravid females were dissected and were found to contain respectively 3, 4, 2, and 4 large eggs, and all had several smaller ones. Another had 8 large eggs in her ovaries and was greatly distended therefrom. The egg is bluntly oval, bright yellow when first laid, but changing in a day or two to black and obscurely shining. It measures 0.35 mm. in length and 0.17 mm. in width, and is therefore considerably smaller than the egg of the European walnut plant-louse. The oviparous forms are described below.

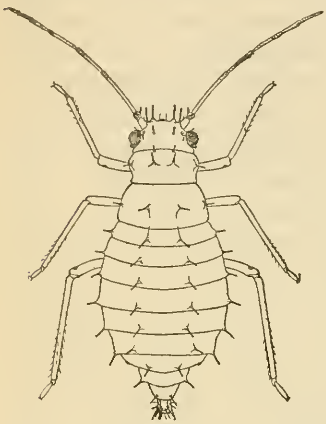

FIG. 11.—*Monellia caryæ:* Oviparous female. (Original.)

THE OVIPAROUS FEMALE, FULL GROWN (FIG. 11).

General color pale greenish yellow or sometimes greenish white, the four apical segments of the abdomen at first colored like the rest of the body and later orange colored. Body rather narrow, not at all flattened, the sides nearly parallel and produced posteriorly into a conical tube. Antennæ a little over one-half the body in length, pale, with the apical third or fourth of joints III to VI dusky gray; joint II gray and armed with a capitate spine on its inner margin; joint III longest; joints IV and V subequal; joint VI shorter than its spur or filament. Legs very pale yellow, with a dark spot close to the apex of the anterior and posterior femora. (In many individuals these spots are absent.) Eyes pink. The arrangement of capitate spines is as follows: The head bears eight, the prothorax six, the mesothorax, metathorax, and abdominal segments 1 to 5, inclusive, four, and abdominal segments 6, 7, and 8 two; these spines appear as four longitudinal rows. Cornicles greenish yellow, broader than long, hardly perceptible, located on segment 6. Cauda concolorous with the body, globular, armed with four noncapitate spines, half as long as the hind tarsus. Genital plate protruding beyond the cauda, pale, its margin beset with short noncapitate hairs. Beak pale, its extreme tip brownish, just exceeding the second pair of coxæ. Measurements: Length of body, 1.68 mm.; width of body, 0.72 mm.; cauda, 0.038 mm.; antenna joint I, 0.04 mm.; joint II, 0.035 mm.; joint III, 0.300 mm.; joint IV, 0.17 mm.; joint V, 0.17 mm.; joint VI, 0.100 mm.; filament, 0.12 mm.

Described from many specimens collected at San Jose, Cal., during 1912.

YOUNG MALE PUPA.

Light red in general color; appressed closely to the leaf surface. Dorsum of head in front black, behind gray. Dorsum of thorax gray. Antennæ six-jointed (i. e., with five joints and filament), one-third as long as the body, pale gray. Eyes bright red. Legs pale, femora dusky gray. Mesothorax, metathorax, and first five abdominal segments each with four black spots in a transverse row. Abdominal segments 6 to 8, inclusive, with two such spots. A single capitate spine arises from each of these spots. Cornicles imperceptible. Cauda pale, short, conical. Beak pale, tip dusky gray, reaching first coxæ.

FULL-GROWN MALE PUPA (FIG. 12).

General color pale brick red; head pale orange. Antennæ half as long as the body, seven-jointed, pale yellow, with dusky articulations. Eyes bright red. Legs very pale, femora usually slightly dusky. Wing pads white. Whole body with four longitudinal rows of dark capitate spines distributed as in the oviparous female. Cornicles on segment 6, appearing as little rims on the body surface, broader than long, concolorous with the body. Cauda bluntly conical, very short, pale yellow. Beak pale yellow, extreme tip brown, reaching to the first pair of coxæ. Measurements: Length of body, 1.58 mm.; width of body, 0.57 mm.; cauda, 0.045 mm. Antenna, joint I, 0.071 mm.; joint II, 0.054 mm.; joint III, 0.257 mm.; joint IV, 0.173 mm.; joint V, 0.200 mm.; joint VI, 0.12 mm.; filament, 0.12 mm.

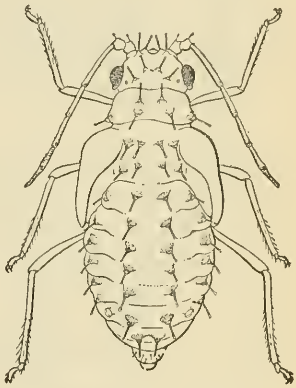
FIG. 12.—*Monellia caryæ:* Male pupa. (Original.)

Described from several specimens collected at San Jose, Cal., in 1912.

WINGED MALE (FIGS. 13; 18, *a*).

General color pale lemon-yellow or greenish yellow; head and a median quadrilateral area on thorax dark brown; scutellum dark brown; eyes dark red. Antennæ not mounted on frontal tubercles, about as long as the body; joints I and II with a dusky central part; joints III to VI pale, with their apices dusky gray; filament pale; joint III longest, bearing about 24 small oval sensoria; joints IV and V subequal, both bearing 10 to 15 small sensoria arranged along the outer margin; joint VI bearing 4 sensoria, of which the most distal is apical; joint VI longer than the filament, the two together scarcely as long as joint V. Ocelli distinct. Wings of medium size; costa and insertions greenish yellow; stigma short and moderately broad, dusky gray, with a large paler central area; veins brown, the third discoidal curving considerably to meet its second fork; second fork twice as near to the first fork as to the apex of the wing; stigmatic vein obsolete in its middle portion. Legs longer in proportion to the body than in the winged viviparous female, pale greenish yellow, with a large dusky area near the apex of all six femora; apices of tibiæ and tarsi dusky gray. Abdomen short, not quite as long as the head and thorax together, widest at the third segment; segments 1 to 7, inclusive, with two lateral black spots, one on each side; segments 1 to 6, inclusive, and segment 8 with two dorsal black spots, one on either side of the dorso-median line; the lateral spots on segments 1 to 6, inclusive, are circular or subcircular; the dorsal pairs on these segments are oval; the dorsal spots on segments 6 and 8 coalesce narrowly in the middle. Cornicles on segment 6, hardly perceptible, broader than long. Cauda globular, dusky, half as long as the hind tarsus. Reproductive organ white, when extended about as long as antennal joint IV. Beak pale yellow, extending a little beyond the first pair of coxæ. Sterna and apical half of the underside of the head dark brown. Very often one or more of the dusky abdominal spots are absent. Measurements: Length of body, 1.39 mm.; width of body, 0.69 mm.; wing expanse, 4.10 mm.; cauda, 0.049 mm.; antennal joint I, 0.051 mm.; joint II, 0.058 mm.; joint III, 0.362 mm.; joint IV, 0.238 mm.; joint V, 0.240 mm.; joint VI, 0.114 mm.; filament, 0.134 mm.

Described from four specimens collected at San Jose, Cal., in 1912.

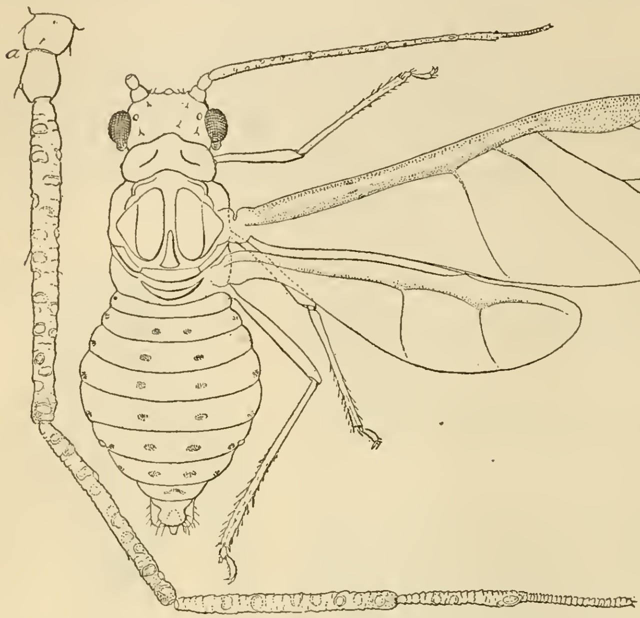

FIG. 13.—*Monellia caryæ:* Winged male. *a*, Left antenna. (Original.)

THE LITTLE HICKORY APHIS (Monellia caryella Fitch).

Aphis caryella Fitch, [First] Report on the noxious, beneficial, and other insects of the State of New York, Albany, p. 163-165, 1855.

Callipterus caryellus Fitch, Third report on the noxious and other insects of the State of New York, Albany, p. 448-449, 1856.

Monellia caryella, Oestlund, Geol. & Nat. Hist. Survey Minn. Bul. 4, p. 45, 1887.

HISTORY OF THE SPECIES.

The little hickory aphis was first collected in New York State by Dr. Asa Fitch, previous to the year 1855. The following is Fitch's original description:

The Little Hickory Aphis (*Aphis caryella*) is pale yellow with white antennæ which are alternated with black rings, the wings are transparent and without spots, their veins slender and pale yellow, the legs yellowish white to their ends. Length 0.12 to the tips of the wings. The abdomen is depressed, egg-shaped, its apex slightly narrowed and elongated. The antennæ are longer than the body, tapering, seven-jointed; two basal joints as broad as long, twice the diameter of the following joints; third joint longest, slightly thicker towards its base; fourth and fifth joints rather shorter than the third, cylindric; two last joints together about equalling the fifth in length; the sixth swelled at its tip into a long oval knob, the seventh more slender but not capillary, shorter than the sixth; a broad black band at the base of the third and each of the following joints. First vein of the fore wings straight and almost transverse; second vein bent near its base, running first towards the apex and then turning rather abruptly and continuing straight to the inner margin, more than twice as far from the first at tip as base; third vein arising from the stigma near its anterior end, and not from the rib-vein forward of the stigma, as it does in the aphides generally, except those pertaining to this group, its base and its apex about the same distance from the second vein that this is from the first, forking rather forward of its middle, strongly bent at this point, and from hence to its tip parallel with the third vein or but slightly diverging from it, its tip a third nearer that of the third vein than this is to the second; second fork nearer the fourth vein at tip than to the first fork, the triangular cell between it and the first fork with its three sides equal; fourth vein short and often nearly abortive, shorter than the second fork, equally curved through its whole length, its tip much nearer that of the rib-vein than that of the second fork; rib-vein very slightly diverging from the margin from the base to the stigma, curved from thence to its tip. Stigma oval, about twice as long as wide, watery, sometimes tinged with yellowish. A variety has the stigma dusky at its tip. Another variety (*costalis*) has the rib-vein coal black interrupted with whitish towards the stigma, which is dusky and black at each end.

In a general discussion of this species before his description Fitch refers to the minute cornicles characteristic of this and kindred species. In his third report on the insects of New York he mentions the European walnut aphis and says "European *C. juglandicola* of Koch" [*Chromaphis juglandicola* Kalt.] "appears closely related to this present species" [i. e. *Callipterus caryellus*]. Fitch gave the host plant of his species as the hickory. Oestlund (1887) reports it in Minnesota from *Carya amara* Nutt. Davis (1910) and other Eastern writers record it from hickory in the Eastern States. In California the normal food plants are the California black walnut (*Juglans californica*) and hybrids derived from this tree.

GENERAL APPEARANCE; CHARACTER AND EXTENT OF INJURY.

In general appearance this aphis is very similar to the American walnut aphis (*Monellia caryæ* Monell) and can not be distinguished from it except when viewed under the microscope or a powerful hand magnifier. Its habits of life and the character and extent of its injury are also very similar to those of *M. caryæ*. The writer had observed this aphis for several months before he realized that it was a distinct species and not a variety of *caryæ*, as he had previously supposed. When the sexed forms appeared it was noticed that the oviparous female of *caryella* differed markedly from the same form of *caryæ*, and this led to a closer scrutiny of the viviparous form resulting in the establishment of the points of divergence shown in Table VIII.

TABLE VIII.—*Divergences of structure between Monellia caryæ Monell and M. caryella Fitch.*

Form.	*Monellia caryæ* Monell.	*Monellia caryella* Fitch.
Winged viviparous female	Antennal joint III very slightly thickened basally. Sensoria on antennal joint III occupying basal half or two-thirds. Antennal joint VI and its spur or filament subequal, or VI less than spur. Dusky knee spots often present.	Antennal joint III quite noticeably thickened for its basal half. Sensoria on antennal joint III occupying basal third. Antennal joint VI one-third as long again as its spur or filament. Dusky knee spots absent.
Pupa of viviparous female	Four longitudinal rows of capitate spines.	Six longitudinal rows of capitate spines.
Oviparous female	Smaller than the viviparous female. Four longitudinal rows of capitate spines.	Larger than the viviparous female. Six longitudinal rows of capitate spines.

LIFE HISTORY AND TECHNICAL DESCRIPTIONS.

Life-history studies on this plant-louse began in August, 1912, at San Jose, Cal., but no rearing work was done until the appearance of the sexed forms in September. Observations taken in August and September indicated a development of the summer generations similar to that found in *Monellia caryæ*. This was further confirmed by studies during 1913. The sexed forms were studied at Walnut Creek and San Jose, Cal. In both localities these did not appear until late in September, even on trees heavily infested. The aphides remained on the trees as long as there were leaves on which they could subsist and were to be found until mid-November. After September the great majority of aphides deposited were oviparous, and of these the males were extraordinarily scarce, the writer observing only one individual of this sex among hundreds of oviparous females. Table IX indicates the life cycle of plant-lice deposited by four viviparous females and shows the preponderance of the sexed form over the asexual in the late fall.

TABLE IX.—*Life-cycle record of the progeny of four viviparous females of Monellia caryella, Walnut Creek, Cal., 1912.*

FEMALE NO. 1; DEPOSITED 3 YOUNG.

No. of larva.	Date of— Hatching.	Molt 1.	Molt 2.	Molt 3.	Molt 4 (becoming adult).	Form of individual.	Life cycle.
							Days.
1	Oct. 4	Oct. 7	Oct. 10	(?)	Oct. 16	Winged viviparous female.	12
2	4	7	11	(?)	18	Oviparous female	14
3[1]						do	

FEMALE NO. 2; DEPOSITED 6 YOUNG.

No. of larva.	Hatching.	Molt 1.	Molt 2.	Molt 3.	Molt 4.	Form of individual.	Life cycle.
1	Oct. 12	Oct. 15	Oct. 18	Oct. 21	Oct. 28	Oviparous female	16
2	12	15	18	21	28	do	16
3	12	15	19	22	29	do	17
4	12	15	19	23	30	do	18
5	12	(?)	(?)	(?)	29	do	17
6	12	(?)	(?)	(?)	30	do	18

[1] Died permaturely.

TABLE IX.—*Life-cycle record of the progeny of four viviparous females of Monellia caryella, Walnut Creek, Cal., 1912*—Continued.

FEMALE NO. 3; DEPOSITED 16 YOUNG.

No. of larva.	Date of— Hatching.	Molt 1.	Molt 2.	Molt 3.	Molt 4 (becoming adult).	Form of individual.	Life cycle.
							Days.
1	Oct. 16	Oct. 21	Oct. 27	Nov. 3	Nov. 7	Oviparous female	22
2	16	21	27	3	7	do	22
3	16	21	27	3	7	do	22
4	17	(?)	(?)	(?)	8	do	22
5	17	(?)	(?)	(?)	8	do	22
6	17	(?)	(?)	(?)	8	do	22
7	17	(?)	(?)	(?)	8	do	22
8	18	(?)	(?)	(?)	8	do	21
9	18	(?)	(?)	(?)	9	do	22
10[1]						do	
11[1]						do	
12[1]						do	
13[1]						do	
14[1]						do	
15[1]						do	
16[1]						do	

FEMALE NO. 4; DEPOSITED 8 YOUNG.

No. of larva.	Hatching.	Molt 1.	Molt 2.	Molt 3.	Molt 4 (becoming adult).	Form of individual.	Life cycle.
1	Oct. 18	Oct. 22	Oct. 27	Nov. 2	Nov. 7	Oviparous female	20
2	18	22	27	3	9	do	22
3	18	22	27	4	9	do	22
4	18	22	27	4	9	do	22
5[1]						do	
6[1]						do	
7[1]						do	
8[1]						do	

[1] Died prematurely.

SUMMARY.

Life cycle (20 oviparous females).	Days.
Maximum	22
Minimum	14
Average	18.92
First instar (13 individuals), average	3.7
Second instar (13 individuals), average	4.5
Third instar (11 individuals), average	5.7
Fourth instar (11 individuals), average	5.6

The viviparous forms, so far as the author has observed, all develop wings.

The eggs of this aphis are larger than those of the American walnut aphis and measure on the average 0.536 mm. in length and 0.222 mm. in maximum width. They are elongate-oval in shape, rather feebly shining, and have a softer shell than is found in the eggs of the majority of plant-lice, but one not so soft as is that of *Chromaphis juglandicola*. They are placed either singly or in groups of two or three around the axils of the buds or in crevices in the bark and in scars caused by fallen leaves on the smaller limbs and twigs. Oviposition is in progress during the months of October and November, each oviparous female laying on the average about 12 eggs. Owing to the scarcity of males in the fall of 1912 at Walnut Creek, Cal., it seemed very probable that a large proportion of the eggs would prove to be sterile, and in the following spring examinations of egg-infested trees showed this assumption to be correct.

The Viviparous Forms.

The stem-mothers commence hatching very shortly after the leaf buds open in the latter part of March. Previous to the first molt they are pale lemon-yellow with red eyes, hyaline legs, and dusky tarsi; the joints of the antennæ have black articulations; on the abdomen are four longitudinal rows of circular dusky spots from each of which arises a capitate spine. They are destined to become winged and in their later stages do not differ from the summer winged viviparous individuals.

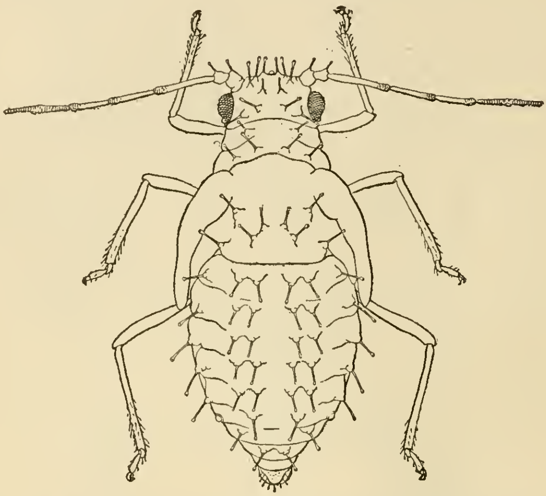

Fig. 14.—*Monellia caryella:* Pupa of winged viviparous female. (Original.)

THE PUPA OF THE WINGED VIVIPAROUS FEMALE (FIG. 14).

General color pale lemon-yellow; some individuals exhibit a decided greenish, others a decided salmon colored tinge. Antennæ two-thirds of the body in length; apices of joints III to VI and the whole filament dusky, otherwise pale yellow, almost white. Eyes bright red. Head with eight capitate spines, six of these on the frontal margin and two near the hind border. Prothorax with six capitate spines, two of these near the middle of the segment and four in a transverse row along the hind margin. Mesothorax, metathorax, and abdomen with six longitudinal rows of capitate spines. Legs pale yellow, tarsi dusky. Wing pads pale, after being imbedded in balsam for a few days becoming dusky. Cornicles barely perceptible, wider than long. Cauda rounded, not as long as the hind tarsi and without hairs. Beak pale with a brown tip, almost reaching the second pair of coxæ. Measurements: Length of body, 1.81 mm.; width of body, 0.72 mm.; antenna, joint I, 0.070 mm.; joint II, 0.050 mm.; joint III, 0.253 mm.; joint IV, 0.198 mm.; joint V, 0.183 mm.; joint VI, 0.134 mm.; filament, 0.105 mm.

Described from four specimens, Walnut Creek, Cal., October, 1912.

THE WINGED VIVIPAROUS FEMALE (FIG. 15).

General color pale lemon-yellow, somewhat varying in shade. Antennæ about four-fifths as long as the body, pale yellow, with joints III to VI, inclusive, bearing an apical black ring (on joint III this ring is narrower than the other joints); filament of joint VI dusky; joint III is the longest; joints IV and V subequal or joint IV slightly longer than V; joint IV about four-fifths as long as III; joint VI together with its filament about equal to V; filament about three-fourths as long as VI; basal third of joint III noticeably swollen and bearing from five to seven oval transverse sensoria; usual apical sensoria on both joints V and VI. Head pale yellow, with the frontal margin black. Eyes bright red. Prothorax pale yellow, with two narrow, black, longitudinal stripes arising from the anterior angles and extending for two-thirds

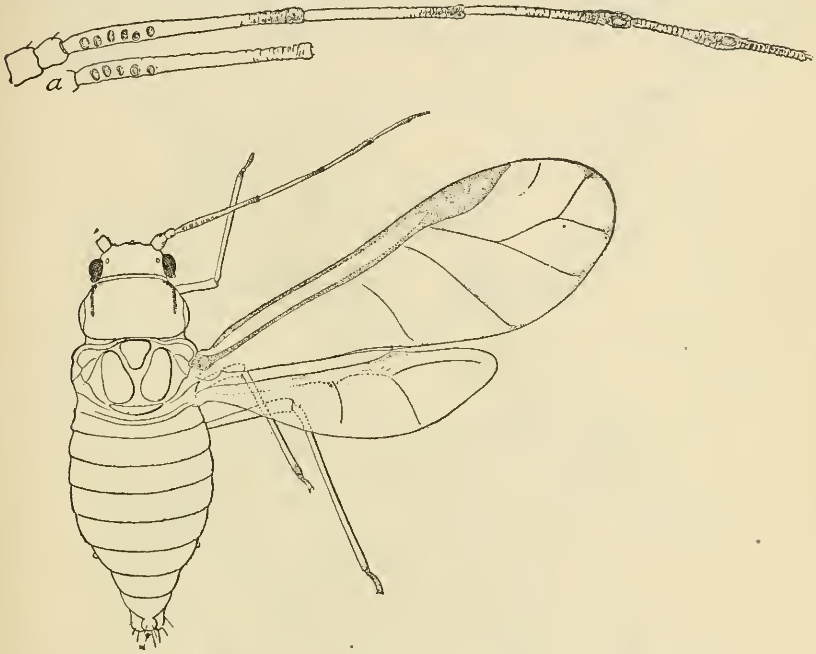

FIG. 15.—*Monellia caryella:* Winged viviparous female. *a*, Right antenna, enlarged, with variations of number of sensoria. (Original.)

of its width. Thoracic lobes and scutellum light brown, sometimes with a salmon-pink tinge. Wing insertions, costa, subcosta, and stigma pale lemon-yellow; discoidals yellowish-brown; first and second discoidals heavier than the other veins; third discoidal obsolete at its immediate base, its first fork equidistant from the second fork and the base of the discoidal, its second fork nearer to the first fork than to the apices of its two branches; branches of second fork equal in length; stigmatic vein very weak, its basal half traceable only with difficulty; lower wing colorless. Legs pale yellow; tarsi and tibial apices dusky. Abdomen entirely pale lemon-yellow, the body widest at the third segment. Body somewhat narrowed laterally. Cornicles pale yellow, hardly perceptible, wider than long. Cauda globular, bearing a fringe of weak hairs, about equal in length to the hind tarsi, concolorous with the abdomen. Genital plates armed with weak hairs, pale yellow. Beak pale yellow, its extreme tip brown, extending halfway between first and second coxæ. Measurements: Length of body (average), 1.67 mm.; width of body (average), 0.61 mm.; wing expanse (average), 4.02 mm.; antenna, joint I, 0.053 mm.; joint II, 0.046 mm.; joint III, 0.41 mm.; joint IV, 0.335 mm.; joint V, 0.32 mm.; joint VI, 0.191 mm.; filament, 0.123 mm.; cauda, 0.084 mm.; Cornicles, 0.009 mm.

Described from numerous specimens, Walnut Creek, Cal., October, 1912.

The Oviparous Forms.

THE OVIPAROUS FEMALE (FIG. 16).

Wingless. General color pale lemon-yellow, in mature individuals the central part of the abdomen diffused with orange. Body elliptical, widest at the third abdominal segment. Antennæ half as long as the body, not on frontal tubercles, pale, with

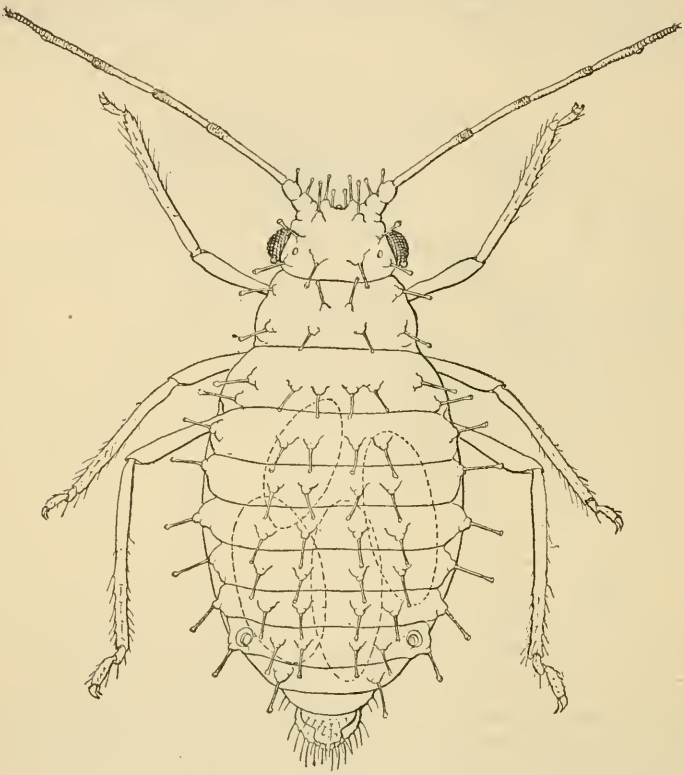

FIG. 16.—*Monellia caryella:* Oviparous female. (Original.)

an apical black ring on joints III to VI, inclusive; joints I, II, and filament dusky; joint III longest; joints IV and V subequal and each about four-fifths as long as joint III; filament a little shorter than VI; VI about four-fifths as long as V. Eyes crimson. Legs pale yellow; tarsi dusky. Hind tibiæ slightly thickened. Cornicles very small, pale. Cauda pale, globular, beset with a fringe of weak hairs, not as long as the hind tarsi. Thorax and abdomen with six longitudinal rows of capitate bristles, each surmounting a pale tubercle. Penultimate segment of the abdomen encircled near its posterior margin with a fringe of weak hairs. Eight capitate spines on the head and six on the prothorax. Tibiæ armed with a row of short bristles on their inner margins. Beak pale, the extreme tip dusky, extending a little beyond the anterior coxæ. The young oviparous female is entirely pale yellow and can be distinguished from the young viviparous female only by its more eliptical shape, that of the latter being more oval. Measurements: Length of body, 1.89 mm.; width of body, 0.92 mm.; antenna, joint I, 0.075 mm.; joint II, 0.042 mm.; joint III, 0.312 mm. joint IV, 0.203 mm.; joint V, 0.218 mm.; joint VI, 0.167 mm.; filament, 0.108 mm. cauda, 0.080 mm.; cornicles, 0.009 mm.

Described from numerous specimens, Walnut Creek, Cal., October, 1912.

WINGED MALE (FIGS. 17; 18, *b*).

General color pale green or greenish yellow. Head and prothorax olive-green. Frontal margin of head and frontal margin of prothorax, black. Prothorax with two

FIG. 17.—*Monellia caryella:* Winged male. (Original.)

bluntly rounded dusky tubercles on the dorsum. Dorsum of head and thorax with indefinite dusky markings. Eyes red. Antennæ dark olive-green, about three-fourths of the body in length; joint VI longer than its filament. Sensoria as follows: III, about 21: IV, 7 to 9; V, 6 to 10; VI, 2 to 4 (besides the usual apical). Wings of moderate size; insertions and subcosta greenish-yellow; stigma light brown, with a paler central area; discoidals 1 and 2 thicker than the other veins and with a narrow smoky border; stigmatic vein obsolete except for its apical third; veins brown. Legs pale greenish-yellow; coxæ, trochanters, apical five-sixths of femora, and basal four-fifths of tibiæ black; tarsi gray. Thoracic lobes and scutellum black. Under the wings

FIG. 18.—*a*, *Monellia caryæ*, antenna of male; *b*, *Monellia caryella*, two views of right antenna of male. (Original.)

occurs a large black spot on the pleuræ. Abdomen unarmed, pale green or greenish yellow; segments 1 to 8, inclusive, with two dusky brown oval spots on each. Cornicles pale, concolorous with the body, very small, considerably broader than long. Cauda concolorous with the abdomen, globular. Abdomen about as long as head and thorax combined, not wider than the thorax. Beak pale, barely reaching second coxæ. Sternum and underside of the eighth abdominal segment black.

Measurements: Length of body, 1.57 mm.; width of body, 0.62 mm.; expanse of wings, 4.62 mm.; antenna, joint I, 0.080 mm.; joint II, 0.041 mm.; joint III, 0.412 mm.; joint IV, 0.317 mm.; joint V, 0.260 mm.; joint VI, 0.175 mm.; filament, 0.108 mm.; cauda, 0.067 mm.; cornicles, 0.009 mm.

Described from three specimens, Walnut Creek, Cal., 1912 and 1913.

MONELLIA CALIFORNICA Essig.

Monellia californicus Essig, Pomona Jour. Ent., v. 4, no. 3, p. 767, Nov., 1912.

In southern California feeding on the underside of the leaves of the California black walnut (*Juglans californica*) there has recently been found a plant-louse closely allied to *Monellia caryæ* and *M. caryella*. The writer has never seen this aphis in nature, but has received specimens from Mr. Essig, who described it.

KEY TO THE SPECIES OF MONELLIA KNOWN TO OCCUR IN CALIFORNIA.

The following key will serve to distinguish the four species of walnut aphides occurring in California.

KEY TO THE SPECIES OF APHIDIDÆ KNOWN TO OCCUR ON WALNUT IN CALIFORNIA.

A. Cornicles quite evident, about as wide as long.
Chromaphis juglandicola Kalt.

AA. Cornicles barely perceptible, considerably wider than long.

B. Tibiæ of winged viviparous female entirely dusky.
Monellia californica Essig.

BB. Tibiæ of winged viviparous female for the most part pale.

C. Filament of joint VI longer than joint VI; oviparous female with four longitudinal rows of capitate hairs.... *Monellia caryæ* Monell.

CC. Filament of joint VI shorter than joint VI; oviparous female with six longitudinal rows of capitate hairs..... *Monellia caryella* Fitch.

NATURAL CONTROL OF WALNUT APHIDES.

INTERNAL PARASITES.

In July, 1912, a small chalcidid wasp was observed ovipositing in a pupa of *Monellia caryæ*. This is the only record of parasitism or attempted parasitism observed during two seasons, so there is good reason to believe that these aphides are practically immune from the attacks of internal parasites.

FUNGOUS DISEASES.

Although occasionally a plant-louse may be noticed here and there killed by fungus, only a single instance of the destruction of a colony by this agency came under the writer's notice. This occurred on May 20, 1911, following a rainstorm, and all the plant-lice on a few leaves were destroyed. The disease did not spread far, some cause or other checking the fungus shortly after its appearance.

PREDACEOUS ENEMIES.

Predaceous enemies are of prime importance in the control of plant-lice on walnuts and where the aphides occur in any numbers may always be found preying on them from June to September. Unfortunately they do not make their appearance on the walnuts until their prey has had time to do much damage to young nuts and to become abundant enough to cause collective injury to the tree. Should these predaceous forms appear in early spring they would quickly wipe out the few plant-lice present at that time and consequently their progeny would starve to death. As injury is thus done to the nuts and to the vitality of the tree before the advent of natural enemies, artificial measures must be practiced in order to insure healthy trees and perfect nut crops.

The predaceous enemies of walnut plant-lice include syrphus-fly larvæ, agromyzid larvæ, chrysopid and hemerobid larvæ, coccinellid beetles and their larvæ, *Camptobrochis brevis* Uhler (Heteroptera) and its larva, and various spiders.

SPIDERS.

The commonest spider predaceous on walnut plant lice is *Theridium placens* Keyserling. This spider may be found on the trees during the months of August and September and has a habit of curling around itself the edge of the leaf under the protection of which to deposit its egg sac. This species was determined by Mr. Nathan Banks, of the Bureau of Entomology, who says of it "* * * a species found on the Pacific coast. They do not choose their food, but from location of web are apt to get many plant lice." This and other spiders are of comparatively small economic importance in the control of aphides.

CAMPTOBROCHIS BREVIS UHLER.

Camptobrochis brevis Uhler, which was determined by Mr. Otto Heidemann, of the Bureau of Entomology, is a small black capsid, measuring in the adult stage 4.2 by 1.9 mm. Its larva is white, with conspicuous black markings. Both immature and mature individuals were observed actively and abundantly attacking plant lice during August, 1912. They do not occur in numbers earlier in the year and disappear in September. Thus their beneficial work is limited.

LEUCOPIS SP.

A fly of the family Agromyzidæ, *Leucopis* sp., in its larval state preys upon walnut plant lice from June to August. The small yellow maggots superficially resemble syrphid larvæ. They are never very abundant and are not a great factor in the control of the "lice." The life cycle in summer is completed in 24 days or less and there are several broods in California.

CHRYSOPID OR LACEWING FLIES.

Of scarcely less importance economically than the ladybird beetles and syrphid maggots are the active reddish-brown larvæ of the "lacewings." *Chrysopa majescula* Banks and *C. californica* Coq. are two species of economic importance in California. Table X shows the predatory activities of two larvæ of the latter species in the fall of 1912. The aphides consumed by these larvæ were of all sizes and averaged about 1.5 by 0.5 mm.

TABLE X.—*Chrysopa californica: Predatory activities on walnut plant lice, Walnut Creek, Cal., 1912.*

Larva No.	Date of— Hatching.	Date of— Molt 1.	Number "lice" eaten to molt 1.	Date of molt 2.	Number "lice" eaten, molt 1 to molt 2.	Date of spinning cocoon.	Number "lice" eaten from molt 2 to pupation.	Total "lice" eaten.	Number days feeding.
1	Sept. 18	Sept. 22	11	Sept. 27	70	Oct. 8	265	346	20
2	18	21	22	26	57	7	300	379	19

Larva No. 1 ate on the average 17.3 "lice" per day, while larva No. 2 consumed 19.9 "lice" per day. The lacewing larvæ appear in numbers toward the end of June and may be found until the end of October. There are probably at least three broods, the last one wintering in the cocoon, which is white, short oval, with a central brown annulation, and is spun among the leaves or under a piece of bark. The closely allied but smaller hemerobiid larvæ also attack walnut plant lice.

SYRPHID LARVÆ.

Next to the ladybird beetles the larvæ of flies of the family Syrphidæ are of greatest importance in the natural control of walnut aphides. The author has reared the following species of Syrphidæ from larvæ collected while they were feeding on walnut aphides: *Catabomba pyrastri* Linnaeus (1911–12); *Sphærophoria melanosa* Williston (Aug. 24, 1912); *Sphærophoria sulphuripes* Thomson (Oct. 15, 1911); *Allograpta obliqua* Say (Aug. 6, 1912); *Eupeodes volucris* Osten Sacken (July, 1911). *Syrphus opinator* Osten Sacken, and probably other members of this genus, prey on the aphides. *Catabomba pyrastri* is the most abundant as well as the largest of these flies. Its aphidophagous capacity is almost double that of any of the other species enumerated above. Table XI indicates the predatory activities of two larvæ of the last brood of this fly.

TABLE XI.—*Catabomba pyrastri: Predatory activities on walnut plant lice, Santa Jose, Cal., 1912.*

Date.	Number of "lice" eaten by—		Date.	Number of "lice" eaten by—		Date.	Number of "lice" eaten by—	
	Larva No. 1.	Larva No. 2.		Larva No. 1.	Larva No. 2.		Larva No. 1.	Larva No. 2.
Aug. 29	(1)	(1)	Sept. 9	53	59	Sept. 18	92	107
30	4	4	10	65	85	19	50	104
31	15	15	11	76	62	20	36	10
Sept. 2	20	15	12	17	20	21	35	[2] 13
3	12	17	13	70	83	22	[2] 14	....
4	11	17	14	62	77			
5	11	18	15	84	63	Total	959	1,035
6	23	36	16	74	83			
8	68	46	17	71	105			

[1] Hatched on this date. [2] Pupated on this date.

The "lice" consumed were of a similar average size to those eaten by the chrysopid larvæ (Table X). The larva of *Catabomba pyrastri* is pale green, with three longitudinal white stripes the whole length of the body, and when fully extended exceeds half an inch in length. The anterior segments of the body are retractile, giving it a sluglike appearance. If food is plentiful the larva moves but little, although it is capable of rapid crawling over the foliage if food is scarce. A parasite, *Bassus* sp., preys upon it, often destroying as much as two-thirds of a brood and thus reducing its economic value. The maggot of the fly pupates commonly among fallen leaves or rubbish at the base of the tree, forming a light brown puparium (sometimes dark purplish-brown, in which case the specimen is parasitized), with a paler median longitudinal stripe. The adult fly is a large, shining black form, with three interrupted, pale-yellow, arcuate cross-bands (rarely wanting), and is 12 mm. long. Syrphid larvæ may be found preying upon walnut plant lice from May to November, although they are quite scarce in the two extreme months.

Ladybird Beetles (Family Coccinellidæ).

Ladybird beetles are the principal enemies of aphides affecting walnuts. The author has observed the following species feeding on these aphides: (1) *Olla abdominalis* Say; (2) *Adalia melanopleura* Le Conte; (3) *Coccinella juliana* Mulsant; (4) *Adalia humeralis* Say; (5) *Hippodamia convergens* Guerin; (6) *Hippodamia ambigua* Le Conte; (7) *Coccinella californica* Mannerheim; (8) *Adalia bipunctata* Linnæus; (9) *Chilocorus orbus* Casey. Nos. 1 to 8 in both adult and larval stages feed on the plant lice on the leaves, while the adults of the *Chilocorus* occasionally attack the winter eggs on the limbs. Nos. 1 to 4 are the most persistent enemies of the aphides, the others only appearing spasmodically on the trees. The Hippodamia group of lady birds seems to prefer such intensely gregarious plant lice as the plum louse (*Hyalopterus arundinis* Fabricius) or the bean aphis (*Aphis rumicis* Linnæus) and pay much less attention to the more sporadic varieties such as the aphides on walnuts.

Table XII indicates the predatory activities of five larvæ of *Olla abdominalis* (the ashy-gray ladybird.)

Table XII.—*Olla abdominalis: Predatory activities on walnut plant lice, San Jose, Cal., 1912.*

Larva No.	Date of hatching.	Date of molt 1.	Number of "lice" eaten to molt 1.	Date of molt 2.	Number of "lice" eaten, molts 1 and 2.	Date of molt 3.	Number of "lice" eaten, molts 2 to 3.	Date of pupation.	Total "lice" eaten.	Date of adult emergence.
1	Aug. 27	Aug. 30	29	Sept. 2	36	Sept. 5	91	Sept. 13	477	Sept. 22
2	31	Sept. 5	38	9	30	12	45	19	417	25
3	31	5	24	9	33	12	50	18	237	25
4	31	5	35	9	27	12	59	18	234	25
5	31	5	39	9	31	12	53	18	320	25

In all, 1,685 "lice" were eaten in 90 days, or 18.7 "lice" per day per larva. The "lice" were of similar average size to those consumed by the lacewing larvæ (Table X). It was noticed that before the first molt the ladybird larvæ would eat only very small aphides.

The following is a brief account of the stages of the ashy-gray ladybird (*Olla abdominalis*) (Pl. III). *The egg:* Yellow, later becoming orange-colored; cylindrical, long oval, slightly tapering to either end, four times as long as broad; deposited in compact masses of from 5 to 25 on the leaf, usually on the underside, and with their long axis at right angles to the leaf surface; size, 1.3 by 0.35 mm. *The larva:* All black at hatching, later with pale markings, becoming more distinct after each successive molt. After the third molt the general color is dark purplish-black, with a median line of pale brick-red spots on the thorax and abdomen and also two lateral rows of similar spots. On segments 1 and 4 of the abdomen occur also two pale spots, one on either side of the median brick-colored spot and midway between it and the corresponding lateral spot. The full-grown larva has a length of 8 millimeters. *The pupa:* General color white, wing pads sienna brown. A large number of black spots and dashes are present but the prevailing color is white. Average size, 4 by 3.3 mm. *The adult:* Hemispherical, ashy-gray, with black markings, the elytra sometimes diffused with dull reddish blotches; head black, with central portion white or light gray; thorax (pronotum) black, with gray margins; elytra ashy-gray, with eight black spots on each elytron; legs yellow; abdomen reddish-yellow; average size, 5.2 by 4.2 mm. The adults of this species, if confined without food, will devour one another.

Table XIII indicates the predatory activities of two larvæ of *Adalia melanopleura* on walnut plant lice.

TABLE XIII.—*Adalia melanopleura: Predatory activities on walnut plant lice, Walnut Creek, Cal., 1912.*

Larva No.	Date of hatching.	Date of molt 1.	Number "lice" eaten to molt 1.	Date of molt 2.	Number "lice" eaten, molts 1 to 2.	Date of molt 3.	Number "lice" eaten, molts 2 to 3.	Date of pupation.	Total "lice" eaten.	Date of adult emergence.
1	Sept. 17	Sept. 20	41	Sept. 24	38	Sept. 26	30	Sept. 30	181	Oct. 12
2	17	19	35	22	34	25	33	30	194	12

In all, 375 plant lice were eaten in 26 days, or 14.4 per day per larva. The feeding period of both larvæ was 13 days as contrasted with an average of practically 18 days for the larvæ of the ashy-gray ladybird. *Adalia melanopleura* is considerably smaller than that species, its larva consuming in a period of 13 days half as many plant lice as the larva of the larger species will devour in 18 days. This larger species will consume 70 larvæ in a single day while the maggot of the large syrphid fly (*Catabomba pyrastri*) will dispose of over 100 and during the 23 days or so of its existence will devour over 1,000, or about 43.5 lice per day. However, in contrasting the two groups of predaceous insects—Syrphidæ and Coccinellidæ—it must be remembered that the former are aphidophagous only in the larval state while both the adults and larvæ of ladybirds feed on plant lice. Mr. E. K. Carnes,[1] experimenting in the State Insectary at Sacramento, Cal., found that 20 adult beetles of *Hippodamia convergens* averaged 21.8 aphides per day and that the larvæ of this species each consumed from 250 to 300 plant lice during their larval existence. He found that adult females would deposit eggs for from a month to six weeks, laying on the average 15 eggs per day and feeding on the plant lice all the time. Essig [2] states that in the walnut orchards of Ventura County, Cal., *Olla abdominalis*, the ashy-gray ladybird, is by far the most beneficial insect in the natural control of the European walnut aphis (*Chromaphis juglandicola*).

ARTIFICIAL CONTROL OF WALNUT APHIDES.

The writer has been unable, save in one instance,[3] to find any published account of artificial control tried or adopted for walnut plant-lice. Until the year 1910 no such work seems to have been performed along this line.[4] In August of that year Mr. P. R. Jones, late of the Bureau of Entomology, carried out a series of laboratory experiments with a view to determining the efficiency of various washes against these aphides. A small hand pump was fitted with an Eddy-chamber nozzle and the applications made at a medium high pressure. Care was taken that not enough pressure was exerted to kill any of the "lice" by the force of the spray alone. Examinations were made 10 minutes after the applications. From these experiments the following results were obtained:

Commercial tobacco extract No. 2, containing 40 per cent nicotine, at strengths of 1–1,040 to 1–2,048, effective; dilutions weaker than 1–2,048, not effective.

Commercial tobacco extract No. 1 containing about 4 per cent of nicotine at strength of 1–60, effective; dilutions weaker than 1–60, not effective (1–80 partially effective).

Commercial tobacco extract No. 1, at strengths varying from 1–60 to 1–200, combined with a 3 per cent distillate-oil emulsion, effective.

Commercial tobacco extract No. 2 at strengths varying from 1–1,000 to 1–2,650 combined with a 3 per cent distillate-oil emulsion, effective.

Commercial tobacco extract No. 1 at strengths varying from 1–60 to 1–200 combined with a 2 per cent distillate-oil emulsion, effective.

Commercial tobacco extract No. 2 at strengths varying from 1–1,000 to 1–2,620 combined with a 2 per cent distillate-oil emulsion, effective.

Distillate-oil emulsion at 2, 3, and 4 per cent strengths, effective.

Commercial lime-sulphur, 1–50, combined with commercial tobacco extract No. 1, 1–100, effective.

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[1] Sept., 1912. Carnes, E. K. Insectary Division Reports for the months of June and July, 1912. Mo. Bul. Cal. State Hort. Com., v. 1, no. 10, p. 820–828.

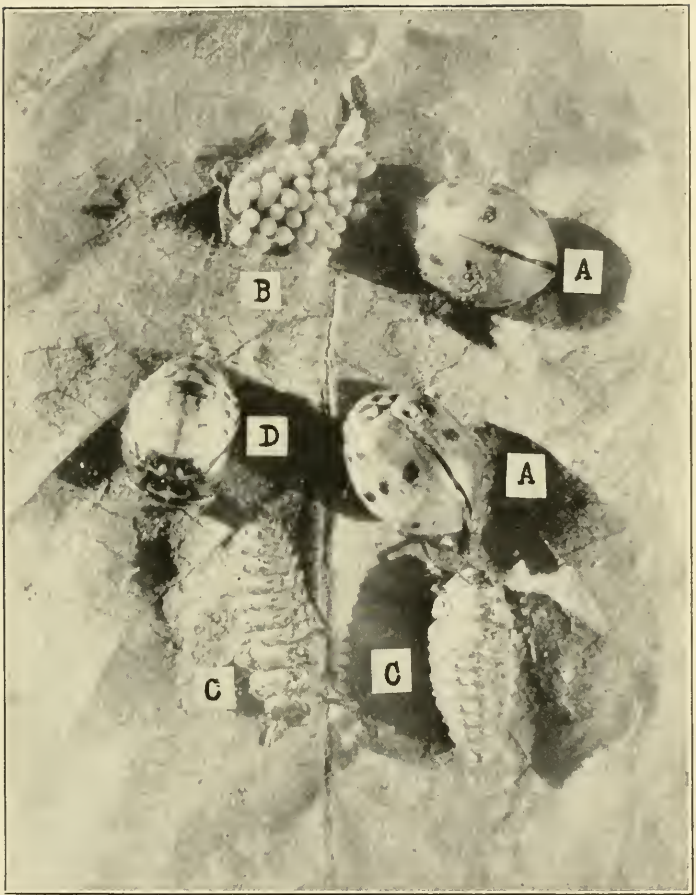
Some experiments with the common ladybird (*Hippodamia convergens*), p. 821–826.

[2] Apr., 1912. Essig, E. O. The walnut plant louse (*Chromaphis juglandicola* [Kalt] Walker). Mo. Bul. Cal. State Com. Hort., v. 1, no. 5, p. 190–194, figs. 72–73.

Control, p. 192.

[3] Cf. Biennial Crop Pest and Hort. Report 1911–1912, Oregon Agr. Coll. Exp. Sta. Jan. 10, 1913, p. 165. "Blackleaf 40" and kerosene emulsion 10 per cent recommended.

[4] Since going to press control experiments undertaken in the spring of 1913 in Southern California by the University of California have been published in Circular 107 of the Agricultural Experiment Station of the University of California.



THE ASHY-GRAY LADYBIRD (OLLA ABDOMINALIS).
[A, adult; B, eggs; C, larva; D, pupa. (After Essig.)]

FIG. 1.—TREE OF THE ROYAL HYBRID WALNUT IN GROVE OF MR. F. LEIB, SAN JOSE, CAL.

FIG. 2.—GENERAL VIEW OF WALNUT GROVE OF MR. F. LEIB, SAN JOSE, CAL.

Commercial lime-sulphur, 1–50, combined with commercial tobacco extract No. 1, 1–200, effective.

Commercial lime sulphur, 1–70, combined with commercial tobacco extract No. 2, 1–1,000, effective.

Commercial lime-sulphur 1–45, combined with commercial tobacco extract No. 2, 1–2,000, effective.

It is noticeable that the weaker solutions of tobacco extracts were not effective alone, but when combined with distillate-oil emulsion or lime-sulphur proved quite satisfactory. Possibly the most successful result was obtained with distillate-oil emulsion of only 2 per cent. Field experiments failed, however, to justify the use of this wash alone, for it proved to lack the killing power found in the tobacco-extract sprays. The emulsion serves, however, as a very good "spreader" for the nicotine killing agent, since it serves to distribute the spray over the leaf surface. Commercial tobacco extract No. 2 proved to have greater insecticidal value than commercial tobacco extract No. 1, judging by the corresponding strengths of the two sprays; and therefore in the field only the former was used. Foliage tests on an Eastern black walnut tree were made of all the washes used in the laboratory experiments, and in no case was any burning observed to result. This type of walnut seems more susceptible to burning injury than does the European or so-called "Persian" walnut.

FIELD EXPERIMENTS.

SPRING AND SUMMER TREATMENT.

Experiment No. 1.—Lime-sulphur (commercial 1–50) combined with commercial tobacco extract No. 2 (1–1,500). Orchard of Mr. I. Du Bois, San Jose, Cal. Two large European walnut trees badly infested with aphides were sprayed July 1, 1911, under an even pressure of 170 pounds. A count made on the following day showed that 95 per cent of the aphides had been destroyed by the wash.

Experiment No. 2.—Three per cent standard distillate-oil emulsion combined with commercial tobacco extract No. 2 (1–2,000). A large, badly infested European walnut tree in the yard of the experiment station at San Jose was treated, July 3, 1911, with this spray at an even pressure of 170 pounds. A count made July 5 showed that over 95 per cent of the aphides had been killed.

Experiment No. 3.—Commercial tobacco extract No. 2 (1–1,500). Orchard of Mr. F. Leib, near San Jose, Cal. (Pl. IV, figs. 1, 2). A block of 10 walnut trees badly infested was sprayed, May 21, 1912, under a pressure fluctuating from 60 to 140 pounds. A count made two days later showed that not over 40 per cent of the "lice" were destroyed.

Experiment No. 4.—Commercial tobacco extract No. 2 (1–1,500) combined with 2 per cent homemade distillate-oil emulsion. Orchard of Mr. F. Leib, near San Jose, Cal. A block of 10 badly infested walnut trees was sprayed, May 21, 1912, under pressure similar to that of experiment No. 3. A count made two days later showed that 98 per cent of the insects had succumbed. Some oil burning appeared on the foliage and nuts owing to insufficient agitation in the preparation of the emulsion and consequent freeing of oil.

Experiments Nos. 3 and 4 were made to determine whether the tobacco extract alone would prove effective in the field. Results indicate that a weak solution of oil emulsion is necessary to act as a "spreader" for the tobacco.

Experiment No. 5.—Distillate-oil emulsion, 2 per cent. Orchard of Mr. F. Leib, near San Jose, Cal. A block of six badly infested walnut trees was sprayed under 110 pounds pressure, July 31, 1912. A count made on August 6 showed that 74 per cent of the "lice" had been destroyed.

Experiment No. 6.—Distillate-oil emulsion, 2 per cent, combined with commercial tobacco extract No. 2 (1–2,000). Orchard of Mr. F. Leib, near San Jose, Cal. (Pl. IV, figs. 1, 2). Six walnut trees, badly infested, were sprayed under a pressure of 110 pounds. A count, made August 6, showed that 85 per cent of the "lice" had been killed by the spray.

Experiment No. 7.—Whale-oil soap, 1 pound; water, 5 gallons. Orchard of Mr. E. I. Hutchinson, Concord, Cal. A block of 12 moderately infested European walnut trees was sprayed under 150 pounds pressure, May 10, 1913. A count made two days later showed that out of 473 "lice" counted, 263, or 55.6 per cent, had been destroyed. A thorough drenching had been applied and the trees were in full leaf. It was noticed that the great majority of the "lice" that escaped were situated close to the base of the midrib. In this position they were partly protected by the projecting rib, and it is to be supposed that the wash lacked the pressure necessary to reach these individuals.

All the foregoing experiments were undertaken on trees on which the foliage was fully developed. It was noticeable that on thickly foliated trees the percentage of plant lice killed was the smallest, while on thinly foliated trees the greatest mortality resulted. Much of the leaf surface on thickly foliated trees is almost inaccessible to spray.

A comparison of the results of the foregoing tests favors distillate-oil emulsion and tobacco. The most desirable combination for spring and summer spraying is a 2 per cent distillate-oil emulsion, commercial or homemade, combined with commercial tobacco extract No. 2, 1 to 1,500. High pressure (150 pounds or over) is desirable, although not absolutely necessary unless the spraying be done before the walnut leaflets have flattened out in spring.

In timing the application for the aphides on the leaves it is desirable to spray as early as possible in order to reduce the amount of leaf surface to be covered by the wash and to destroy the plant lice before they attack the nuts. On the other hand it will be found very hard to destroy the plant lice before the leaflets flatten out, for the young leaflets are pressed against one another in a manner that affords very good protection to the insects from a spray. Moreover at this period all the stem-mother plant lice will not have hatched from the winter eggs. The time most preferable for the application is just as soon as the growing leaflets shall have flattened out and before they have attained their full size. At this time the "lice" have all hatched and are all exposed on the underside of the leaves. Should an oil spray be applied care should be taken that there is no free oil in the emulsion, as the young nuts are susceptible to burning. No stronger than a 2 per cent distillate-oil emulsion should be used for this early application. The spray should be directed to the underside of the leaves, and angle nozzles used. A round nozzle is to be preferred to one of the Clipper type, as the former will diffuse the spray better over the leaf surface. Such a driving-spray nozzle as that devised by the Massachusetts Agricultural College is desirable for spraying trees of large size. If there are unsprayed walnut trees in the vicinity it may be necessary to make a second application some two or three weeks later, as plant lice are apt to have migrated from these to the sprayed trees.

On account of the extended period over which the sexual forms are produced, fall spraying for these forms, unless repeated again and again, will be of little value.

It should be borne in mind that the number of "lice" hatching in the spring from the winter eggs varies considerably year by year in a given locality or orchard and also that the hatching time of these "lice" is regulated by the sap flow in that particular tree upon which the eggs happened to be placed. The hatching of the winter eggs is not regulated by temperature conditions. Hence the stage in the seasonal development of the aphidids corresponds to the stage in development of that particular tree on which the stem-mother lice were produced, leaving out of consideration the possibility of migrants arriving from other trees. This point is of importance when it is considered that the different varieties of cultivated walnuts put out their leaves and produce their nuts at different times and that these functions are performed by individual varieties at different times dependent on locality and seasonal meteorological conditions.

Table XIV summarizes the control experiments made for spring and summer treatment.

TABLE XIV.—*Summary of spring and summer spraying experiments against walnut aphides, San Jose and Walnut Creek, Cal., 1911, 1912, and 1913.*

Character of spray.	Date of application.	Number trees sprayed.	Result of spray; per cent of plant lice killed.	Cost per diluted gallon.
Commercial lime-sulphur, 1-50 and commercial tobacco extract No. 2 (1-1,500)	July 1, 1911	2	95	$0.012
3 per cent distillate-oil emulsion (homemade) and commercial tobacco extract No. 2 (1-2,000)	July 3, 1911	1	95	.0088
Commercial tobacco extract No. 2 (1-1,500)	May 21, 1912	10	40	.008
2 per cent distillate-oil emulsion (homemade) and commercial tobacco extract No. 2 (1-1,500)	do	10	98	.0098
2 per cent distillate-oil emulsion (commercial)	July 31, 1912	6	74	.0067
2 per cent distillate-oil emulsion (commercial) and commercial tobacco extract No. 2 (1-2,000)	do	6	85	.0127
Whale-oil soap (homemade), 1 pound to 5 gallons water	May 10, 1913	12	55.6	.004

WINTER TREATMENT.

Experiment No. 1.—Crude-oil emulsion, 12 per cent (crude oil, 27° Baumé). Orchard of Mr. George Whitman, Concord, Cal. A block of 31 European walnut trees of moderate size were sprayed February 25, 1913, under a pressure of from 150 to 175 pounds. Three gallons of spray were applied to each tree and "Friend" nozzles used. The trees were well drenched. Examination made April 5, 1913, showed that trees were starting to leaf. Most of the leaves were as yet tightly closed, but the basal leaves of many shoots were opened. A general survey of the sprayed block and of a check unsprayed block indicated equal infestation by young stem mothers. Plant lice were not all hatched. An examination made April 15, 1913, showed that trees were well out in leaf. All stem mothers had hatched. A general survey of sprayed and unsprayed trees showed no apparent difference in infestation. A count of 28 leaf clusters selected at random from the sprayed trees yielded 21 stem mothers, while a similar count of the same number of leaf clusters from unsprayed trees yielded 29 stem mothers. It may be inferred from this experiment that the crude-oil emulsion destroyed few, if any, of the winter eggs.

Experiment No. 2.—Commercial lime-sulphur, 1–10. (Concentrated solution, 33° Baumé.) Orchard of Mr. George Whitman, Concord, Cal. A block of four large trees of the European walnut were sprayed March 5, 1913, under a pressure of 100 pounds. About 14 gallons of spray were applied to each tree and "Friend" angle nozzles used. Eggs were abundant on both sprayed and check trees. The leaf buds on these trees began to open April 1, 1913. Examination was made April 15, 1913. Trees were then well out in leaf. The stem mothers were all hatched. The lime had no effect in retarding leafing. A count of 20 leaf clusters taken at random on the sprayed block yielded no plant lice, while a similar count of the same number of leaves on the check trees yielded 27 stem mothers. Further examination showed that on the sprayed trees no plant lice could be found, while on the check trees nearly every leaf cluster had one or more of the insects.

A subsidiary experiment was undertaken on two young California black walnut trees, both infested with eggs. One of these trees was treated with commercial lime-sulphur, 1–9 (concentrated solution 33° Baumé), and the other left as a check. On the sprayed tree no eggs hatched and when examined on April 17, 1913, the eggs were shrunken and distorted, the embryos having been destroyed within the eggshell. The eggs on the check tree hatched normally about the end of March.

Experiment No. 3.—Crude-oil emulsion, lime-sulphur, and "Yel-ros." Vrooman orchard, Santa Rosa, Cal. Four plats were sprayed, April 9–11, 1913, with a power outfit at high pressure, as follows: Plat 1, 40 trees, crude oil (22° Baumé) emulsion, 8 per cent; plat 2, 40 trees, lime-sulphur, 1 to 8; plat 3, "Yel-ros," 1 to 25, 16 trees; plat 4, "Yel-ros," 1 to 40, 24 trees. These applications were made on late Franquette walnuts, dormant at the time of spraying. The orchard was well infested with the winter eggs of the plant lice. An examination, May 27, 1913, showed that the trees were well out in leaf. Stem mother plant lice were mostly about two-thirds grown. Counts of 80 leaves (about 480 leaflets) taken at random from each of the four plats and from a check unsprayed plat resulted as follows:

TABLE XV.—*Winter spraying experiment No. 3 against walnut aphides, Vrooman orchard, Santa Rosa, Cal., 1913.*

Plat.	Number of "lice" on 80 leaves.	Per cent of number on check.
Crude-oil emulsion, 8 per cent	11	10.6
Lime-sulphur, 1 to 8	2	1.9
"Yel-ros," 1 to 25	14	13.4
"Yel-ros," 1 to 40	97	93.2
Check—unsprayed	104	100.0

The best results, therefore, were obtained by the lime-sulphur wash. The greater efficiency of the 8 per cent crude-oil emulsion over the 12 per cent crude oil used in experiment No. 1 is probably due to the heavier grade of oil (22° Baumé) used in the 8 per cent experiment. The heavier oil remains longer on the trees and coats the eggs of the aphides more satisfactorily than the oil of lighter grade. As may be seen from Table XVI both the 8 per cent crude-oil emulsion and "Yel-ros," 1 to 25, gave good results, but "Yel-ros," 1 to 40, was quite ineffective. Table XVI is a summary of experiments against the winter eggs:

TABLE XVI.—*Summary of experiments on the winter eggs, Walnut Creek and Santa Rosa, Cal., 1913.*

Character of spray.	Date of application.	Number of trees sprayed.	Date of examination.	Plant lice present (check—100).	Cost per diluted gallon.
				Per cent.	
Crude-oil (27° Baumé) emulsion, 12 per cent	Feb. 25	31	Apr. 5, 15	72.4	$0.01
Commercial lime-sulphur, 1 to 10	Mar. 5	4	do	.0	.02
Crude-oil (22° Baumé) emulsion, 8 per cent	Apr. 9-11	40	May 27	10.6	.0073
Commercial lime-sulphur, 1 to 8	do	40	do	1.9	.025
"Yel-ros," 1 to 25	do	16	do	13.4	.028
"Yel-ros," 1 to 40	do	24	do	93.2	.0175

It is in a measure unfortunate that the homemade 1–2–1 lime-sulphur spray was not tried. This is considerably cheaper than the commercial article, but there is no reason to suppose that the winter formula of the homemade lime-sulphur would not prove quite effective judging by the results obtained with commercial lime-sulphur.

In recommending winter sprays for the plant lice infesting walnut trees the writer must accord the preference to lime-sulphur, 1–8 to 1–11, while good work may be expected from crude-oil emulsion, 8 to 12 per cent, using the heavier grades of oil (not lighter than 24° Baumé), and from "Yel-ros," 1–25. The oil emulsion (homemade) is the cheapest winter spray, although there is little difference between its cost and that of the homemade lime-sulphur wash, winter formula.

In applying the spray for the aphis eggs the wash should be directed so as to cover completely every part of the twigs and limbs. Late spraying, i. e., making the application just before the buds are beginning to swell, is preferable to spraying earlier, especially if crude-oil emulsion is used, as the oil does its best work soon after it is applied and the plant lice at hatching time are more easily destroyed by it.

In concluding the section on artificial control the author would like to express his thanks to Mr. Frank Leib, San Jose, Cal., and Messrs. George Whitman and E. I. Hutchinson, Concord, Cal., for their help and cooperation in the carrying out of field experiments on their orchards, and also to Balfour, Guthrie & Co., San Francisco, Cal., by whose courtesy the Santa Rosa experiments were made possible, they having made the spray applications under the author's supervision.

SUMMARY.

The life history of walnut aphides in California is briefly as follows: A week or so before the buds open on the trees in the spring the aphidids begin to hatch from the winter eggs. As soon as the young foliage appears the "lice" settle on it, and after feeding for a month or so become adults. These stem mothers are always winged and like plant lice of later generations are capable of migrating to other trees and orchards. As soon as they are fully developed they produce young parthenogenetically. These second-generation young become mature in three weeks and in turn produce young. The individuals of the third and subsequent generations of summer mature in about 16 days. On early-leafing varieties there are 10 or 11 viviparous generations in the year while on late varieties there are 8 or 9. The production of the sexual generation is prolonged over four months, these forms first appearing in July. After the sexes (comprised of the winged male and the wingless female) mate, the female repairs to the twigs and limbs of the tree, there to deposit her eggs. Winter is passed in the egg stage only.

In general the aphidids inhabit the underside of the leaves, but those of the second, third, and fourth generations often attack the nuts, sometimes seriously dwarfing them (see Pl. I, fig. 1). Occasionally the "lice" will be found on the upper surface of the leaf. When infestation on the leaves and nuts is severe the vitality of the infested tree is impaired. The aphidids excrete a sweet, gummy, transparent substance much sought after by ants, and in this thrives a black sooty fungus. This black fungus often covers the upper sides of the lower leaves and the upper part of the nuts, thereby interfering with the respiratory action of the plant tissues.

Walnut plant lice have many natural foes, all predatory. These serve to keep the aphidids in check but do not appear in sufficient numbers until after the "lice" have had time to injure the nuts. The most persistent of them is the ashy-gray ladybird beetle (*Olla abdominalis* Say).

Aphidids on walnuts can be controlled artificially with sprays. The winter spraying directed against the eggs is the easier to apply, and high trees can be reached by a winter wash with ease, whereas in the spring and summer so thick is the foliage that a thorough application is hard to accomplish satisfactorily. Furthermore, far less material is required when the trees are bare. Lime-sulphur and crude-oil emulsions are effective, especially the first named. The spray should be directed all over limbs and twigs so as to cover every part. If it is necessary to spray in spring or summer, a combination of 2 per cent distillate-oil emulsion and commercial tobacco extract No. 2 (1 to 1,500) will prove effective provided it be applied under a pressure of at least 150 pounds and the spray directed on the nuts and underside of the leaves.

BIBLIOGRAPHY.

CHROMAPHIS JUGLANDICOLA Kaltenbach.

1843. Kaltenbach, J. H. Monographie der Familien der Pflanzenlause . . . Aachen, 1843.

"*Lachnus juglandicola.*" Original description, with colored figures.

1857. Koch, C. L. Die Pflanzenläuse Aphiden, Nürnberg, 1854–1857.

"*Callipterus juglandicola* Koch," p. 224, fig. 297, 1857. Description and colored figures.

1860. Passerini, Carlo. Gli Afidi, Parma, 1860.

"*Callipterus juglandicola* Kalt." recorded.

1870. Walker, Francis. Notes on aphides. Zoologist, ser. 2, v. 5, pp. 1996–2001, Feb., 1870.

"*Callipterus juglandis,*" p. 2000; Callaphis proposed, p. 2000. "*Chromaphis peglandicola,*" p. 2001. Genus Chromaphis erected.

1881. Buckton, G. W. Monograph of the British Aphides, v. 3, London, 1881.

"*Pterocallis juglandicola* Kalt.," p. 32–34. Description and colored plate.

1906. Schouteden, H. Catalogue des Aphides de Belgique. Mem. Soc. Ent. Belg., v. 12, pp. 189–246.

"*Callipterus juglandicola* Kalt.," p. 209–210. Recorded.

1909. Essig, E. O. Aphididæ of southern California, II. Pomona Col. Jour. Ent., v. 1, no. 2, pp. 47–52, June, 1909.

"*Callipterus juglandicola* Koch," p. 51–52. Description and figures.

1910. Gillette, C. P. Plant-louse notes, family Aphididæ (continued). Jour. Econ. Ent., v. 3, no. 4, pp. 367–371, pl. 24.

"*Chromaphis juglandicola,*" p. 367, fig. 4. Note of occurrence and figure of antenna of winged female.

1910. Wilson, H. F. A key to the genera and notes on the synonymy of the tribe Callipterini, family Aphididæ. Canad. Ent., v. 42, no. 8, pp. 253–259, Aug., 1910.

"*Chromaphis juglandicola* Kalt.," pp. 257–258. Refers to Walker's erection of the genus Chromaphis.

1912. Essig, E. O. The walnut plant louse (*Chromaphis juglandicola* (Kalt.) Walker). Mo. Bul. Cal. State Com. Hort., v. 1, no. 5, pp. 190–194, figs. 72–73, April, 1912.

Description and figures, natural control notes.

1913. Wilson, H. F., and Lovett, A. L. Miscellaneous insect pests of orchard and garden. Bien. Crop Pest and Hort. Rpt. 1911–12, Oregon Agr. Col. Expt. Sta., pp. 147–165.

"*Chromaphis juglandicola* Kalt.," p. 165. Note of occurrence and remedies.

MONELLIA CARYÆ Monell.

1879. Monell, J. Notes on the Aphididæ of the United States, Part II. Notes on Aphididæ, with descriptions of new species. U. S. Geol. and Geog. Survey Bul. 5, no. 1, pp. 18–32, Jan. 22, 1879.

"*Callipterus caryæ*, n. sp.," p. 31. Original description.

1879. Thomas, Cyrus. Eighth Report of the State Entomologist on the Noxious and Beneficial Insects of the State of Illinois, Springfield, 1879.

"*Callipterus caryæ*, n. sp.," p. 199. Note of occurrence.

1910. Williams, T. A. The Aphididæ of Nebraska. Nebr. Univ. Studies, v. 10 no. 2, pp. 85–175, April, 1910.

"*Callipterus caryæ* Monell," p. 115. Description and note of occurrence.

1910. Gillette, C. P. Plant-louse notes, family Aphididæ (continued), pl. 24. Jour. Econ. Ent., v. 3, no. 4, pp. 367–371, Aug., 1910.

"*Monellia caryæ,*" p. 367. Note of occurrence and figure.

1910. Davis, J. J. A list of the Aphididæ of Illinois, with notes on some of the species. Jour. Econ. Ent., v. 3, no. 5, p. 407–420, Oct., 1910.

"*Callipterus caryæ* Monl.," p. 417. Note of occurrence.

MONELLIA CARYELLA Fitch.

1855. Fitch, Asa. First Report on the Noxious, Beneficial, and other Insects of the State of New York, Albany, 1855.

"*Aphis caryella* Fitch," pp. 163–165. Original description.

1856. Fitch, Asa. Third Report on the Noxious and other Insects of the State of New York, Albany, 1856.

"Hickory gay-louse, *Callipterus caryellus* Fitch," pp. 448–449. Short description.

1862. Walsh, B. D. On the genera of Aphididæ found in the United States. Proc. Ent. Soc. Phila., v. 1, pp. 294–311.

"*Callipterus caryellus* Fitch," p. 302. Reference.

1879. Thomas, Cyrus. Eighth Report of the State Entomologist on the Noxious and Beneficial Insects of the State of Illinois, Springfield, 1879.

"*Callipterus caryellus* Fitch," pp. 170–171. Note of occurrence.

1887. Oestlund, O. W. Synopsis of the Aphididæ of Minnesota. Geol. and Nat. Hist. Survey Minn. Bul. 4.

"*Monellia caryella* Fitch," p. 45. Genus Monellia erected. Note of occurrence.

1910. Davis, J. J. A list of the Aphididæ of Illinois, with notes on some of the species. Jour. Econ. Ent., v. 3, no. 5, pp. 407–420.

"*Monellia caryella* Fitch," p. 419.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 104

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
July 10, 1914.

THRIPS AS POLLINATORS OF BEET FLOWERS.

By Harry B. Shaw,
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INTRODUCTION.

While conducting breeding experiments with sugar beets during a period of more than five years, it could never be observed that the beet flower, despite the pungent fragrance of its nectar and the remarkable abundance of its pollen, attracted nearly as many insect visitors as numerous blooms offering less pronounced attractions. Especially significant was the rarity of the visits of the honeybee and other common species of Hymenoptera. It appeared as though nature had vainly provided powerful insect lures, excepting only those of conspicuous size and color. It is true that insects, some of them capable of transferring pollen from flower to flower, do visit beet flowers, but relatively their numbers are small and their visits few.

These breeding experiments necessitated the isolation and hand pollination of numerous beet flowers. Not infrequently, in spite of careful technic, it was found that single flowers which had been emasculated and protected by paper bags from pollination became fertilized and produced seed in a manner at the time inexplicable. Although the actual percentage of such cases was small, it was sufficient to attract attention and to cast doubt upon the thoroughness of the protection afforded by the bags. Not only is the beet flower protandrous, but numerous attempts of the writer to effect close fertilization by preserving the pollen until the stigma of the same flower should become receptive, then applying the pollen, have failed. The above-mentioned fertilization, therefore, could not have been accomplished by pollen from any one of the single flowers operated on, even had such pollen reached the stigma; in other words, the beet flower can not be self-fertilized. The most probable explanation for the fertilization of these isolated flowers was the

Note.—The investigations and experiments reported in this bulletin are of interest to horticulturists and plant breeders.

unobserved access of minute pollen-bearing insects. None of the common visiting insects other than thrips is minute enough to gain entrance through the interstices between the mouth of the paper bag and the stem when the bag is tied closely about the beet spike. Thrips, however, are so tiny as scarcely to be visible to the naked eye, the mature larvæ being about $\frac{1}{27}$ inch long and only about $\frac{1}{70}$ inch long immediately after hatching; hence it seemed probable that some of these insects might have crawled up within the mouth of the tied bags and dropped on the stigmata of the isolated flowers some of the pollen they were carrying.

OCCURRENCE OF THRIPS ON BEET FLOWERS.

Besides several other species not identified, the Bureau of Entomology determined the following among specimens of thrips col-

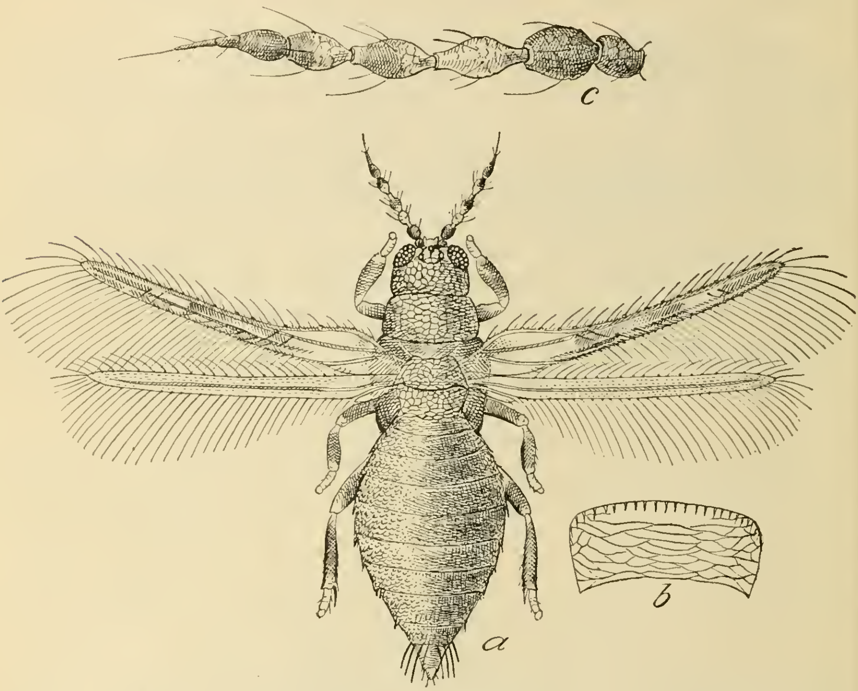

FIG. 1.—The bean thrips (*Heliothrips fasciatus*): *a*, Adult female; *b*, ventral side of abdominal segment of same; *c*, antenna of same. *a*, Greatly enlarged; *b*, *c*, more enlarged. (After Russell.)

lected from beet flowers at Garland, Utah, in 1909 and 1910: *Heliothrips fasciatus* L. (fig. 1), *Frankliniella fusca* Hinds, and *Frankliniella tritici* Fitch. The species most abundant during the seasons of 1911 and 1912 at Ogden, Utah, was *Thrips tabaci*, the onion thrips. The few observed at Jerome, Idaho, during the summer of 1913 have not yet been determined.

At Garland the seed beets were grown near fields of alfalfa, whence many of the thrips found on beets doubtless migrated, the same species

THRIPS TABACI DISLODGED FROM THE BEET FLOWERS SHOWN IN PLATE II.
NATURAL SIZE. (ORIGINAL.)

BRANCHED SPIKE OF BEET FLOWERS FROM WHICH THE THRIPS SHOWN IN PLATE I WERE DISLODGED. NATURAL SIZE. (ORIGINAL.)

being exceedingly abundant in alfalfa blossoms. In Ogden the experimental plats were located in the heart of a trucking district, where many onions and other general truck crops are grown. At Jerome the beet plats were surrounded by alfalfa fields. At Garland these insects were fairly abundant. At Ogden in 1911 they were very abundant. This may be better appreciated by a glance at Plate I, which shows the thrips that were dislodged from the small branched spike depicted in Plate II after the spike of flowers had been exposed for a short time to the fumes of chloroform. Before the thrips had recovered from anesthesia the spike and its branches were distinctly outlined by the stupefied insects. Notes taken at the time read as follows:

August 7, 1912.—After treatment with chloroform, 85 thrips fell from a spike possessing 80 open flowers; from another branched spike 190 thrips were dislodged.

Inspection of beet flowers sometimes revealed as many as five or six thrips in a single perianth.

FIG. 2.—Side view of the head of a thrips, showing the mouth parts. Much enlarged. (After Moulton.)

In 1912, on the site of an old Chinese truck garden at Odgen, thrips became extraordinarily numerous during the late blooming period, when they fairly swarmed in and about the beet flowers. It was then ascertained that in addition to drinking the nectar and devouring the pollen they may also injure the floral organs.

Earlier studies of the injurious effects of various sucking insects, including aphides, red spiders, and thrips, on sugar beets, had established the fact that the last-named insects sustain their unenviable character on sugar beets also; they cause on young sugar beets a great diversity of leaf curls and distortions. On the spikes and bractlets of seed beets small silvery scars may be found as a result of their attacks. The thrips is more destructive than most sucking insects, because, not satisfied with merely puncturing, it tears and grubs up the surface tissues of its food plants with its powerful mouth cones, or proboscis (fig. 2), in order to release a more copious flow of the plant juices.[1] It reminds one of the actions of a hog.

These studies were extended to the observation of thrips on the inflorescence of sugar beets. The spikes and spikelets of the sugar beet, with their closely arranged spirals of flower clusters, are very numerous and afford excellent hiding places for these insects. It was found that as the period of most abundant bloom approached, thrips became increasingly numerous, partly through migration from

[1] Moulton, Dudley. The pear thrips and its control. United States Department of Agriculture, Bureau of Entomology, Bulletin 80, pt. 4, p. 54, 1912.

other plants, but more especially through breeding. Eggs are deposited and hatched on the spikes themselves. On hatching, the young larvæ quickly seek the flowers, doubtless attracted by the pungent fragrance of the nectar, and literally wallow in the nectar and pollen, avidly drinking the one and voraciously devouring the other.

Observations covering five seasons have shown that several species of Thysanoptera visit beet flowers and that the number of individuals varies greatly with the locality and general environments, notably with the crops in the vicinity. At Jerome, Idaho, in 1913, on land only recently cleared from sagebrush, thrips were rather scarce, although somewhat abundant in alfalfa in near-by fields. These insects have also been seen in moderate abundance on seed beets in Indiana and Michigan.

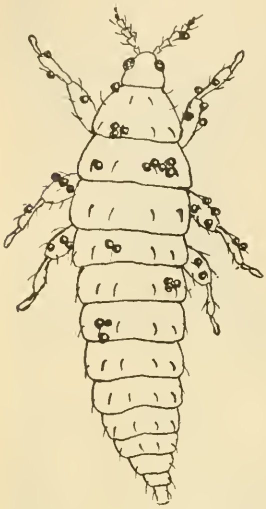

FIG. 3.—Larva of *Thrips tabaci* (second stage) taken from a sugar-beet flower. The insect carries numerous beet-pollen grains on its body. × 50. (Sketch of the larva after Russell.)

THRIPS AS POLLEN BEARERS.

The writer has been able to discover in the literature very little reference to thrips as a pollen bearer and no proof of its ability to bring about the fertilization of flowers.

Darwin was familiar with the visits of thrips and kept in mind the possibility that they might gain entrance through his nets.

Hermann Müller [1] records their occurrence in the flowers of several genera and species, but does not mention beets. In a paragraph on Thysanoptera he says that "probably few flowers, if any, are altogether exempt from their visits, and though they have seldom been detected in the conveyance of pollen, yet from their great abundance, their value as fertilizers must not be overlooked. It is almost impossible to exclude these tiny insects by means of nets. The Thysanoptera seek both pollen and honey. They seize a single pollen grain in their mandibles and convey it to the mouth."

Uzel,[2] in Bohemia, has noted the visits of several species of Thysanoptera among sugar and stock beets, but adduces no evidence in proof of the actual pollination of those flowers by thrips.

On August 3, 1911, at the experimental plats in Ogden, Utah, spikes of beet flowers were exposed to the fumes of chloroform to

[1] Müller, Hermann. The fertilisation of flowers. Tr. and ed. by D'Arcy W. Thompson, London, 1883, p. 44–45.

[2] Uzel, Heinrich. Über die Insekten, welche die Blüten der Zucker- und Futterrübe besuchen. Zeitschrift für Zuckerindustrie in Böhmen, Jahrg. 37, p. 182–197, 1913.

dislodge insects that might be harboring in them. As already stated, thrips in unsuspected number were thus removed. (Pls. I and II.) A microscopic examination of many of these—larvæ and adults—showed that without exception beet pollen grains were present on their bodies (fig. 3).

The original notes under this date are as follows:

August 3, 1911.—Discovered that *Thrips* sp. [later determined as *Thrips tabaci*] are exceedingly numerous on and among beet flowers. Some spikes were collected, and absorbent cotton sprinkled with chloroform was held over them to stupefy any insects that might be present. Thrips fell off and were microscopically examined. Without exception, each bore among its body hairs numerous sugar-beet pollen grains. Some open flowers were then examined, and thrips, as they recovered from their stupor, were observed to enter the perianth, where they moved about quite actively, traveling over every part. Many pollen grains were picked up by the insects' body hairs, others were dropped; pollen was also transferred from one insect to another when they came in contact one with another.

Almost at the close of the blooming period of beets, counts were made of the pollen grains borne by a number of thrips dislodged with chloroform from beet spikes, as shown in Table I.

TABLE I.—*Beet pollen grains on thrips, near the close of the blooming period.*

Stage of development of the insect.	Number of grains found on surface indicated.		
	Dorsal.	Abdominal.	Total.
Nymph	30	10	40
Adult	62	78	140
Do	53	82	135

These pollen grains were distributed over every part of their bodies, even along the antennæ. Nor do these figures represent unusual individuals. The blooming period was practically over at this time; pollen was therefore not very abundant. Both larval and adult thrips have since been seen to be literally covered with beet pollen.

EXPERIMENTS IN THE POLLINATION OF BEET FLOWERS.

The foregoing results were both interesting and surprising, and at once suggested, among others, the following queries:

(1) Do the thrips in this instance redeem themselves from their hitherto wholly evil reputation by playing an essential, or even an important, rôle in the fertilization of beet flowers? Or, do they simply convey pollen from one flower to another on the same plant and thus effect close pollination only? [1]

[1] Other experiments have shown close pollination of beet flowers to be almost absolutely ineffective in bringing about fertilization, which is undesirable even when successful. Self-fertilization is not possible. The term "self-fertilization" is here used to mean that resulting from the pollen of the same flower; "close pollination," or "close fertilization," that effected by the application of pollen from one flower to another on the same plant; "cross-pollination," that between any two plants.

(2) Inasmuch as they consume large quantities of pollen, do they thus work injury to beets?

(3) Do they injure the floral organs of beet flowers?

To be effective agents in the fertilization of beet flowers, they must do more than convey pollen from one flower to another on the same spike, stem, or plant; they must bring about true cross-pollination.

Although already late in the season when the foregoing observations were made, experiments were at once planned to ascertain whether pollination and fertilization might be effected through the agency of thrips. To this end several vigorous seed beets, still in bloom, were selected. On August 7 and 8, 1911, the largest buds on a number of spikes were emasculated, the smaller and more immature buds being trimmed off. This work was done at the stage when the sepals were just about to separate at the tips and disclose a tiny yellow spot of the anthers, and it was performed under a pollinating tent in order to exclude flying insects and wind-carried pollen (fig. 4). As each set of buds was emasculated it was at once covered with a white manila paper bag, 4 by 6 inches in size. A tuft of absorbent cotton was first wrapped carefully about the spike some inches below the buds. The bag was then drawn over the spike until the emasculated buds were situated inside the bag near the top, while the mouth of the bag reached well below the buds and came in contact with the wrapping of cotton. The mouth of the bag was then folded diagonally in such a manner as to pinch the cotton-wrapped stem in one corner; then it was folded a second time to make tight contact. Metal clips were finally set along the edge of the double fold to secure it (fig. 5). The stems bearing these spikes were tied to stakes to prevent too much movement and to keep them in an upright position. Before covering the spikes a close search was made for thrips or other small insects, any such being removed. The stigmata of these flowers became receptive three days later. Thrips were then collected from other beet flowers into small vials. As each lot was collected it was immediately transferred to one of the bagged spikes.

FIG. 4.—Pollinating tent of white sheeting, which may be completely closed and secured with hooks and eyes or buttons. (Original.)

FIG. 1.—FLOWERS OF SUGAR BEETS TO WHICH THRIPS HAD ACCESS. NATURAL SIZE. (ORIGINAL.)

FIG. 2.—SPIKES OF SUGAR-BEET FLOWERS ON CHECK PLANTS, WHICH REMAINED STERILE. NATURAL SIZE. (ORIGINAL.)

To accomplish this a slit was made in one side of the bag at least 2 inches below the buds of the inclosed spike, so that no pollen or thrips might fall upon the flowers when the vial was inverted over the slit, and the pollen-bearing thrips were jarred downward into the bag. This being done, the slit was closed with adhesive plaster, leaving the inclosed thrips free to seek the nectar and distribute the pollen they carried. About 25 thrips were put in each bag.

Three forms of control or checks were employed at this time:

(1) Spikes of emasculated buds were isolated, as above described, and left undisturbed.

(2) Similar spikes were isolated, and when the inclosed flowers had become receptive, slits were made in the bag and at once closed without introducing thrips.

(3) Spikes of buds were prepared as for emasculation and isolated without that operation being performed. These also were then left undisturbed.

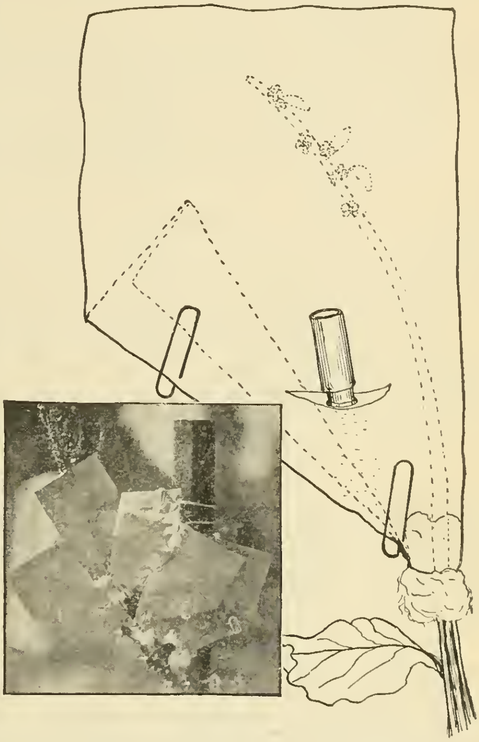

FIG. 5.—Spikes of beet flowers isolated by means of paper bags, showing the method of admitting pollen-bearing thrips through an opening. (Original.)

One month later, all the bags were opened to examine the inclosed flowers. The time had been too brief for the maturation of seed, but it was ample for fertilization and for the development of seed to the milky stage. The results were as follows:

Every flower on the checks remained sterile, the sepals of some remaining green. In other cases the entire flower had withered (Pl. III, fig. 2). Among those to which thrips had been introduced, one set of flowers was lost; of a second set, 16.66 per cent of the flowers became fertilized and produced seed; a third showed 20 per cent of fertilization; and a fourth, 28.6 per cent. For the entire set, the percentage of effective pollination by thrips was 20.37 (Pl. III, fig. 1).

On August 26, 1911, eight spikes of wild-beet flowers were similarly treated. Three of these were used as checks. Thrips were placed with the others in the manner above described. Some of these spikes were afterwards broken off, but of those remaining none of the checks became fertilized; of those to which thrips had been admitted only one remained, and 20.5 per cent of its flowers had been fertilized and produced seed.

The flowers of a beet spike open successively; therefore, few at any one time attain the same stage of development. This fact not only limits the number of available buds on each spike, but also may reduce the percentage of effective hand pollination as much as 50 per cent. The above results may therefore be considered not only positive, but surprising. The complete notes of the results of this experiment are shown in Table II.

TABLE II.—*Pollination of beet flowers—experiment of August 26, 1911.*

Spike.	Description.	Flowers.		Seeds.		Remarks.
		On spike.	Sterile.	Number.	Per cent.	
No. 1a	Check	22	22	0	0	Not emasculated; spike dry and brown.
No. 2a	do	14	14	0	0	Do.
No. 2b	do	36	36	0	0	Emasculated.
No. 2c	do	22	22	0	0	Do.
No. 3a	do	10	10	0	0	Emasculated; stems and flowers green.
	Total	104	104	0	0	
No. 3b	Thrips admitted	7	5	2	28.6	
No. 3c	Missing					
No. 4a	Thrips admitted	12	10	2	16.66	
No. 4b	do	35	28	7	20.00	
	Total	54	43	11	20.37	For the entire set.
	Wild beets.					
No. 1	Check					
No. 2	do					
No. 4	do		All.	0	0	Broken off.
No. 3	Thrips admitted					Do.
No. 5	do					Do.
No. 6	do					Do.
No. 7	do					Do.
No. 8	do	24	19	5	20.83	

During the following season two similar experiments were carried out. The first experiment was made on June 26, 1912, when the plants were flowering abundantly. On this date two spikes were prepared as already described, except that the additional precaution was taken to spray thoroughly all parts of the flowers and spikes with water from an atomizer to remove any thrips that might be hidden there. Three days later thrips were collected and transferred to the bags. A month later complete notes were made, with the results shown in Table III.

On July 12, 1912, the second experiment was started in the same manner with three spikes, and a month later the data shown in Table III were secured.

These experiments demonstrate that thrips transferred from one flowering beet to another may carry sufficient pollen on their bodies to effect fertilization.

TABLE III.—*Pollination of beet flowers—experiments of June 26 and July 12, 1912.*

Experiment of June 26, 1912.						Experiment of July 12, 1912.					
Spike.	Description.	Flowers.		Seeds.		Spike.	Description.[1]	Flowers.		Seeds.	
		On spike.	Sterile.	Number.	Per cent.			On spike.	Sterile.	Number.	Per cent.
No. 1	Thrips admitted	18	6	12	66.66	No. 1	Thrips admitted	13	8	5	38.46
No. 2	....do	14	4	10	71.14	No. 2	....do	20	17	3	15
						No. 3	Check	20	20	0	0
	Total[2]	32	10	22	68.75						

[1] Of the 33 flowers to which thrips were admitted in this experiment, 24.24 per cent are shown to have been fertilized, while all the checks remained sterile.
[2] For entire set.

CROSS-POLLINATION BY THRIPS.

As already stated, other studies have shown that close pollination of beets rarely results in fertilization and that self-fertilization does not take place. To be of service to beets, thrips must therefore bring about cross-pollination. The writer has found the impression rather general that thrips do not travel from plant to plant to any great extent. On this point the following evidence from the writer's notes is available:

July 19, 1912.—A great number of thrips had been shaken from seed beets in full bloom into a large pan. In the slanting rays of the evening sun many of the adults, which are winged, could be seen to fly from the collecting pan and alight on adjacent plants. Their flight was sustained and fairly steady, though not nearly so rapid as that of gnats.

July 21, 1912.—Since attention was attracted to the flight of thrips, careful watching, when their wings glitter in the evening sunshine, revealed the fact that their flight from plant to plant is voluntary and frequent; this flight is well sustained, though very slow. They were seen to travel not only from one plant to the next, 4 feet away, but to more distant ones. The flight of many of these thrips was intercepted by a sheet of white paper, upon which they alighted. Some of them were chloroformed and examined. Pollen at this time was not very abundant, because the plants were long past the time of maximum bloom. Counts were made showing that 5 different thrips carried grains of pollen, as follows: No. 1, 5 grains; No. 2, 44 grains; No. 3, 3 grains; No. 4, 38 grains; No. 5, 4 grains.

July 23, 1912.—An examination of the seed beets in plat 2, where seed is almost ripe, showed an absence of thrips. The number of these insects on the plants now in bloom in plat 1 is immense. [Plat 1 lies about 50 feet north of plat 2. Many beets in plat 1 were planted later than those in plat 2 and were therefore still in bloom.] Thrips were fairly numerous in plat 2 when the plants there were in bloom; therefore it would appear that thrips migrate some distance in pursuit of pollen and nectar. An examination of plants in plat 1, some of which had been planted earlier than others, showed the earlier planted ones, now without bloom, to be devoid of thrips.

This study established the fact that not only are thrips capable of collecting and carrying pollen on their bodies and of effecting cross-pollination and subsequent fertilization when transferred from one flowering beet to another, but that they voluntarily travel from plant to plant and carry pollen throughout a sustained flight.

From this evidence there can remain no doubt that these insects are capable of playing an important rôle in the pollination of beet flowers. May it not be a very significant one? It is known that in certain parts of Europe and the United States beets have sometimes, perhaps frequently, failed to produce seed, although an abundance of bloom appeared. It seemed possible that the presence or absence of thrips in great number might in part be responsible for this phenomenon. Subsequent observations, however, afford evidence in disproof of this theory. It is safe to say that thrips undoubtedly assist in the pollination of beet flowers, perhaps to a greater extent than any other species of insect. It can scarcely be doubted that they perform a like service for many other plants.

INJURY TO SEED BEETS.

Thrips feed avidly upon the nectar and pollen of beets, but beet pollen is so abundant that unless thrips be present in enormous numbers they apparently do no damage to the floral organs, preferring as food the nectar and pollen. However, should they become extraordinarily numerous, as was the case at Ogden in 1912 during the latter part of the season, it would seem that the nectar and pollen are not sufficiently abundant to supply their truly voracious appetites. They then attack the more delicate and succulent parts of the flowers. Sometimes the styles are cut through at the base, but more frequently the papillæ, with which the lobes of the stigma are thickly studded, are torn to pieces. Furthermore, they may devour so much pollen as to interfere with both wind and insect pollination by too greatly diminishing the supply. Thrips move actively from flower to flower of the same spike, from spike to spike and stem to stem of the same plant, and in this way bring about much more close pollination than cross-pollination, and in fact effect all the close pollination and fertilization of which the plant is susceptible. This in itself is undesirable and even harmful. Close fertilization has been shown to cause degeneration among beets, even in the sense of pollination and fertilization between different individuals of the same progeny.

TROUBLE TO PLANT BREEDERS.

The writer has experimentally shown that the larvæ of thrips in all stages readily pass through the meshes of fine silk chiffon and much more readily through the net, cloth, and sheeting frequently used by horticulturists and plant breeders to isolate flowers designed to be hand-pollinated. He has also been able to demonstrate that they actually do effect pollination and fertilization after passing through such covers.

The following is an instance of what might be expected to occur through the agency of thrips: The horticulturist of a well-known firm of seedsmen in the United States noted that his asters became fertilized although covered with cloth bags. The writer suggested that thrips might be responsible for this. The horticulturist replied in part that "the aster flowers were merely covered with coarse-meshed cloth to see if they were self-fertile. Insects as small as thrips would not have been excluded. We merely learned that the fertilization of asters is not dependent on the insects—mostly beetles—that one ordinarily sees on the flowers."

The horticulturist and plant breeder may not disregard these insects. They introduce an element of uncertainty to be guarded against with the utmost care and circumspection. Their minute size, inconspicuous color, great numbers, and the fact that they are almost ubiquitous make them a factor to be reckoned with by every worker along these lines and necessitate the development of special precautions and technic.

Covers of net, cloth, and sheeting afford no real protection against them; even paper bags must be applied with great care. The writer found the method described and illustrated in connection with these experiments to be simple and efficacious.

It is as necessary to rid the isolated portion of plant and flower of thrips already present as to prevent the access of others after isolation. In these experiments the practice was made of carefully scrutinizing each spike of buds or flowers before covering it and brushing off any thrips that might be present with a camel's-hair or sable brush, sometimes also spraying the spike thoroughly with water. In the summer of 1912 the use of nicotine sulphate also was tried, as shown in the following notes:

July 24, 1912.—At this late blooming period, thrips have become exceedingly numerous on all spikes in bloom; they interfere seriously with pollination work. To ascertain whether a simple, practical method might be available to rid the individual spikes completely of these pests, the following experiment was carried out: Some spikes, badly infested with thrips, were selected. Before operating on the spikes, they were immersed in the following solution: Water, 2 pints; nicofume (nicotine sulphate), 1 tablespoonful.

Spikes 1, 2, and 3 (in their normal condition, i. e., bearing flowers of all stages—buds, flowers just opening, and flowers already fertilized) were immersed in the above solution 10 seconds; then they were at once isolated with manila paper bags in the manner previously described.

Spike 4, with selected buds emasculated, was treated with nicofume like the preceding, bagged, and (when stigmata had become receptive) pollinated.

Spikes 5 and 6 were treated like No. 4, but not pollinated.

Spike 7 was merely shaken and flowers blown upon to dislodge thrips; flowers emasculated.

August 19, 1912.—All spikes examined.

Nos. 1, 2, and 3 in good condition; no signs of thrips or other insects; no injury from nicofume; good seed formed.

No. 4. No injury from nicofume apparent; no evidence of thrips or other insects; emasculated July 24, 1912; pollinated July 27, 1912; of 10 flowers pollinated 8 produced seed.

No. 5. General condition similar to No. 4; emasculated July 24, 1912; not pollinated; 13 flowers emasculated; all remained sterile.

No. 6. Similar to No. 5; all flowers remained sterile.

No. 7. Check; spike dead.

This experiment shows that the treatment with nicotine solution did not perceptibly injure beet flowers and that it at the same time removed thrips from them.

CONCLUSION.

From these experiments it is seen that these minute insects, the numerous species of Thysanoptera, some of which more or less injuriously infest practically all our plants, are also active agents in pollination. Among beet flowers they are frequently very numerous indeed, effecting both close pollination and cross-pollination upon them. However, after taking into account the various forms of injury they do, it is doubtful whether the balance remains in their favor in regard even to beets. Under ordinary conditions, in fields of commercial seed beets, it is believed that on the whole their work is beneficial; but should they become excessively numerous, they sustain their reputation as one of our really destructive pests. To the horticulturist and plant breeder they are pests of the worst type, necessitating constant watchfulness and a refined technic in all pollination work.

The suggestion is ventured that certain supposed mutations may really have been the result of unsuspected cross-pollination by means of one or another species of thrips, whether in cereals supposedly not susceptible to cross-pollination without the intervention of man or in flowers which were thought to have been isolated against cross-pollination.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 111

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 11, 1914.

(PROFESSIONAL PAPER.)

THE SEQUOIA PITCH MOTH, A MENACE TO PINE IN WESTERN MONTANA.

By Josef Brunner,
Agent and Expert, Forest Insect Investigations.

INTRODUCTION.

In the area near and at the divide between Swan River and Clearwater River in Montana and extending, so far as known at present, about 8 miles southeast from that divide, the sequoia pitch moth (*Vespamima sequoia* Hy. Edw.)[1] is at present the most destructive insect. It menaces the lodgepole pine timber, in which it propagates, and all other trees in the vicinity of those attacked are jeopardized by the forest fires fed by the dead timber resulting from the work of its larvæ. The range of its peculiar injury to trees in that region has also been traced by the writer about 6 miles west from the wagon road which unites the Clearwater and the Swan River country from Rainy Lake toward the Mission Range. Roughly, the area in which the insect is a very serious factor in forest destruction is about 12 miles long by as many miles wide and covers about 144 sections of forest land, or more than 90,000 acres.

Control and practical elimination of this insect, as a serious menace to the very existence of the forest growth of this area, depends largely on a knowledge of its habits and life history. Insufficient familiarity with these two points would result in unnecessary waste of time in locating infested trees and in conducting control operations at a time of the year when the result would be out of proportion to the cost.

DESCRIPTION OF THE INSECT.

Vespamima sequoia (fig. 1) is a clear-winged moth in general appearance strongly resembling a hornet or "yellow jacket." This resemblance is so perfect that a truck gardener near Missoula, Mont., evi-

[1] Identification by August Busck, as the species which was first found to inhabit the sequoia.

Note.—This bulletin is a report on an insect infesting lodgepole pine in the Rocky Mountain region of Montana.

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dently familiar with the hornet, refused to believe that a specimen which had just emerged and was being observed on the tree in which it had attained maturity was not a "stinger" until the difference was pointed out to him.

The female is about two-thirds of an inch in length and the male is somewhat smaller. In the female the last three segments, and in the male the last four, are bordered with rich lemon-yellow, which makes the sexes easily distinguishable, even to the uninitiated.

The mature larva is from three-fourths inch (male) to 1½ inches (female) long and is of a dirty white or yellowish color.

FIG. 1.—Female pitch moth (*Vespamima sequoia*) 15 minutes after emerging. (Original.)

LIFE HISTORY.

Observations on this species in different localities, together with the dates of emergence of adults reared in the laboratory, show that the general flight of the mature insects and oviposition occur between June 25 and July 15, the greater number of them probably flying about July 10. However, variation in latitude and altitude and unusual weather conditions prevailing during the spring of certain years may put the date of this general emergence a few days ahead or behind those given here. The flight and oviposition of the insect are over by August 1.

It appears that the adult insect is rather short-lived, as all the specimens that were reared and observed in captivity died within four days of emergence. Out of 20 females thus under observation only one oviposited, the rest dying without issue. This would show that the female dies, unless she is fertilized, within three days after emergence.

As this species is very active it is reasonable to suppose that it deposits but few eggs in any one place. In fact, it was frequently observed that wherever two larvæ are too close together one of them invariably dies. Wherever an occasional pitch mass is found to contain as many as three larvæ, each one of them occupies an independent tube. This shows that the scattering of the eggs is necessary in order to enable most larvæ to survive the evidently fierce struggle for existence. Exactly how long it takes the eggs to hatch is unknown to the writer, but the injury to the newly infested trees by the young larvæ is quite perceptible by August 15. By the time frost arrests their activity, about October 1, the larvæ, especially the females, have attained considerable size. The following summer is devoted by the larva to lengthening the tunnel and growing, and toward the second winter it drives a rather roomy tunnel into the pitch exudation which, during the following June, it lines with silky thread preparatory to pupation.

During the two months preceding pupation all the larvæ of the same sex are of practically the same size, so that the two generations are almost inseparable. However, one familiar with this and allied species can separate them by the difference in color and density of skin, which is rather white in the younger generation and yellowish, leathery, in the older one.

The length of the pupal stage is 30 days, i. e., the insect remains in the chrysalis for 30 days from the day it transforms into that stage until it emerges as adult. The chrysalis is free in the tunnel, moving back and forth in it at will by means of spines on the body, and is usually found on warm days quite near the surface and far back when it is cold. When ready to emerge the pupa forces about half its length out through the thin shell of pitch at the mouth of the tunnel and the adult insect (fig. 1) emerges by bursting the shell of the chrysalis. This occurs two years after the egg was laid. In other words, the larvæ hatching from the eggs deposited in June and July of one year develop into adults during the same months two years later, thus making the generation biennial.

There seems to be indication of an alternation of seasons of abundance and scarcity of the insect. During late autumn, 1913, the young larvæ were quite scarce in the vicinity of Rainy Lake, especially east of the wagon road from Clearwater to Swan River, while

1-year-old larvæ were abundant. If this observation holds good, the insect being biennial, we should be able to forecast the years when it will be abundant and when scarce. Hence there should be great flights during 1914, 1916, 1918, etc., unless the insect is controlled, and small flights during 1915, 1917, 1919, etc.

RELATION TO THE MOUNTAIN PINE BEETLE.

The only insect which is of any consequence in its relation to the pitch moth in the Clearwater country is *Dendroctonus monticolae* Hopk. This beetle frequently attacks trees infested by the larvæ of the moth. This attack is always fatal to the latter, because Dendroctonus kills the tree almost immediately, and without the flow of sap the larvæ of the moth can not survive. On October 1 every larva of the moth which was found in trees attacked by the beetle after August 1 was dead. Some of the trees had the appearance of having been infested by the beetle only two or three weeks; nevertheless, the moth larvæ were dead, although they were in perfectly fresh condition otherwise.

Vespamima sequoia is apparently little subject to attack by either parasitic or predaceous enemies. In fact, it is less troubled by insect enemies or diseases than any other species known to the writer; and as birds also never seem to pursue it, there is no present evidence that natural agencies might check it in the course of time.

HABITAT.

The insect prefers sunny openings within the forest and slopes where the soil is rather sandy and quick to dry. Ridges along watercourses are also favorite places for it. It avoids the damp and densely shaded bottom lands along streams. It prefers pine, open stands of lodgepole pine, as, for example, within and alongside the big old burn which extends from the wagon road toward and along the Flathead Range, where there are few trees 3 or more inches in diameter that have escaped attack and are not infested now.

HOST TREES, AND CHARACTER OF INJURY.

Lodgepole pine is numerically the principal species of tree in the region and, with the rare exception of the yellow pine, is the species subject to attack by the pitch moth, although the moth attacks almost all kinds of conifers in other localities within its range.

The trees infested by this insect (see fig. 2) are readily located by the never-absent pitch exudation over the tunnel of the larva. This may be readily seen at quite a distance, if the stand of trees is not too young. Even on very small trees of but 1 or 2 inches in diameter the pitch tube is of the size of a walnut the first season of the infestation and more than twice that the second year.

The pitch exudation on the tree shown in figure 3 weighed over 10 pounds, and such trees are so numerous that many tons of pitch could be collected within the comparatively small area infested by this insect.

The trees are all of them attacked at the extreme base, and the exuding pitch flows out from the tree not infrequently a distance of 10 or 12 inches upon the humus which covers the ground.

THE WORK OF THE LARVA.

The larva begins its mine in a crevice in the bark, where the egg was deposited, proceeding through the outer layers until it reaches the cambium. Close to the wood it begins to construct a transverse

FIG. 2.—Lodgepole pine trees infested by the sequoia pitch moth. Trees of all sizes are infested in the Clearwater country of Montana.

mine running in both directions from where it entered. It widens this tunnel at the center, thereby causing the appearance of a central chamber. In small trees the mine is always practically straight across the grain of the wood.

It is a puzzle to the writer how the larva determines how far it can go in the two directions without entirely girdling the tree, thus killing it and thereby depriving itself of sustenance. It is a noteworthy fact that of the great many trees less than 3 inches in diameter examined, all were found girdled to within 1 or 2 inches, and none entirely girdled.

It is evident that the entire girdling of about 0.5 per cent of the older infested trees is accomplished by more than one larva which happen to infest these trees at one and the same time. Each larva evidently tries to get as far away from its neighbor as it can, and thus the tree is girdled. But, as indicated, plural infestation is rare. To test this point experimentally the writer has several times planted in captivity two larvæ on one piece of wood, and invariably one of them left the sustaining slab. On a few occasions when, because

FIG. 3.—A lodgepole pine tree infested by the sequoia pitch moth. The new, flowerlike exudation indicates present infestation. (Original.)

none vacated, the writer supposed he had made a success of "double planting," he found later that one of the larvæ was dead.

Tunnels in trees infested only the second year, as well as those in trees that have been infested by several successive generations of the insect, look as if they had been engraved by the larvæ eating the wood, but such is not the case. The appearance is caused by the larvæ preventing the wood from forming a new layer across the tunnel. Thus the tunnel, in the course of many seasons, gradually becomes deeply embedded in the wood tissues.

In rare cases the tunnel is slightly slanting, running on one side of the center, a few inches below the surface of the ground, while the end of the other side is several inches above ground. Under no circumstances is the tunnel parallel to the grain of the wood.

As stated, the activity of the larvæ within the cambium of the tree causes a heavy flow of pitch toward the exterior, and fresh, flowerlike nodules upon older exudations (fig. 3) are a definite proof that the tree is still infested.

EFFECT OF THE INFESTATION ON TREE GROWTH AND THE FOREST.

It is obvious that with one-half and, in the majority of cases, two-thirds of the circumference of the tree trunk cut off from the root

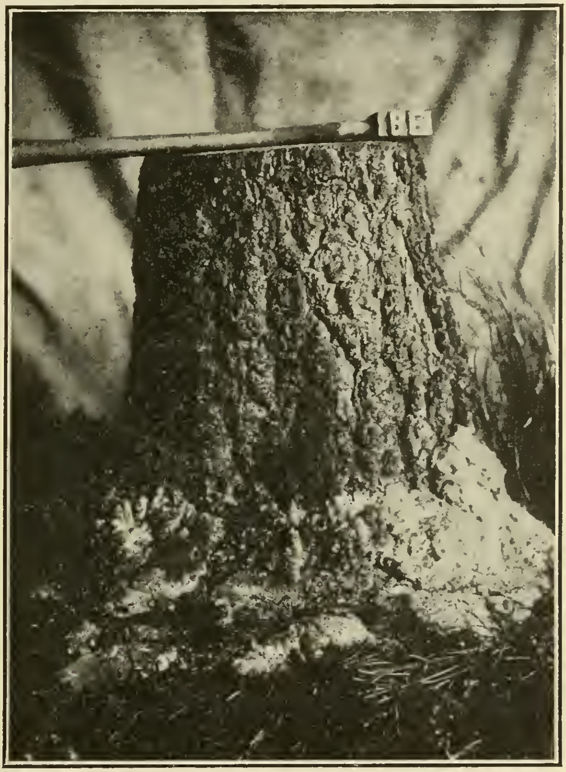

FIG. 4.—Stump of a pine tree 64 years old which grew to be 9⅜ inches in diameter breast high at 41 years of age and added only seven-eighths inch to this diameter during the last 23 years of its life, owing to attack by the Sequoia pitch moth. (Original.)

system by the dividing tunnel, the growth of the afflicted tree has to suffer. Count of annual rings and measurements on a tree which was considered to be a fair example of the general injury in the area brought out the fact that during the first 41 years of its life and normal health it had added annually about one-fourth inch to its diameter, while it added only about one thirty-second of an inch, or the thickness of an ordinary visiting card, annually during the 23 years it had been infested by the pitch moth. (See fig. 4.)

SECONDARY INJURY BY FIRE.

About one-half of 1 per cent of the trees infested by *Vespamima sequoia* is killed. In case of a slight surface fire in places where, outside of humus, no litter covers the ground, all the infested trees which are not killed outright come through it with the bark on the sides where the pitch exudation is located literally cooked, and for the balance of their existence they display the "fire wounds" (fig. 5), of which the pitch moth was the primary cause. They remain green but add little to their size annually. Subsequent fires fell them

FIG. 5.—Fire wounds on pine tree injured by the Sequoia pitch moth. (Original.)

readily, and their burning injures and kills perfectly healthy trees, which would otherwise have remained unscathed.

There is abundant proof in the area under discussion that unattacked trees, on ground not littered with fallen timber, pass through surface fires with but slight injury. Thousands of such trees are mingled with as many which display "fire wounds" and the tunnel of Vespamima burned indelibly into the base of the latter, thus explaining why it is that some trees are half burned while others, under the same conditions and at the same place, have escaped with scarcely a scar.

Many trees with fire wounds are reinfested on the sound side and killed, thus adding to the material which makes a surface fire in the area really serious. The heat generated by them in burning, either standing or prostrate, injures and kills healthy trees in the immediate vicinity.

During decades fallen timber, primarily caused by insects, accumulates and provides such an amount of inflammable material among the uninjured green trees that finally a fire sweeps such areas clean of all tree growth and enters and destroys adjoining areas which contain healthy trees only.

In the infested zone in the vicinity of Rainy Lake the forest looks much like a checkerboard. There is an area of 50 acres here with a stand of 10-year-old trees on them; adjoining this is a square-cut piece of 200 acres with 40-year-old trees as a cover; next to this are 80 acres on which reforestation started only a few years ago, and so on. This thing has been going on for at least 100 years, so far as can be traced, and probably existed before time was counted. Everyone of these variously aged tree patches is the result of a separate fire. The explanation of the occurrence of so many of them within an area comparatively so small is found in the peculiar meteorological conditions prevailing here.

TOPOGRAPHY OF THE AREA.

Running from the southeast toward the northwest are the rocky walls of the Flathead Range; west and parallel to it lies the Mission Range; and on the divide between Swan River and Clearwater River, extending from the Mission Range toward the wagon road which passes over the lowest elevation, and running from west to east is a high ridge. This ridge forms an effective barrier to storm clouds driven up Swan River between the walls of the Flathead and Mission Ranges. Their only outlet is between that ridge and the Flathead Range over the Rainy Lake territory.

The clouds driven up Swan River, inconsequent though they might be under different conditions, strike the ridge dividing the two water courses and are promptly thrown back upon their own mass by the resistance of the ridge. On the west are the walls of the Mission Range, so there is no escape for them in that direction; thus they drift eastward and toward the outlet over Rainy Lake. Part of them escape there. But the greater part are thrown upon the walls of the Flathead Range, from which they tumble back upon the oncoming mass in a turmoil before this also by and by finds its way to the only avenue of escape. The great numbers of lightning-struck trees in this area abundantly testify to the great rôle played here by lightning.

Remembering that in the comparatively small zone about Rainy Lake infested by the pitch moth there are tens of thousands of trees with heavy pitch exudation at their base which, once ignited, will burn for several days, rain or shine, and that during the violent thunder storms there many trees are struck by lightning and the pitch set on fire, we will have the combination which explains the frequency of fires in that area.

Let us illustrate. Lightning strikes a tree infested by Vespamima and sets it afire. During the storm the ground is soaked sufficiently to prevent the fire from spreading. The pitch, however, owing to its thickness and inflammability, continues to burn. On the following day a clear sky allows the sun to dry the ground cover around the burning pitch sufficiently so that a surface fire is started which will be ended by the next shower. If the stand consists of medium or small sized trees and the area has passed through fires before, everything is killed, and the place, when it has been reforested, will stand out clear in the checkerboard of forest and elemental battles even after half a century or more, as is the actual case in this territory.

As storms are evidently quite frequent there, the patches burned are usually small, ranging from 50 to 200 acres. However, there are also some burns which an accumulation of débris had undoubtedly so augmented that whole sections were swept. All the traceable evidence in the biggest burn in the area points to insect work as the primary cause, just as in the smaller burns where the evidence is more definite and is easier of location.

With a knowledge of these facts, one can not but conclude that the peculiar results of the work of *Vespamima sequoia* are the chief and primary contributing cause of the frequency, we might almost say continuity, of fire damage to forest growth in this area. To eliminate or ameliorate this condition, it is manifestly necessary to eliminate the insect or at least reduce it to such an extent that it loses its menacing aspect.

REMEDY.

Since nature and its agencies are powerless in the control of this insect, the scourge has to be combatted by man through direct action if it is not to continue its injurious activity in the future as it has in the past. There is only one way to reduce the insect, and that is to destroy it while it is in the larval stage.

As is apparent from the portion of this bulletin relating to the life history of the moth, larvæ can be found in the infested trees at any time of the year.

However, in order to destroy the greatest number of them with the same amount of effort, operations should be conducted during the months of September to June, inclusive, when there is no snow on the ground to cover the pitch exudations. During most seasons the snow eliminates November, December, and January as control months.

By September 1 all of the eggs which have not been lost have hatched, and the young larvæ have attained a size sufficient so that they can be seen and destroyed, and up to June 25 hardly any of the second-year larvæ have reached the adult stage.

The statements under "Habitat" suggest where to look for infested trees. To locate the larvæ, separate the pitch exudation from the trees, thereby exposing the larvæ. Killing the larvæ outright, or taking them up for later counting and destruction, or, in other words, hand picking, is really the only thing that can be done to reduce the numbers of the insect.

RECOMMENDATIONS.

If the control work is done without utilization of the pitch, it will be at direct cost; and the taking up of the larvæ, though slower than destruction on finding, is preferable, as it enables a proper checking up of the extent of damage and of the amount of control work accomplished. But if the pitch is of sufficient commercial value to pay the cost of its collecting and shipment, it would be possible to control the insect by utilizing its products.[1] If the pitch is marketed, it is not necessary to keep a close check on the work beyond keeping tab on the weight of the pitch shipped and the returns from the sales.

NOTE.—The statements in this paper, with the exception of those under "Description of insect," "Life history," "Relation to the mountain pine beetle," and, to a certain extent, "Remedy," refer to *Vespamima sequoia* in the Clearwater country of Montana alone and are not applicable in other regions where the destructiveness of the insect is known to assume a different character.

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[1] Just before going to press analyses of these resins were received from the U. S. Bureau of Chemistry, with the following comment.—A. D. HOPKINS, *in Charge of Forest Insect Investigations.*

"The volatile oils obtained from these two resins are slightly heavier than ordinary oil of turpentine. They show smaller percentages, distilling below 170° C. However, as turpentines as heavy as these will find a market as paint and varnish thinners, it is anticipated that no difficulty would be encountered in disposing of the turpentine produced from this material. Especially is this opinion held since * * * it is more than likely that owing to the size of the sample and the manner of packing, as well as the exposure of the crude gum, the percentage of volatile oil is lower than it would be in material which was collected in the ordinary commercial way.

"The rosins do not appear to differ essentially from the rosin made from longleaf pine, and we have no hesitation in expressing an opinion that it would be entirely suitable for soap-making purposes and would command the ordinary market price according to the grade. Attention may be called to the fact that lighter colored rosins, therefore higher grade rosins, would undoubtedly be made in practice, provided bark, dirt, etc., are kept out of the resin.

"Nothing was observed in this examination which would warrant the opinion that the nature of the product was due to the particular manner of its production. It is believed that essentially the same product would be obtained by the ordinary commercial chipping of the tree except so far as prolonged exposure on the trunk of the trees, as probably took place with these samples, favors volatilization of the light oils and this affects the relative proportions of volatile oils and of rosin and the specific gravity of the oils."—F. P. VEITCH, *Chief of Leather and Paper Laboratory, Bureau of Chemistry.*

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 112[1]

Contribution from the Bureau of Entomology, L. O, Howard, Chief.
August 21, 1914.

THE OAT APHIS.[2]

By J. J. Davis.

Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

Of the three important plant-lice attacking wheat and oats above ground, the oat aphis (*Aphis avenæ* Fab.)[3] is probably the most widely distributed and most common over its area of distribution, and is second in importance as a wheat pest, first rank being held by the so-called "green bug" (*Toxoptera graminum* Rond.), a species well known in the Southwest because of its periodic depredations. Like the "green bug," the insect under discussion is an imported species, and was probably introduced into the United States during the first half of the last century, at least previous to 1851, the date of what appears to be the first published record of its occurrence in this country.[4]

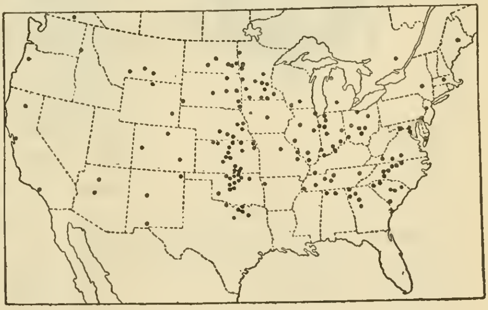

Fig. 1.—Distribution of the oat aphis in the United States. (Original.)

The oat aphis has never been considered a pest of great importance, although observations would lead to the belief that it is worthy of more consideration and study. It does not ordinarily appear suddenly in great swarms as does the "green

[1] This bulletin describes an insect found on the small grains, more especially oats. The bulletin is of interest to growers of cereals.

[2] This common name, used by some of the early writers, is adopted here, since the name European grain-aphis, used by some authors, is scarcely distinctive, all three of the common grain aphides probably being native to Europe.

[3] Specimens labeled "*Aphis avenæ* Fabr.—*A. padi* Kalt. on *Triticum vulgare,* Russia merid.," received from Dr. N. A. Cholodkovsky, of St. Petersburg, agree well with the *Aphis avenæ* of this country.

This species has the following synonyms: *Siphocoryne avenæ* Fabricius, *Siphonophora avenæ* of some authors, *Aphis mali* of some authors, *Aphis annuæ* Oestlund (included as a synonym on the authority of Mr. Theodore Pergande, U. S. Dept. Agr., Div. Ent., Bul. 44, p. 9, 1904), and *Aphis fitchii* Sanderson.

[4] Fitch, Asa. Fourth Ann. Rpt. Regents Univ. N. Y., 1851, p. 65; reprinted in Lintner, J. A., Ninth Rpt. . . . on the insects of N. Y., 1893, p. 405.

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bug," although occasionally it may be found in conspicuous and alarming numbers, but it is ever present on wheat; and, especially in the fall, when it occurs at the base of the plant and on the roots, it is easily overlooked by the casual observer. However, there is no doubt that these plant-lice, even though they may not be conspicuous and apparent, weaken the plants and decrease the yield. This decrease in yield is presumably general, but may not as a rule be locally conspicuous as in the case of the "green bug," that is, not enough to be recognizable. On the whole, however, it can hardly be doubted that these little insects are responsible for the loss in this country of thousands of bushels of wheat annually.

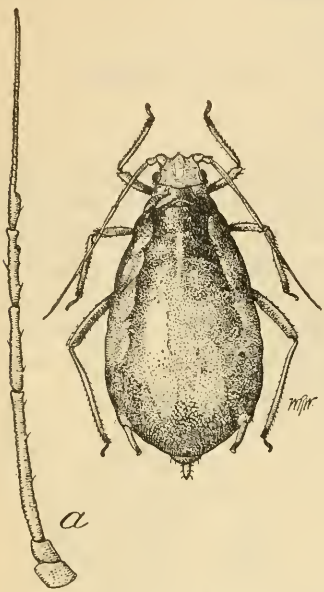

FIG. 2.—The oat aphis (*Aphis avenæ*): Wingless viviparous female, much enlarged. *a*, Antenna of same, still more enlarged. (Original.)

DISTRIBUTION.

The oat aphis is almost cosmopolitan in its distribution, and in this respect rivals such well-known plant-lice as *Macrosiphum pisi* Kalt., *M. granarium*, and *Toxoptera graminum*. It has been found in all parts of Europe, as well as in most of the States of the United States. Quite likely it will also be found to occur in Asia, and probably in Africa, although we believe it has never been reported in literature from these countries up to the present time.

The map (fig. 1), compiled from records made by assistants in the Cereal and Forage-Crop Insect Investigations and from authentic published records, indicates the present known distribution in the United States. It will be observed that the species has not been found in the Gulf region.

DESCRIPTIVE.

On grain two forms of the oat aphis are found—the winged and wingless viviparous females. As will be explained later, it occurs on the apple where there are to be found, in addition, the sexual forms, namely, the wingless oviparous female, the winged male, and eggs. (See fig. 5.)

The *wingless viviparous female* (fig. 2) is yellowish green to olive green, often somewhat mottled. The stem mothers on apple in the spring are more often lighter, with a darker green median longitudinal area, while those found on wheat in the fall of the year are darker, sometimes becoming greenish brown. The bases of the cornicles are surrounded, in the spring forms, with areas yellowish to orange in color, while these areas are larger and are usually orange to dark reddish in the fall and in hibernating individuals. The antennæ are about one-half the length of the body, and the cornicles, or "honey tubes," are slightly vasiform.

The *winged viviparous female* (fig. 3) has a black head and thorax, the abdomen being olive green, sometimes paler, with a row of more or less conspicuous black spots on each side anterior to the cornicles, and usually with a rusty or brownish red area about the base of each cornicle. The antennæ are black and reach a little beyond the middle of the body. The cornicles are black and slightly

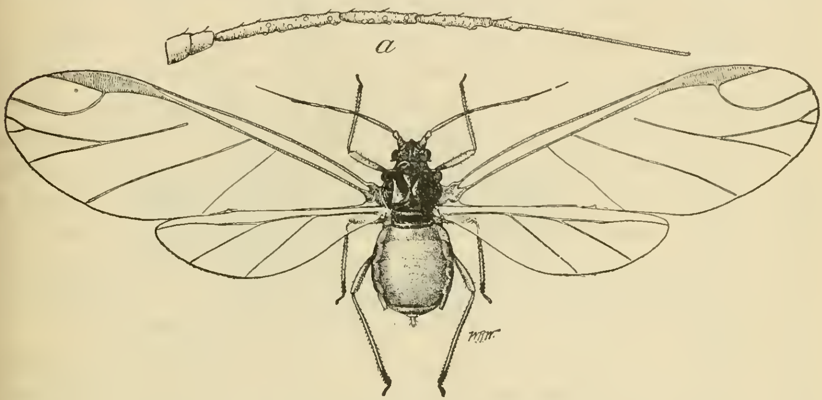

Fig. 3.—The oat aphis: Winged viviparous female, greatly enlarged. *a*, Antenna of same, still more enlarged. (Original.)

vasiform. The last branch of the median vein in the wings branches near the apex of the wing.

The *immature* aphides are paler green, but almost invariably the yellowish to pinkish areas about the bases of the cornicles are quite noticeable, although sometimes faint in very young individuals.

The *winged male* is similar to the winged viviparous female except that it is smaller and has a narrower abdomen, and the color is usually more of a dusky green.

The *wingless oviparous female* is somewhat like the viviparous female, but the abdomen is more tapering toward the tip, and the color is pale yellowish green to greenish dusky, or even has an orange tint. Rather conspicuous orange or reddish areas are present on the abdomen at the bases of the cornicles.

The *eggs* (fig. 5, *a*) are laid in the crevices of the bark or between the leaf bud and twig, and when first deposited are pale greenish, but they soon change to shining black and retain this color until they hatch in the spring.

SPECIES LIKELY TO BE CONFUSED WITH THE OAT APHIS.

This species may be recognized in the grain field by the pinkish, orange, or reddish areas on the abdomen at the bases of the cornicles. It may also be distinguished by the wing venation, by the short, slightly swollen cornicles, by the mottled pattern of coloration of the abdomen, and in the winged form by the rows of black spots on either side. The antennæ also differ from those of other species.

The large green grain-aphis (*Macrosiphum granarium* Kirby) is larger than *Aphis avenæ* and does not have the colored areas at the base of the cornicles. These last are longer, reaching nearly to the tip of the cauda, or tail, and are more cylindrical, and the antennæ are longer in relation to the length of the body.

The spring grain-aphis, or "green bug" (*Toxoptera graminum* Rond.), is more nearly the size of *Aphis avenæ*, but it need not be confused with that species if we remember that it is pale green, about the color of the wheat leaf, and that this coloration is quite uniform over the entire abdomen; that it does not have the orange or reddish areas at the bases of the cornicles; and that the winged female is without the black spots on each side of the body. Further, the venation is ordinarily different in the two species, the median vein of *avenæ* (fig. 3) being twice branched, except in rare instances, while in the "green bug" (fig. 4) it is but once branched.

Aphis avenæ is readily distinguished from other aphides on apple. *Aphis pomi* De G., the most common apple aphis, is quite different, the wingless individuals being uniformly pale apple green with black and rather conspicuous cornicles and no trace of orange or pink on the abdomen about the cornicles. The winged individuals are similar, except that the head and thorax are shining black and the abdomen pale apple green; also the venation of the wing is different, the last branch of the median vein not dividing near the apex of the wing. This aphis spends its entire life cycle on the apple and related trees.

The rosy apple aphis (*Aphis sorbi* Kalt.) varies greatly in color from the greenish blue, pulverulent females hatching from eggs to the more or less pinkish forms. It is slightly larger than the oat aphis and does not have the pinkish or orange areas about the bases of the cornicles, although the distal end of the abdomen may be pinkish, and in some stages, such as the pupal stage of the spring migrants, the entire body may be pinkish or salmon colored. The

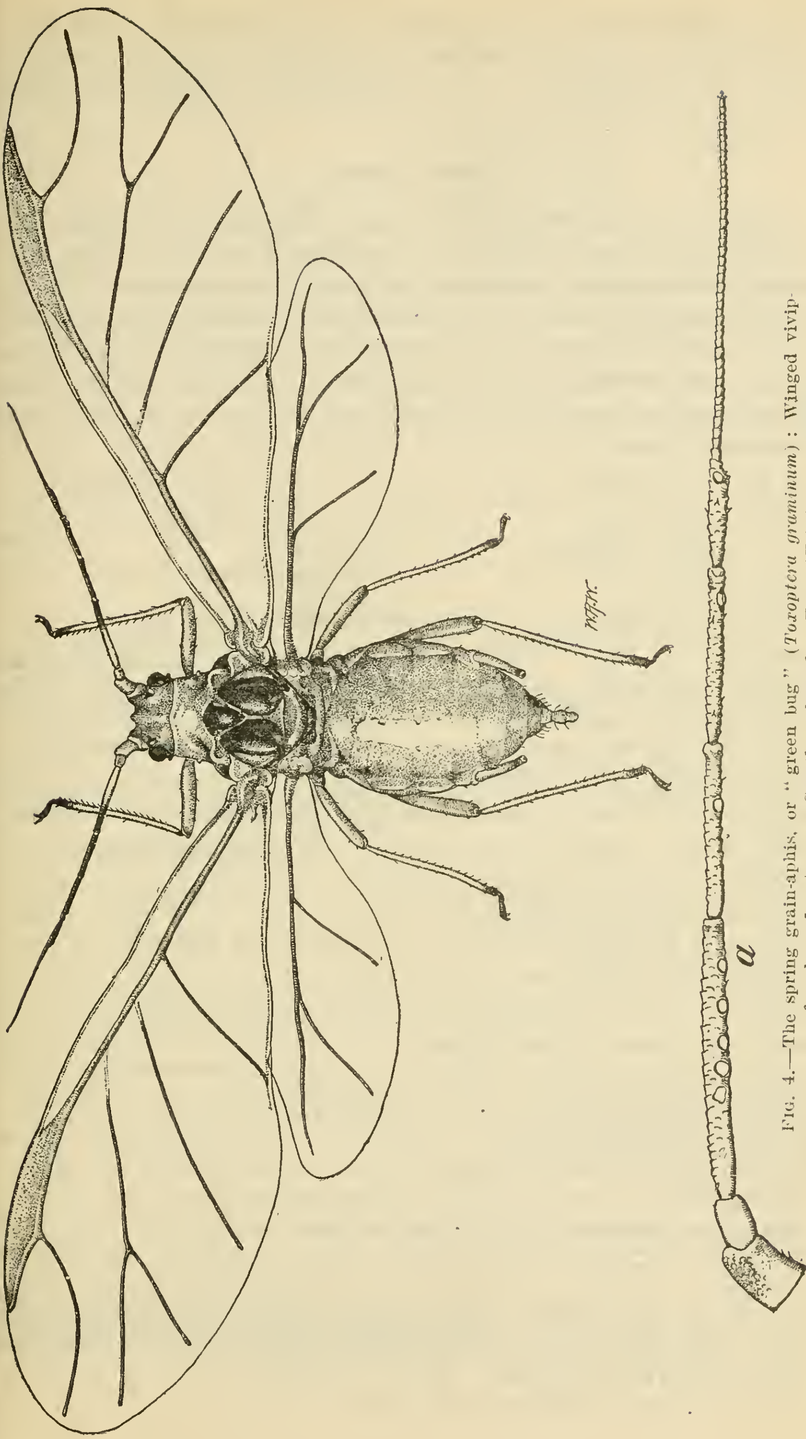

FIG. 4.—The spring grain-aphis, or "green bug" (*Toxoptera graminum*): Winged viviparous female and antenna. Greatly enlarged. (From Webster and Phillips.)

winged female has its wing venation much like that of *Aphis pomi;* the cornicles are black, tapering and reaching almost to the tip of body, and the abdomen is rather conspicuously marked by a large black patch on the dorsum.

HOST PLANTS.

Aphis avenæ has been recorded from a large number of plants, particularly of grasses. Owing to the confusion with the larger grain aphis (*Macrosiphum granarium*) in some of the literature, it is impossible in many cases to determine which species of plant-louse was meant, and consequently the following list includes only those plants in cases where the identity of the aphis is reasonably certain. This list does not include all of the plants upon which this species has been found in Europe.

GRAMINEÆ.

Wheat, *Triticum vulgare*
Triticum dicoccum [1]
Rye, *Secale cereale*
Oat, *Avena sativa*
Wild oat, *Avena fatua* [2]
Tall oat grass, *Arrhenatherum elatius* [3, 4]
Barley, *Hordeum vulgare*
Two-rowed barley, *Hordeum distichon* [2]
Wall barley, *Hordeum murinum* [4]
Timothy, *Phleum pratense*
Canada blue grass, *Poa compressa*
Kentucky blue grass, *Poa pratensis*
Annual or dwarf meadow grass, *Poa annua* [1]
Rough-stalked meadow grass, *Poa trivialis*
Crab grass, *Syntherisma sanguinale*
Upright chess, *Bromus racemosus*
Rescue grass, *Bromus unioloides*
Cheat, *Bromus secalinus* [3, 4]
Hungarian brome grass, *Bromus inermis* [3, 4]
Orchard grass, *Dactylis glomerata*
Italian rye grass, *Lolium multiflorum* [3, 4]
Perennial rye grass, *Lolium perenne* [3, 4]
Redtop, *Agrostis alba* [3, 4]
Red fescue, *Festuca rubra* [3, 4]
Sheep's fescue, *Festuca ovina* [3, 4]
Meadow fescue, *Festuca pratensis* [=*elatior*] [3, 4]

GRAMINEÆ—continued.

Hard fescue, *Festuca ovina duriuscula* [3, 4]
Reed canary grass, *Phalaris arundinacea* [3, 4]
Melic grass, *Melica bauhini* [1]
Melica penicillaris [1]
Johnson grass, *Andropogon halepensis* [5]
Broom corn, *Andropogon sorghum* var.
Sorghum, *Andropogon sorghum* var.
Koeler's grass, *Koeleria cristata* [1]
Wild rye, *Elymus geniculatus* [=*arenarius*] [1]
Virginia wild rye, *Elymus virginicus* [4]
Nodding wild rye, *Elymus canadensis* [4]
Corn, *Zea mays*
Teosinte (*Euchlaena mexicana*) [3, 4]

TYPHACEÆ.

Cat-tail, *Typha latifolia* [4]

AMMIACEÆ.

Celery, *Apium graveolens*

COMPOSITÆ.

Tickseed, *Coreopsis* sp.?

MALACEÆ.

Apple, *Malus malus*

[1] Recorded by Mordwilko as hosts of *Aphis padi* Kalt.—*avenæ* Fabr.
[2] Recorded by Fabricius; so far as known, there is no record on this plant from America.
[3] In 1909 Mr. T. H. Parks, at that time connected with the Bureau of Entomology, confined this species with various plants and found that it would breed contentedly and freely on these plants. Other plants tried, and which the aphides refused, are Muhlenbergia, *Agropyron occidentale, Panicum virgatum,* and *P. bulbosum.*
[4] Recorded here for the first time.
[5] Recorded as hosts of this species by Passerini.

MALACEÆ—continued.

Pear, *Pyrus communis*
Hawthorn, *Cratægus coccinea*, etc.
American mountain ash, *Sorbus americana*
Quince, *Cydonia vulgaris*
Double-flowering crab apple (*Malus* sp.)
Wild crab apple (*Malus* sp.)

ROSACEÆ.

Ninebark, *Opulaster opulifolius*.[1]

AMYGDALACEÆ.

Plum, *Prunus* sp.
Choke cherry, *Padus virginiana*
Wild black cherry—
Padus serotina
Padus padus

In addition to the foregoing list of food plants, Mr. Theodore Pergande lists dogwood (*Cornus* sp.), shepherd's purse (*Bursa bursa-pastoris*), and burdock (*Arctium minus*); but in each case he notes that it is, or evidently is, accidental.

Although this species, as shown, has a large number of available host plants, it is more often to be found in the fall and spring on wheat, blue grass, apple, and pear. In early summer it is frequently found on oats, wheat, blue grass, and, previous to June, on apple and pear, and in later summer on volunteer wheat and oats and on blue grass.

INJURIES AND METHOD OF WORK.

Probably no other species among the plant-lice has been so completely confused in literature as the one under discussion. Numerous reports of injury to apple, wheat, and oats have been made since its discovery in 1851, but in most instances there seems to have been some confusion in the species, and it is impossible in such cases to determine just which of several species may have been responsible for the damage. Thus in 1865 Fitch [2] described and figured a Macrosiphum on wheat, although some of his observations doubtless refer to *Aphis avenæ*. In 1879 Thomas [3] reported a plant-louse which damaged wheat considerably in Illinois in 1866 and again in 1876, but in his description he has confused two species, *Macrosiphum granarium* and *Aphis avenæ*, and there is no means by which the particular species troubling grain in the years mentioned can be identified. Again, Riley in his report for 1889 [4] discusses, under the name *Siphonophora avenæ*, at least two species, and the facts relating to life history, injuries, parasites, etc., refer to more than one species; consequently this data must be ignored for the present, although the colored figures and probably most of the data contained in the article refer to *Macrosiphum granarium* rather than to the species under discussion. The same must be said of many other references to grain

[1] Recorded here for the first time.
[2] Sixth report on the insects of N. Y., 1865, p. 91–97. "*Aphis avenæ*, Fabricius."
[3] Eighth report of the State entomologist on the * * * insects of the State of Illinois, 1879, p. 51–55. "*Siphonophora avenæ*, Fab."
[4] U. S. Sec. Agr. Rpt. for 1889 (1889), p. 348.

aphides in which the author has either failed to describe the insect or its habits, or has confused two or more species in his descriptions.

On the other hand, we have one important reference to injury recognizable as that of the true *Aphis avenæ*. In Insect Life [1] Prof. F. M. Webster says:

> The wingless viviparous females of this species flock to the fields [of wheat] and on these [wheat plants] give birth to their young, which at once make their way to the roots, where they continue reproduction, sapping the life from the young plants. On very fertile soils this extraction of the sap from the roots has no very serious effect, but where the soil is not rich, and especially if the weather is dry, this constant drain of vitality soon begins to tell on the plants. Though they are seldom killed outright, these infested plants cease to grow, and later take on a sickly look * * *. It is very seldom that the affected plants fully recover, at least in autumn, and the results must be to reduce their productiveness the following year.

In January, 1891, Mr. Christian Steiffel, of Salem, Ind., reported this plant-louse as injuring wheat, causing it to turn yellow and die out in spots.

Prof. Webster received a report from Wooster, Ohio, of serious injury to wheat in December, 1898, on land subject to overflow. The wheat came up very well and remained green for about a month, after which it began to assume a brownish cast, and the warmer the weather and the more sunshine the plants got, the browner they became. In a letter dated December 4, 1901, to this bureau, Mr. J. D. Hummell, of Carroll, Ohio, writes:

> This plant louse seems to have almost completely destroyed one field of wheat in which it appeared early in the fall, and is not yet dormant, although we have had nights when the temperature was down to 15° F.

November 12, 1908, Mr. E. O. G. Kelly, of this bureau, reported this species abundant on the roots and stems of wheat at Caldwell, Kans., and doing considerable and noticeable injury to the early sown wheat.

Mr. A. A. Cooke, in a letter dated August 21, 1910, reported damage by this aphis to dwarf broom corn at Dale, Union County, N. Mex., the insect covering the plants and causing the foliage to turn a reddish color.

This insect was abundant in western North Carolina in March, 1913, reports of serious damage to wheat, oats, and rye having been received from several parties.

Numerous reports were received by this bureau from Oklahoma and northern Texas in December, 1913, and January, 1914, to the effect that the "green bug," which had ravaged the wheat fields in these areas in 1907, was again abundant and destructive to oats and wheat. Detailed examinations were made by Messrs. W. E. Penning-

[1] U. S. Dept. Agr., Div. Ent., Insect Life, v. 6, no. 2, Dec., 1893, p. 152.

ton and H. E. Smith, of this bureau, under directions from Prof. Webster. They found very few of the "green bug," while the oat aphis was present in considerable numbers. After a careful examination of the fields, the conclusions reached were that the injuries were due to one or more of three causes, namely, attacks by the oat aphis, impoverished soils, and weather conditions, particularly excessive rains during the late fall and early winter. Of these, weather conditions seem to have been the cause of the greatest amount of injury, although in certain areas the damage was more probably the result of attacks of the oat aphis. However, the parasites were in noticeable evidence everywhere, so that with normally late winter and spring weather they should prevent the aphides from becoming injuriously abundant.

As described by Prof. Webster in the foregoing quotation, the infested plants take on a yellowish or greenish yellow color, appear sickly, and cease to make any apparent growth, and since the insect works on the lower parts of the plant and is not always easily detected, the cause of the injury may sometimes be overlooked. During the summer this aphis usually feeds on the under surface of the leaves, on the stems, and in the axils of the leaves—seldom in the grain heads, as does *Macrosiphum granarium*.

CAUSES OF OCCASIONAL OUTBREAKS.

Prof. Webster[1] has made clear the reason for periodic outbreaks of the spring grain-aphis (*Toxoptera graminum*), and the usual abundance of the oat aphis in certain years may be attributed to the same cause. As in the case of the spring grain-aphis, the oat aphis breeds and multiplies at a temperature of about 40° F., or above, while the common parasite of these and many other aphides, *Aphidius testaceipes* Cress., is hardly active at a temperature less than 56° F. Consequently, mild winters and cool springs, when the temperature fluctuates between 40° and 56° F., permit the aphis to multiply, uninterrupted by attacks from their common natural enemy.

LIFE HISTORY OF THE INSECT.

The oat aphis occurs on grains and grasses throughout the summer, the spring colonies originating either from viviparous females which passed the winter on wheat, grasses, etc., or from spring migrants from apple and related trees—that is, the progeny of aphides hatching from eggs laid the previous fall on such trees. The plant-lice usually become more abundant toward fall, and as the weather becomes cooler they seek the lower parts or roots of wheat and other

[1] U. S. Dept. Agr., Bur. Ent., Circ. 85, Mar. 29, 1907, and U. S. Dept. Agr., Bur. Ent., Bul. 110, Sept. 6, 1912.

plants of the grass family and here pass the winter as viviparous females; or the winged fall migrants from grain may seek such trees as the apple, where the true sexual forms are produced, the oviparous females of this generation in turn depositing eggs on the twigs and branches, usually in the axils of the dormant buds or in crevices in the bark. (Fig. 5.)

In the latitude of La Fayette, Ind., the species commonly winters either as viviparous females on grains and grasses or in the egg stage on apple. Farther north, and especially in extremely cold winters, this species is probably unable to winter in any but the egg stage, while in the southern parts of the United States, where the winters are moderate, the aphides may live over winter as viviparous females only, no egg stage appearing.

The theory, put forth by Pergande,[1] "that the species is biennial and that the progeny of the spring migrants from the apple subsist almost exclusively upon various grains and grasses until the fall of the second year, when a generation of return migrants makes its appearance," is hardly a correct one. The writer's experience shows that while the apple may be a fall or spring host of *avenæ*, it is not a necessary alternate host, and that the species may subsist indefinitely on grains and grasses, and especially is this probably the rule in the Southern States. The species has been reared through more than 60 consecutive generations, covering a period of over two years, and through three winters on wheat, the warm greenhouse being used to carry the species through the winter months, and the line of viviparous generations could probably have been continued indefinitely but for an accident, the aphides having been killed when the greenhouse was fumigated without the knowledge of the writer.

Continuous-generation experiments were conducted at La Fayette, Ind., in 1909 by Messrs. W. J. Phillips and T. H. Parks and in 1911 and 1912 by the writer. In 1909 and 1911 the summers were unusually hot, and the experiments were not satisfactory, but in 1912 it was possible to get continuous first-born and last-born generation series without breaks. In 1909 Phillips and Parks obtained a maximum of 15 generations from May 15 to October 7 and a minimum of 8 generations in the same length of time. In 1911 a maximum of 18 generations was obtained from April 29 to October 12, and in 1912 a maximum of 23 and a minimum of 9 generations from May 3 to November 13, or a mean average of 16 generations. In the Southern States, where the species may breed throughout the winter months, a much greater number of generations would occur. In the experiments of 1909 the average number of young per female, in the 21 cages where records were kept, was 30.6; in 1911 the average for

[1] U. S. Dept. Agr., Div. Ent., Bul. 44, 1904, p. 7.

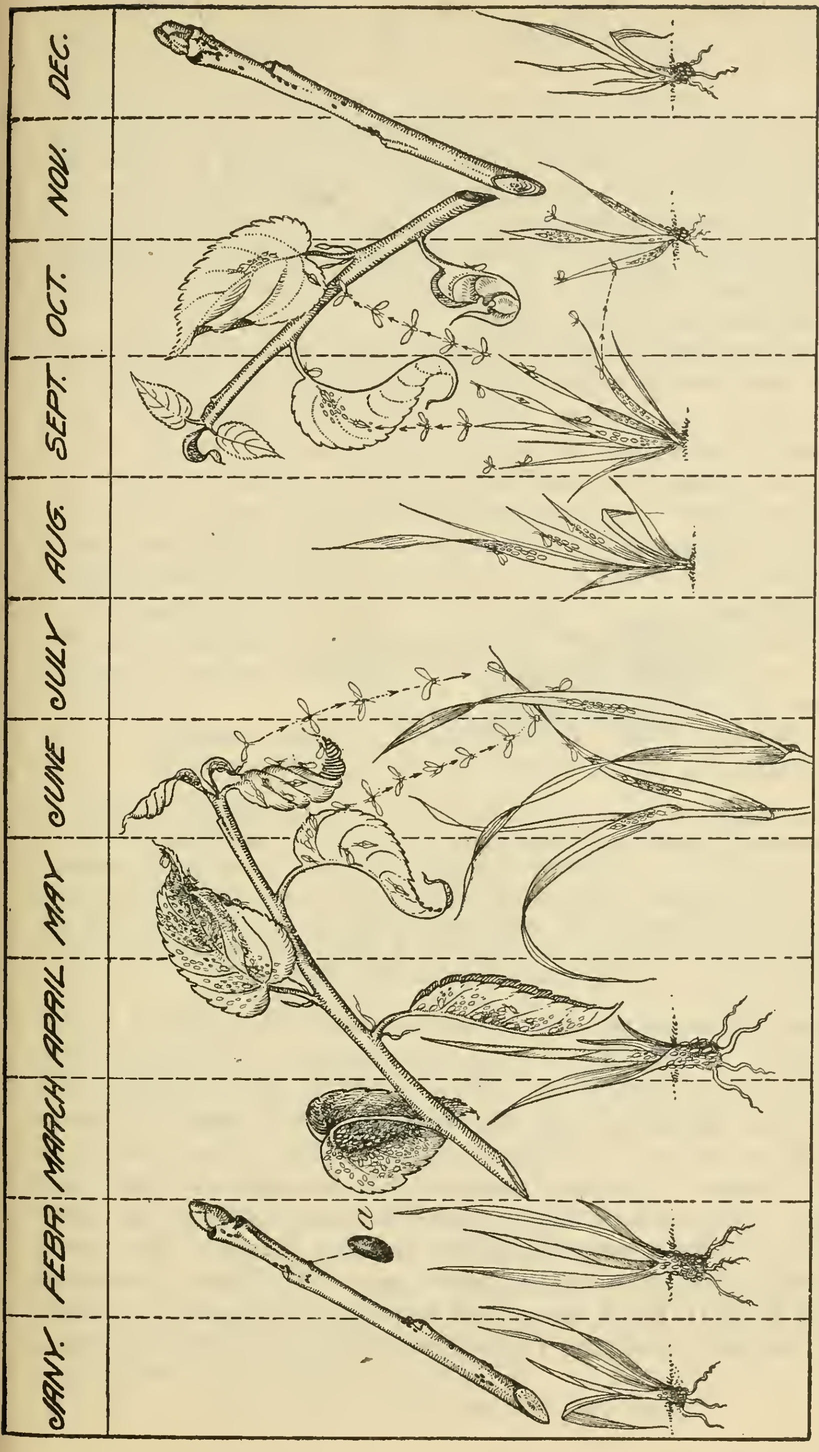

FIG. 5.—Diagrammatic explanation of the life cycle of the oat aphis. January–February, in egg (*a*) stage on apple and related trees or as wingless females on lower parts and roots of wheat and grasses. March–June, progeny from eggs hatching on apple migrate to grasses and grains. September–November, migrants return to apple, where several forms are produced and eggs laid. Others remain on grasses or migrate to fresh grass hosts, passing the winter as viviparous females. (Original.)

17 mother plant-lice was 22.1 young; and in 1912 the average for 43 individuals was 32.7 young, with a range of from 12 to 65 young per female. There was thus an average for the three years of 32.3 young. The largest number of young produced by a single female was 103, and normally, in the cooler parts of the year, the number ranged between 50 and 60. The number of young produced per day ranged from 1 to 8 per female, and the length of the period from birth to maturity varied from 6 to 15 days and averaged about 8½ days, excepting in late fall, when the length of time was ordinarily much greater. According to the numerous tests the species molts but four times, as do other species.

It will be seen from the foregoing that this species, like many other plant-lice, is quite prolific, although not so prolific as the "green bug" (*Toxoptera graminum*). It is computed that in 15 generations, averaging 30 young per female, the progeny from a single individual, providing all lived and reproduced, would cover almost the entire land area of the world, or, if packed 256 to the square inch and piled 25 high to the inch (6,300 to the cubic inch), would cover the entire State of Texas to a depth of 7 inches. Fortunately plant-lice are delicate insects, being highly susceptible to rains and inclement weather, and are preyed upon by many predaceous and parasitic animals, as well as being subject to fungous diseases.

In 1879 Dr. Cyrus Thomas[1] aptly discusses the winter habits of the wintering viviparous females in the following words:

> When winter appears they move down toward the ground, some of them, at least, entering the soil and feeding upon the sap of the roots. At any rate, I find the apterous ones at this time working upon the roots, but at the same time I find a winged individual above ground. I have also observed them heretofore at the root of the wheat, late in winter, while snow was on the ground; and what somewhat surprised me, I found them busy at work under the snow, and the apterous females bearing well formed larvæ.

There are numerous office records in which the occurrence of this plant-louse is reported on wheat and grasses during the winter months, but the following individual record will substantiate the belief that the insect may survive even rather severe winters as viviparous females. At Wellington, Kans., Mr. T. H. Parks found adult wingless viviparous females of the oat aphis on wheat roots April 9, 1910, and these had undoubtedly passed the winter on wheat, or were the direct progeny of overwintering females. The winter of 1909–10 was an unusually severe one at Wellington, according to Mr. E. O. G. Kelly, the ground becoming frozen early in December, 1909, and remaining frozen until February, 1910, after which

[1] Eighth Rept. State Entomologist, Ill., 1879, p. 53.

it alternately froze and thawed until March, 1910, the weather being so severe that 50 to 75 per cent of the wheat in that vicinity was killed by the cold.

Sometimes these winter root forms are attended by ants, as has been observed by Prof. Webster and the writer. The forms which go to apple migrate early in October in the latitude of La Fayette, Ind., and usually fully a month later in the latitude of northern Oklahoma. In the rearing cages it has never been possible to get the forms from wheat to migrate to apple, the failure doubtless resulting from the use of too small cages. On the other hand, there was no difficulty in getting the spring migrants to go to wheat and there continue to reproduce throughout the summer from apple shoots, even in small lantern globe cages.

NATURAL CHECKS.

Like most plant-lice of the genus Aphis, *avenæ* is freely attacked by various parasitic and predaceous animals, principally insects, and doubtless these are responsible for the usual control of this pest.

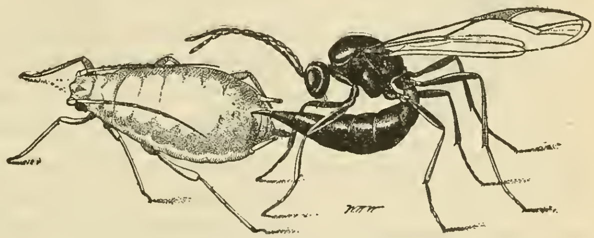

Fig. 6.—*Aphidius testaceipes* ovipositing in the body of the spring grain-aphis. Enlarged. (From Webster.)

Among the internal parasites, Fitch[1] has recorded *Toxares triticaphis* Fitch, (*Praon*) *Aphidius avenaphis* Fitch, and *Allotria tritici* Fitch, but it is probable that he reared these from *Macrosiphum granarium* rather than from *Aphis avenæ* as was supposed by Mr. Pergande.[2] In 1894 F. M. Webster[3] reports rearing *Pachyneuron micans* Howard and (*Lysiphlebus*) *Aphidius testaceipes* Cresson (*tritici* Ashmead). The latter species (figs. 6 and 7) is the one which ordinarily holds the spring grain-aphis (*Toxoptera graminum*) in check, and doubtless is likewise beneficial in preventing undue multiplication in *avenæ*. Mr. Theo. Pergande[4] reared another species of *Aphidius* (*A. nigriceps* Ashmead) in considerable numbers from this aphis.

Among the predaceous insects Pergande[4] has reared a common syrphid fly (*Syrphus americanus* Wiedemann) (fig. 8); the writer has reared a species of Aphidoletes from larvæ feeding on *Aphis*

[1] Sixth Rpt. on the noxious and other insects of the State of N. Y., 1865, pp. 98–112.
[2] U. S. Dept. Agr., Div. Ent., Bul. 44, 1904, p. 13.
[3] Ohio Agr. Expt. Sta., Bul. 51, 1894, p. 117.
[4] Op. cit.

avenæ at La Fayette, Ind., and Washburn[1] says that this plant-louse is attacked by a "red mite." Of the ladybird beetles which attack this aphis, Fitch mentions *Hippodamia parenthesis* Say, *Coccinella 9-notata* Herbst, and *Coccinella 5-notata* Kirby, although it seems probable that Fitch was dealing with a different plant-louse, and he may not have observed them feeding on the oat aphis. At different times assistants of the Cereal and Forage-Crop Insect Investigations have observed the following ladybird beetles, or their larvæ, feeding on the oat aphis in various parts of the United States: *Cycloneda munda* Say, *Coccinella 9-notata* Herbst, *Megilla maculata* DeG., *Scymnus* sp., and *Hippodamia convergens* Guér. (fig. 9), the last species being by far the most abundant, and consequently the most useful of the coccinellids in the control of the aphis.

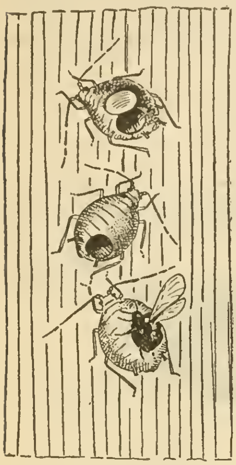

FIG. 7.—Dead aphides, showing holes from which the matured parasites of *Aphidius testaceipes* emerge. The top figure shows the lid still attached, but pushed back; the bottom figure shows the parasites emerging. Enlarged. (From Webster.)

In addition to the foregoing enemies, the larvæ of several species of lace-wing flies (Chrysopidæ) are known to feed upon this aphis.

Miss Margaret Morse, of Worcester, Mass., (in litt.) has found that quails eat these aphides in confinement, and while definite field observations are lacking, it is quite probable that the quail, or bobwhite, as well as other birds frequenting grain fields, plays an important part in the control of this and other grain aphides.

Among other natural agencies which assist in holding the aphis in check are fungous diseases. These, like most fungi-attacking insects, thrive best under moist conditions; hence the diseases commonly attacking plant-lice are most prevalent and useful in moist seasons. Rains likewise have a beneficial effect, particularly "driving" rains.

Webster,[2] in his Ohio report, "suspects" two minute insects, *Gonatocerus brunneus* Ashm. [MS.] and *Polynema longipes* Ashm. (*Cosmocena citripes* Ashm.) as destroying eggs of *avenæ*, but this observation has apparently never been authenticated.

REMEDIAL AND PREVENTIVE MEASURES.

As in the case of the well-known spring grain-aphis, or "green bug" (*Toxoptera graminum*), it is practically impossible to control

[1] Twelfth Rpt. State Entomologist of Minn. for 1907 and 1908, Dec., 1908, p. 50.
[2] Op. cit., p. 117.

the oat aphis after it has once gained much headway in numbers and diffusion, but by proper precautions it is possible to prevent serious outbreaks.

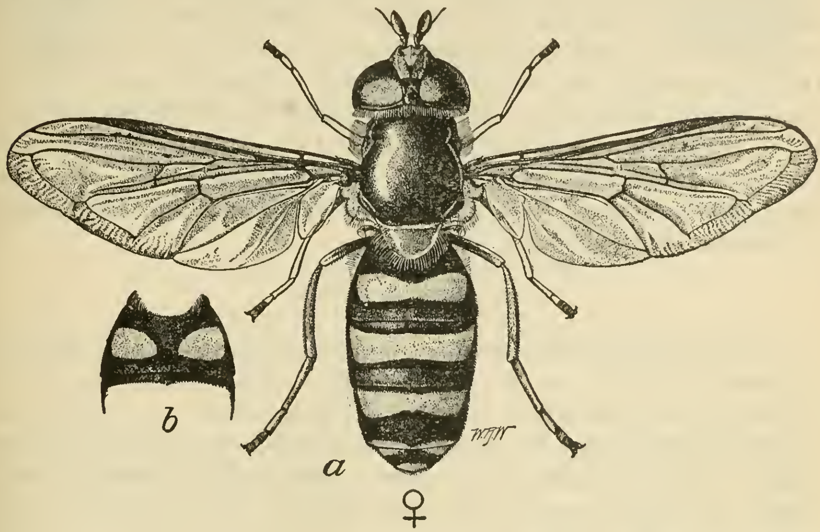

Fig. 8. *Syrphus americanus,* whose larva destroys the oat aphis. *a,* Female fly; *b,* second abdominal segment of male. Enlarged. (From Webster and Phillips.)

DESTRUCTION OF BREEDING PLACES.

As has been observed by the writer and other assistants of the Cereal and Forage-Crop Insect Investigations, the plant-louse under discussion thrives best in rank-growing wheat, for instance in spots where manure piles or straw stacks have stood, as well as in the vicinity of straw stacks where the growth of grain is usually luxuriant. In fact, observations show that the latter place is the usual center of infestation, for during the colder winter months the plant-lice may be found here when it is impossible to locate them elsewhere. Such locations also provide much better protection from inclement weather, and reproduction may continue, more or less, throughout the winter. Therefore it is evident that if the growth about straw

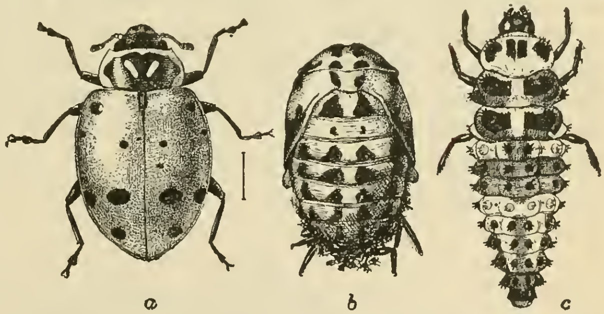

Fig. 9.—The convergent ladybird (*Hippodamia convergens*), an enemy of the oat aphis: *a,* Beetle; *b,* pupa; *c,* larva. Enlarged. (From Chittenden.)

stacks be plowed under or otherwise destroyed late in fall, the aphides harbored thereon will be destroyed. In some cases it may be desirable to destroy this vegetation even earlier; that is, before the winter wheat is planted or at least before it makes any growth above ground. Likewise the pasturing of cattle in wheat and oat fields in Oklahoma and Texas during the late fall and early winter is desirable; indeed, observations made by Messrs. W. E. Pennington and H. S. Smith, of the Cereal and Forage-Crop Insect Investigations, show that where this procedure had been followed, the grain was practically free from the oat aphis, although adjoining unpastured fields showed rather heavy infestation.

CULTURAL METHODS.

As in the case of many other grain pests, crop rotation is of much importance in the control of this aphis. Wheat fields should be located as far from the previous year's grain fields as possible, and especially should they be planted some distance from standing straw stacks. It is also advisable to plant grain as far as possible from apple and other trees, which harbor the insect during the fall, winter, and spring months.

SPRAYING.

Direct applications are hardly practicable in grain fields, but where only small areas are badly infested spraying with blackleaf-40 at the rate of 1 part of this insecticide to 900 parts of water, plus 1 pound of soap to each 100 gallons of spray liquid, will doubtless prove efficacious, providing the application is thorough.

Another method which might be adopted in localities where the aphides freely migrate and deposit eggs on apple, is spraying such trees early in spring before the eggs hatch, preferably just previous to their hatching and while the trees are yet in a dormant condition, with commercial lime-sulphur mixture at the rate of 1 part of the mixture to 8 parts of water.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 113

Contribution from the Bureau of Entomology, L. O. Howard, Chief

August 22, 1914.

(PROFESSIONAL PAPER.)

THE LESSER BUD-MOTH.

By E. W. Scott and J. H. Paine,

Entomological Assistants, Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the spring of 1912, while engaged in apple spraying experiments at Benton Harbor, Mich., the senior author noticed the work of a small larva in the buds of unsprayed apple trees. The injury inflicted by this minute insect was quite severe in a neglected orchard near the laboratory, and this insect, among others, was the most important factor in the destruction of the entire crop of fruit. From the character of the injury, the attack on the swelling buds; and the tying together of the growing leaves the damage was at once attributed to the eye-spotted bud-moth (*Tmetocera ocellana* Schiff.).

In 1913 a study was made of the life history and habits of this insect, supposedly the eye-spotted bud-moth, and experiments were tried with remedial measures. The first discrepancy noticed between the habits of this insect and those of the eye-spotted bud-moth, as stated in literature, was the fact that the hibernaculæ were not necessarily situated near the buds, but were to be found in any suitable place upon the limbs. Following this, many other even more striking differences in habits were noted during the course of the season, and the fact was soon impressed upon the writers that they had to deal with an insect whose economic importance had not been recorded in the United States.

The adult moths, upon submission to Mr. August Busck, of the Bureau of Entomology, were identified as *Recurvaria cratægella* Busck (1903),[1] a species described by him (with no indication of its life history) in 1903 from material submitted by Mr. William Dietz from Hazleton, Pa., who reared it from hawthorn (*Cratægus tomen-*

[1] Bibliographic citations in parenthesis refer to "Literature cited," pp. 15 and 16.

NOTE.—Describes an imported insect which is very destructive to several kinds of growing fruit and has attained quite wide distribution throughout the Northeastern and North Central States.

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tosus) in June. Busck makes the following statement in his description:

I am, at present, unable to separate this species from a series of authentic European specimens of *R. nanella* Hübner, and I am conscious of the probability of my making a synonym of this species, the life history of which, according to Meyrick's Handbook of British Lepidoptera, is not definitely known, but which is variously said to feed in flowers or the shoots of pear or on lichens growing on the trunk.

However, in the same year Houghton (1903) published a short though complete account of the life history of *Recurvaria nanella*, corresponding in detail to our observations in Michigan. In view of this identity between the life histories as observed in Europe and America, Busck feels certain of the identity of the two insects, as appears in a statement by him in the accompanying footnote.[1]

HISTORY OF THE SPECIES IN EUROPE.

Stephens (1834) records *Recurvaria nanella* as "not very uncommon in gardens within the metropolitan district (London), frequenting the trunks of apple trees in June and the beginning of July."

Stainton (1854) records the larva as feeding in May, in England, on the pear, making a gallery across the flowers with pieces of the petals and stamens interwoven with silk.

Rössler (1871–72) observed the tying together of the young leaves of fruit trees by larvæ of *Recurvaria nanella* and its effect in hindering the development of the new leaves, at Wiesbaden, Prussia. The insect was present in such large numbers as to attract the attention of the public to the deformed trees and to arouse the fear that serious harm would result. In view of the fact that the larva was so small, ate so little, and did not attack the blossoms, Rössler considered that it was not to be feared.

Houghton (1903) published quite a complete though short account of the life history and habits of *Recurvaria nanella* from an economic point of view, as observed by him in England. His attention was directed to the insect in an apricot orchard, where the crop had been practically destroyed by it in previous years. He was the first to note the fact that the larva, after hatching, passes the time before hibernation as a miner in the leaf. He also observed that it was the habit of the larvæ to bore into the swelling buds in the spring. The larvæ appeared in swarms on peaches and apricots and less commonly on cherries and plums. In his description of the larva he men-

[1] *Recurvaria crataegella* Busck (Proc. U. S. Nat. Mus., v. 25, p. 811, 1903) is identical with the European *R. nanella* Hübner, as already suggested in the description. At that time the life history of the species was but fragmentarily known in Europe, and it was deemed the soundest course to give the American form a separate name, even though it was realized that it would probably prove the same as the European species. The subsequent careful study of the life history in Europe by J. T. Houghton and in this country removed all doubt about the synonymy.—A. B.

tions the different colors assumed by the caterpillars as they near maturity, and this observation corresponds with our own.

DISTRIBUTION OF THE SPECIES.

The distribution of *Recurvaria nanella* in Europe is given by Staudinger and Rebel (1901) as follows: Central Europe, Sweden, northern Spain, southern France, central and northern Italy, Dalmatia, and southwestern Russia.

Specimens of *Recurvaria nanella*, all identified by Busck, have been received by the Bureau of Entomology and by the United States National Museum from a number of localities in the United States. As previously stated, the first specimens were received in 1903 from Mr. William Dietz, Hazleton, Pa. Others have been received from Pittsburgh, Pa., collected by Henry Engle; from Denton, Md., collected by Quaintance in April, 1905, on peach; from College Park, Md., by Girault in August, 1905, on apple, "from fruit;" from Bennings, D. C., collected by Girault in May, 1905, "found resting in numbers on trunks and larger limbs, simply swarming on peach trees;" from Albany, N. Y., by Felt; from Hampton, N. H., by Shaw; from Dublin, N. H., by Busck; and from Cleveland, Ohio, by Prior, the larvæ eating apple leaves.

It is improbable that the insect has attained this distribution in the United States through natural means from a single importation from Europe, but it is likely that it has been imported a number of times on nursery stock shipped to various points in this country. In fact, the importation of this insect, which spends six or seven months in hibernation concealed in minute cracks and crevices of the bark, could occur most easily.

FOOD PLANTS.

In the earlier references to *Recurvaria nanella* the pear is usually given as the host plant. Houghton, however, failed to observe it infesting this fruit, but finds it swarming on the apricot, destroying the crop. On the other hand, it is certain from the observations of other authors that the pear is a favorite food plant, for the insect has often been observed frequenting pear trees in the vicinity of London. Other European host plants are apple, peach, plum, cherry, wild plum, and hawthorn. It has been recorded as attacking the peach in swarms. At Benton Harbor, Mich., the insect was reared from apple, peach, pear, plum, and sweet and sour cherries. The infestation was light on plum and cherry. At Hazleton, Pa., it was reared from a wild hawthorn.

It is interesting to note the immunity of the Kieffer pear to the attack of the young larva in the fall or leaf-mining stage. The larvæ, upon hatching, bore into the tissue of the leaves of this variety, showing no discrimination against it; the mines, however, are never developed to any great extent, for the tissue of the leaf about the mine turns dark and apparently hardens, effectually stopping the operations of the insect. Many larvæ must thus meet their death, being unable to secure food. This is another instance illustrating the resistant qualities of the Kieffer variety of pear.

CHARACTER OF THE INJURY.

The first attack by the larvæ of *Recurvaria nanella* in the spring is aimed at the swelling buds (Pl. II, figs. 3 and 4) of both blossoms and leaf. The insect bores into the bud, eating the tender tissues as it goes, showing particular partiality for the young stamens and pistil, if it has been lucky enough to select a blossom bud. As the buds open and the leaves begin to expand the larva ties the tips of the leaves together, spinning about them a tiny silken thread, thus greatly deforming and hindering the succeeding leaves as they develop (Pl. I, fig. 2). It is this injury, when inflicted by countless numbers of this tiny caterpillar on nearly every bud on a tree (Pl. I, fig. 1), that results in a serious, if not almost total, loss of the crop.

SYNONYMY.

Recurvaria nanella.

Tinea nanella (Schiff.) Hübn., 1796 (?), Tineæ, pl. 39, fig. 267.
Euota pruniella Schiff., 1776, Syst. Verz. Schmet., C. 75.
Tinea alcella Fab., 1794, Ent. Syst., v. 3, pt. 2, p. 317.
Recurvaria nana Haw., 1829, Lep. Brit., v. 4, p. 554.
Trichotripis nanella Hübn., 1816, Verz. bek. Schmet., p. 425, No. 4143.
Anacampsis nana (Haw.) Curt., 1827, Brit. Ent., v. 4, pl. 189.
Anacampsis alcella (Fab.) Steph., 1829, Syst. Cat. Brit. Ins., pt. 2, p. 197.
Gelechia nanella (Hübn.) Her.-Schäf., 1853–1855, Syst. Bearb. Schmet., v. 5, No. 416.
Recurvaria nanella (Hübn.) Heinem., 1870, Die Schmet. Deutsch. u. d. Schweiz., Bd. 2, p. 280.
Aphanaula nanella (Hübn.) Meyrk., 1895, Handb. Brit. Lep., p. 580.
Recurvaria cratægella Busck, 1903, *in* Proc. U. S. Nat. Mus., v. 25, p. 811.

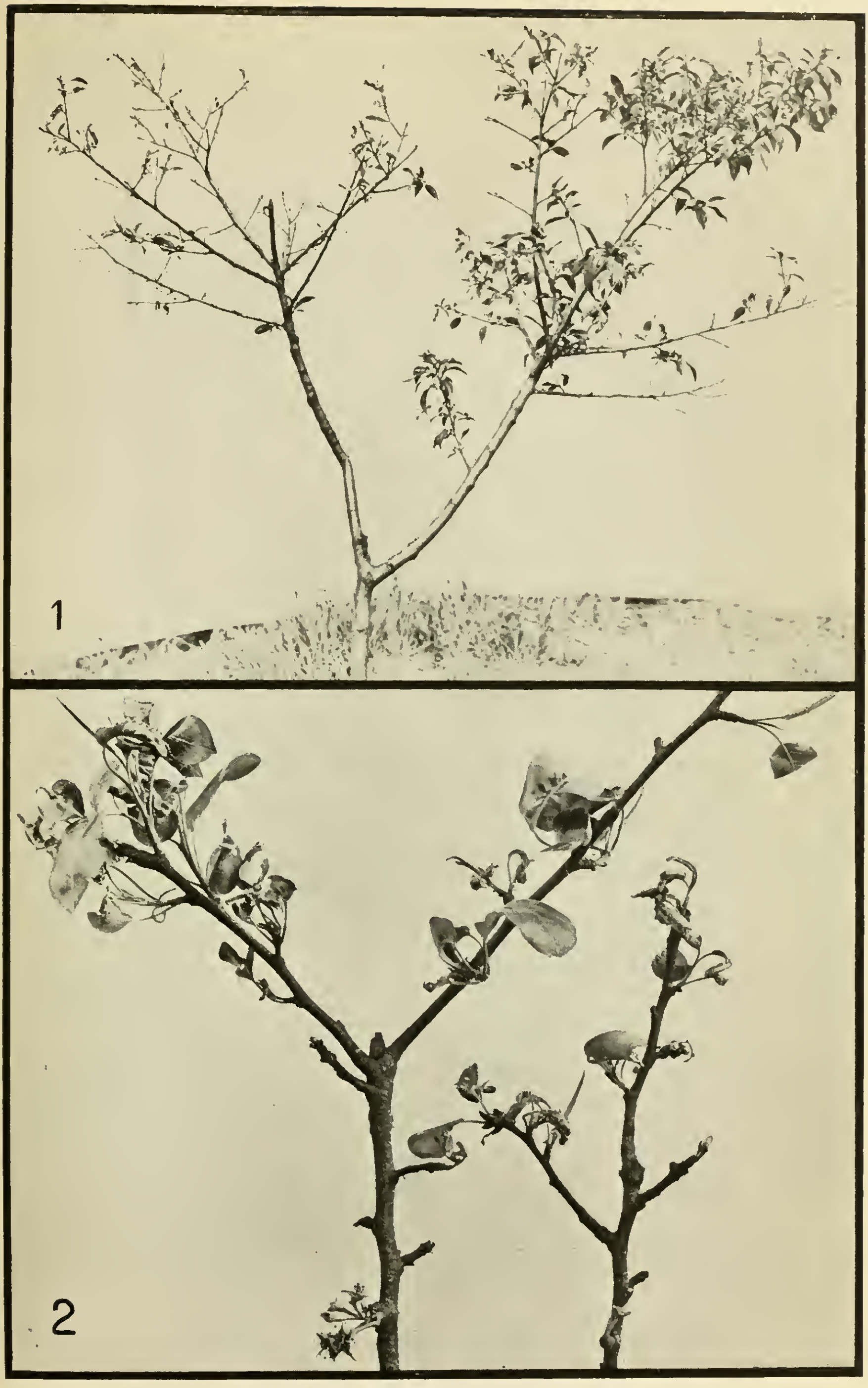
DESCRIPTION OF THE LESSER BUD-MOTH.

THE ADULT.

The adult (Pl. II, fig. 6) of *Recurvaria nanella*, or lesser bud-moth, is a very small streaked moth with a wing expanse of half an inch, although as it appears on the tree trunks it is not more than one-fourth of an inch long; the black and white banded legs are quite conspicuous. The following technical description is as given by Busck for *R. cratægella* (1903):

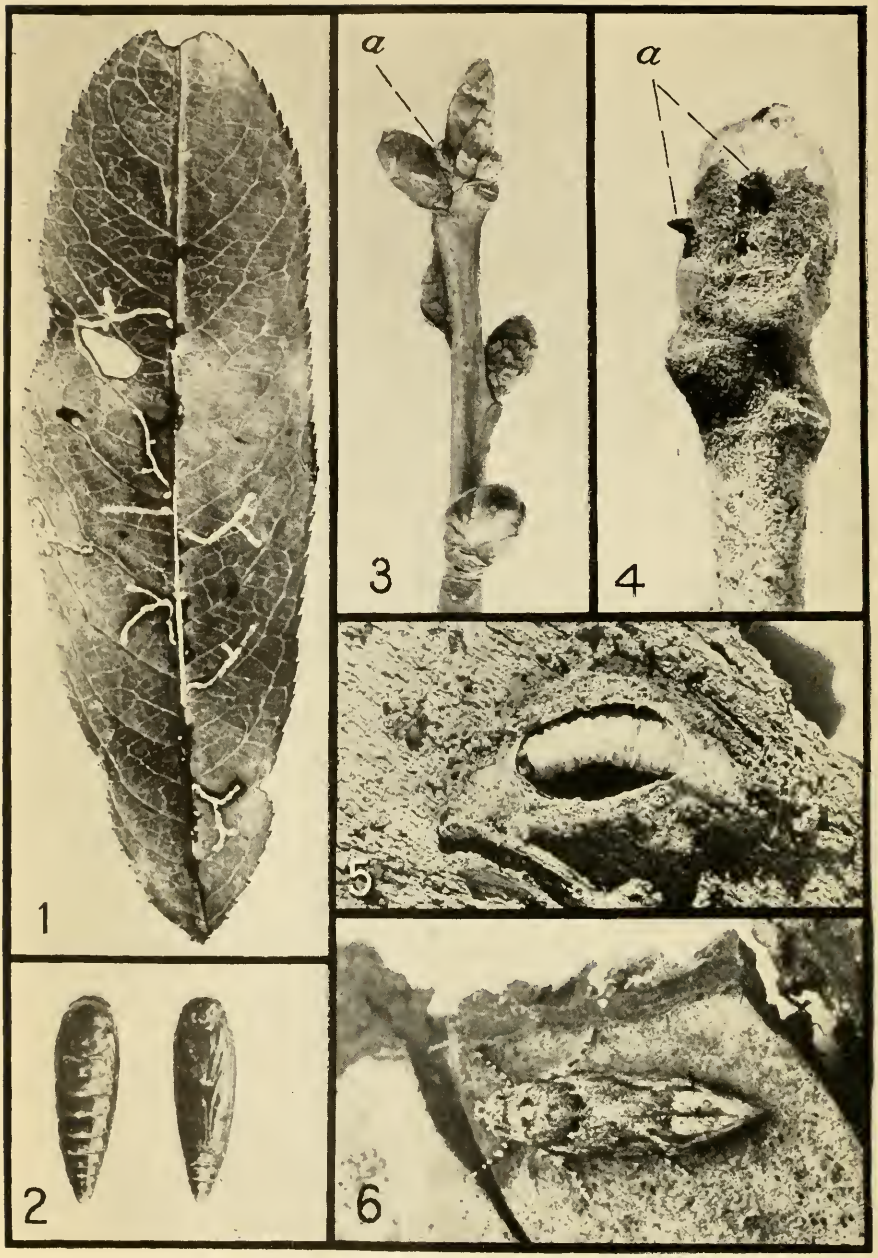
Antennæ whitish, with indistinct, narrow, dark-brown annulations. Labial palpi whitish, with two black annulations on each joint; tip white. Face, head, and thorax white, suffused with fuscous.

Fore wings white, thickly sprinkled with fuscous.. From near the base of the costa is an outwardly directed, oblique, ill-defined black streak, which



WORK OF LARVÆ OF THE LESSER BUD-MOTH (RECURVARIA NANELLA).

Fig. 1.—Neglected peach trees partially defoliated by larvæ. Fig. 2.—Work of larvæ on pear twigs resulting in the destruction of some of the buds. (Original.)



THE LESSER BUD-MOTH (RECURVARIA NANELLA).

Fig. 1.—Partially developed mines of larvæ in a peach leaf. Fig. 2.—Upper and lower views of pupa. Fig. 3.—Exerement (*a*) deposited at entranee to larval burrow in cherry bud. Fig. 4.—Apple bud infested with larvæ, showing excrement (*a*) deposited at entrance to burrows. Fig. 5.—Full-grown larva in eocoon on bark removed from trunk of pear tree. Fig. 6.—Moth at rest on bark. Fig. 1, slightly enlarged; figs. 2, 5, 6, about six times enlarged; fig. 4, about twice enlarged; fig. 3, natural size. (Original.)

does not reach the dorsal edge and which is more or less interrupted at the fold and bordered on the outside with white scales. From the middle of the costa is a similar, parallel, interrupted dark streak still less clearly defined. At the end of the cell in the middle of the wing is a short, black, longitudinal streak; below this on the dorsal edge is a small black spot, and on the costal edge are two similar black spots, one at the apical third, the other just before apex. Cilia white, speckled black, and fuscous. Hind wings light silvery fuscous; cilia a shade lighter than wing; male without costal hair pencil.

Abdomen dark fuscous, anal tuft silvery gray; legs white, with black annulations; hairs on posterior tibia silvery white. Alar expanse, 12 mm.

The species is very near the other fuscous species of the genus and is easily confused with *Recurvaria cristatella* Chambers, but besides minor colorational variations, it differs in the lack of the hair pencil at the base of the hind wings in the male.

THE LARVA.

In the larva (Pl. II, fig. 5) the usual characters of Gelechiidæ are exhibited. Up to the time of hibernation the young larvæ are light reddish brown, with the head, a plate on the second segment, a small plate on the anal segment, and the upper surface of the legs vandyke brown. Soon after issuing from their hibernacula in the spring they lose the anal plate, and as they reach their full growth many of them turn from brown to pale green, while others exhibit various shades between the two. This color variation of the larva has no effect on the appearance of the moth, for both brown and green larvæ have been isolated and reared, resulting in adults of a uniform type.

The larva shortly after hatching measures a little over 1 mm., or about one-twentieth of an inch, in length. It grows slowly and at the time of hibernation measures from 2.1 to 2.6 mm., and when full grown from 8 to 10 mm., or about three-eighths of an inch, in length.

THE PUPA.

The pupæ (Pl. II, fig. 2) shortly after the transformation takes place vary in color from brown to green, as do the larvæ; in a few days, however, they all turn brown. They measure 4 or 5 mm., or three-sixteenths of an inch, in length.

LIFE HISTORY AND HABITS.

ADULT STAGE.

The first moths (Pl. II, fig. 6) issued in rearing cages at Benton Harbor, Mich., on June 22. Some individuals may have emerged in the orchards before this date, for they were found there in considerable numbers on June 23. In the rearing cages the maximum emergence took place on June 30, and the last moths to appear issued on July 10; the period of emergence thus covered 19 days. In Table I is given the record of the emerging moths in cages in the rearing shelter and the emergence of hymenopterous parasites of the larvæ. The total number of adults that issued was 383; of larval parasites, 14.

TABLE I.—*Record of emergence of adults and larval parasites of the lesser bud-moth in rearing cages at Benton Harbor, Mich., in 1913.*

Date of emergence.	Number of moths.	Number of larval parasites.	Date of emergence.	Number of moths.	Number of larval parasites.
June 22	5	0	July 2	13	0
23	10	0	3	35	0
24	12	2	4	11	0
25	17	4	5	0	0
26	21	6	6	1	0
27	36	2	7	0	0
28	64	0	8	2	0
29	47	0	9	0	0
30	65	0	10	2	0
July 1	42	0	11	0	0

In figure 1 this record of the emergence of the adults is graphically shown.

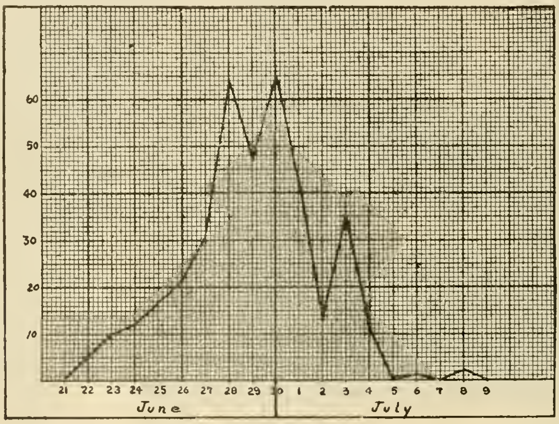


FIG. 1.—Graphic representation of time and relative emergence of adults of the lesser bud-moth in rearing cages at Benton Harbor, Mich. (Original.)

During the first few days of emergence the number of males issuing was greatly in excess of the females; toward the last of the period, however, the reverse was true. Table II shows the proportion of males and females as they issued on successive days.

TABLE II.—*Relative number of males and females of the lesser bud moth issuing in rearing cages at Benton Harbor, Mich., in 1913.*

Date.	Number of males.	Number of females.	Date.	Number of males.	Number of females.
June 24	20	4	June 30	7	15
25	12	3	July 1	3	4
26	10	4	2	6	13
27	12	14			
28	16	17	Total	97	103
29	11	29			

In the field the moths were found in large numbers resting on the trunks of the trees. They remained motionless until touched, and even then often flew only a short distance, taking a new position on the same trunk. As many as 15 were counted on the shady side of the trunk of a small Kieffer pear tree. However, the insects did not confine themselves to the trunks of the trees alone, but were occasionally found resting upon near-by weeds or upon the branches and, in a few cases, upon the leaves.

All attempts to feed the moths in captivity failed. They apparently refused to taste the brown-sugar sirup offered them. Nor were attempts to obtain eggs in confinement more successful, as the insects would not oviposit under the unnatural conditions of the rearing cage.

EGG STAGE.

Although a most diligent search was made for the eggs of the lesser bud-moth, no trace was found of them. This failure is in a measure due to the fact that nothing of the habits of the insects was at that time known to us. The adults were seldom observed anywhere except at rest on the tree trunks, although without doubt they deposit their eggs on the underside of the leaves singly, as evidenced by the location of the entrance opening to the leaf mines. Eggs in the egg tubes of the females were observed when dissected, but nothing of their appearance after oviposition could be surmised.[1]

LARVAL STAGE.

It is in the larval stage that *Recurvaria nanella* spends most of its life. In Benton Harbor the eggs commenced hatching about July 15. The larvæ at this time are very small, measuring scarcely more than 1 mm. in length. They at once bore through the epidermis of the leaf on the underside and commence the construction of a most curiously shaped mine in the inner tissues of the leaf. (See Pl. II, fig. 1.)

The larva first eats its way in a small circle, then constructs a main burrow which soon divides, the branches in turn again dividing, often after the manner of the branching of a tree. The form of these mines, however, is by no means regular, but shows considerable diversity. The insect does not finish the construction of any branch of the mine at once, but feeds at will in all parts, keeping the whole

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[1] As this paper is going to press, specimens of eggs of the lesser bud-moth have been received from Mr. E. H. Siegler, of the Bureau of Entomology, who has been successful in obtaining them from moths confined in glass jars, at Benton Harbor, Mich. Some of the eggs received had been loosely deposited among the hairs on the underside of an apple leaf, singly or several sticking together, for the most part along the veins of the leaf. Another lot had been deposited on a twig under the edge of a small scale. The egg is oblong, inclined to be cylindrical, though irregularly so, and is flattened where it comes in contact with another in the cluster. It is minute in size, measuring about 0.32 mm. long by 0.2 mm. broad, and is pale, shining yellow in color.

mine open and ejecting all excrement at the point of entrance. Thus, if the larva, which can be seen through the epidermis, be disturbed, it will rapidly crawl to another part of the mine; and if followed, will escape at the entrance hole.

The larvæ show no preference as to the point of entrance, eating their way into the leaf tissues at any point from the midrib to the edge.

One or many mines may be constructed in a single leaf, according to the degree of infestation. Where the insects are numerous, the mines form a network covering the leaf. It is evident that the adult female in depositing her eggs lays a number at one time on adjacent leaves, as the mines usually appear in groups, several affected leaves occurring on the same twig or neighboring twigs.

Upon the arrival of the first cold days of fall the larvæ begin leaving the mines to construct the small silken hibernacula in which they pass the winter. The desertion of the leaf mines commenced about September 12 (1913), the temperature showing the first considerable drop of the season at that time. By September 17 practically all the larvæ had disappeared from the mines. However, upon picking off small pieces of loosened bark, or lifting up old bud scales, the larvæ were discovered spinning the minute cocoons which were to be their winter shelter.

No preference was shown in the selection of a place for hibernation, the larvæ taking possession of the first available protection. On large trees they confine themselves to the twigs and smaller branches, but on small trees they may be found in abundance on the larger limbs and trunk. The hibernating larvæ on large trees, even where the infestation is severe, are difficult of location, being very small and inconspicuous. However, after a few warm days in the spring the larvæ begin to appear in great numbers, as if spontaneously.

As the weather warms and the buds on the fruit trees swell, one may discover, upon close observation, minute masses of reddish or greenish pellets upon the buds. This is the excrement which the larva within has deposited at the entrance to its burrow (Pl. II, figs. 3 and 4).

The first larvæ at Benton Harbor were observed working in the buds in considerable numbers on April 15, when the buds were just beginning to swell. They probably began emerging in small numbers one or two days before.

The insect appears to show little preference as to the point of its attack on the bud, for it enters either at the side or at the tip. As a rule those entering at the side do so just at the edge of the bud scales, although sometimes one will pierce the scales themselves. In a few cases larvæ were noted entering buds which had not begun to swell, but which were still in a dormant state. Over the entrance to the burrow the caterpillar spins a fine netlike web. The larva burrows to the center of the bud both by means of eating its way, the material passing through its alimentary canal, and by biting off bits and carrying them to the outside. The latter method is used when the insect is piercing the tough outer layers of the bud.

Should the temperature drop after a warm day has tempted the caterpillars to come out of hibernation, but before they have had the opportunity to enter a bud, they will seek shelter under loose bark on the limbs. Many larvæ were found under the bark on April 16, but by April 23 all had apparently entered buds.

As before mentioned, the larva upon entering a bud makes its way directly to the center, there feasting on the tender ovary of the unopened flower, provided the insect has entered a flower bud, which the majority do. It is this habit which does the greatest amount of injury (Pl. I, fig. 1), for often every bud on a large limb will be affected. After consuming the inner portions the larvæ feed upon the leafy tissue of the bud, remaining within until the bud expands and the leaves begin to unfold.

As the first leaves open out, the larva fastens them together, spinning its fine strand of silk as it crawls about (Pl. I, fig. 2). It now constructs for itself a shelter or cocoon of silk, often rolling over the edge of a leaf and constructing it from within, or bringing the tips of several leaves together and spinning it in the midst, or making a combination of the two methods. As a rule, the larvæ during the day are to be found at rest within this cocoon, giving evidence for the supposition that the insects are nocturnal feeders.

On May 15 it was noticed that some of the nests in the leaves were empty, and by the next day a large percentage of the larvæ had disappeared. However, a search revealed the caterpillars under bits of loose bark on the limbs and trunk constructing cocoons in which to pupate (Pl. II, fig 5). On large trees where there is a great deal of roughened bark the cocoons are difficult to locate, but on smaller trees they will be found clustered in the crevices on the trunk; this is especially true on young pear trees, where most of the bark is smooth, affording the insects no shelter. A search among the leaves and débris on the ground beneath the trees revealed a few larvæ transforming in the shelter there afforded.

The last crawling larvæ in the orchard were found on June 19. Thus the larval stage covers an average period of about 10 months.

The number of molts of the larva was not accurately determined, the only data taken on this subject being measurements of the width of the head taken at successive intervals during the development of this stage of the insect. These measurements, arranged numerically, are given in Table III. It is not the writers' opinion that these figures show definitely the number of molts, but they are presented merely for what they are worth. However, a study of Table III seems to warrant the interpretation that there are five instars, or four larval molts. In the last instar considerable variation in the width of the head will be noticed, but as this same variation is found among full-grown larvæ taken from their cocoons, they are all considered as belonging to the same stage.

TABLE III.—*Measurements of width of head of larvæ of the lesser bud-moth taken at intervals throughout their development at Benton Harbor, Mich., in 1913.*

Date.	Width of head.	Stage.
	Mm.	
July 29 (just hatched).	0.12	First instar.
	.12	
	.12	
	.14	
	.15	
	.15	
	.16	
	.16	
	.16	
	.16	
	.16	
August	.16	
	.16	
	.16	
	.16	
	First molt.	
	.19	Second instar.
	.19	
	.19	
	.19	
	.20	
	.21	
	.21	
	.21	
	.21	
	Second molt.	
	.245	Third instar.
	.245	
	.25	
September	.26	
	.275	
	.275	

Date.	Width of head.	Stage.
	Third molt.	
	Mm.	
	0.31	Fourth instar.
	.31	
April 8 (in hibernation).	.34	
	.35	
	.36	
	.36	
	.38	
	.38	
April 18 (in buds)	.38	
	.41	
	.41	
	.43	
	.43	
	.48	
	Fourth molt.	
	.56	Fifth instar.
	.57	
	.57	
	.59	
	.60	
	.62	
	.62	
	.64	
	.64	
	.64	
	.66	
	.86	
	.96	
	1.12	
	.60	
May 27 (in cocoon)	.64	
	1.02	

PUPAL STAGE.

The first pupæ (Pl. II, fig. 2) of the lesser bud-moth were found on May 18 under the loose bark on the trunks of young peach trees, incased in their small, white, silken cocoons. The last larvæ to pupate in the rearing cages did so on June 16. The average time spent as a pupa is about 19 days, varying, however, from 15 to 30 days.

Table IV is a record kept of isolated larvæ, giving dates of pupation and of emergence as adults.

TABLE IV.—*Pupation and emergence record of the lesser bud-moth in rearing cages at Benton Harbor, Mich., in 1913, showing number of days spent as pupæ.*

No. of observation.	Date of—		Days.	No. of observation.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.	
1	June 2	June 25	23	19	June 12	June 30	18
2	Jnne 3	June 27	24	20	June 14	...do....	16
3	...do....	...do....	24	21	...do....	...do....	16
4	...do....	July 3	30	22	...do....	...do....	16
5	June 6	June 27	21	23	...do....	...do....	16
6	...do....	...do....	21	24	...do....	July 1	17
7	...do....	...do....	21	25	...do....	July 3	19
8	...do....	...do....	21	26	June 16	July 1	15
9	...do....	...do....	21	27	...do....	...do....	15
10	...do....	June 28	22	28	...do....	...do....	15
11	...do....	...do....	22	29	...do....	July 2	16
12	June 9	June 27	18	30	...do....	...do....	16
13	...do....	June 26	17	31	...do....	July 3	17
14	...do....	June 28	19				
15	June 10	...do....	18	Average			18.9
16	...do....	...do....	18	Maximum			30
17	...do....	...do....	18	Minimum			15
18	June 12	June 30	18				

INSECT ENEMIES.

The following hymenopterous parasites, representing six families and seven genera, were reared from *Recurvaria nanella*, from material collected in the larval and pupal stages, and confined in breeding jars. Braconidæ: *Phanerotoma recurvariæ* Cushman; Ichneumonidæ: *Diadegma* sp. and *Itoplectis* sp.; Pteromalidæ: A broken, undetermined specimen; Encyrtidæ: *Eupelmus* sp.; Eurytomidæ: *Eurytoma* sp.; Chalcididæ: *Dibrachys* sp.

EXPERIMENTS IN CONTROL.

EXPERIMENT I.—A young apple orchard at Benton Harbor, Mich., was used for experimental spraying against the lesser bud-moth. This orchard consisted of 50 trees of the Oldenburg (*Duchess*) variety about 9 years old. Early in the spring, before the buds began to swell, the trees were examined and numerous hibernating larvæ were found under the loose bark, the infestation appearing uniform over the entire orchard. The orchard was divided into eight plats, each plat consisting of not less than eight trees. The material was applied with a hand barrel sprayer equipped with Vermorel nozzles. The results were determined by actual count of all infested and uninfested fruit and leaf buds from five trees of each plat, 10 days after the blossoming period. The results are shown in Table V.

TABLE V.—*Spraying experiments against the lesser bud-moth on apple, Benton Harbor, Mich., 1913.*

Plat No.	Treatment.	Number of buds infested.	Number of buds sound.	Total number of buds.	Total percentage of sound buds.
I	One application of commercial lime-sulphur solution (1 gal. to 8 gals. of water) on Apr. 8. Trees dormant	1,638	7,534	9,172	82.14
II	One application of soda-sulphur solution (1 lb. to 5 gals. of water) on Apr. 8. Trees dormant	680	4,228	4,908	86.14
III	One application of unfiltered lime-sulphur solution (1 gal. to 8 gals. of water) on Apr. 8. Trees dormant	924	5,918	6,842	86.49
[1] IV	Two applications of arsenate of lead (2 lbs. to 50 gals. of water) on Apr. 16, when buds began to swell, and on May 1, when cluster buds opened	956	7,019	7,975	88.01
[1] V	Three applications of arsenate of lead (2 lbs. to 50 gals. of water) on Apr. 16, when buds began to swell, on Apr. 24, when cluster buds were half open, and on May 1, when cluster buds were open.	523	8,006	8,529	93.86
VI	Check (unsprayed)	4,949	4,129	9,078	45.48

[1] Lime-sulphur solution, 1½ gallons to 50 gallons of spray, was added in the last application in plats IV and V, mainly for the control of apple scab.

As will be noted, the best results were obtained on Plat V, where three applications of arsenate of lead were used. In this case the buds were kept covered with poison, so that the larvæ had little chance to gain entrance into them. The next best results were obtained where two applications of arsenate of lead were used. However, the application of the lime-sulphur and the soda-sulphur solutions when the trees were dormant, both used at the strength recommended for the San Jose scale, were almost as effective as the arsenate of lead. The action of the sulphur compounds on the larvæ is not known, but they probably act largely as repellents.[1] The larvæ were examined in their hibernacula at various intervals from the time the application was made until they came out to enter the buds, and in all cases they were found unhurt and untouched by the spray. However, this was expected, since their hibernacula were protected from the spray by the loose bark under which they were hidden. Then, too, the hibernacular cases are of such construction that they can not be easily penetrated by spray. When the larvæ emerged, they disappeared, either having been repelled from the tree or killed by the action of the sulphur sprays subsequent to their emergence.

Almost the entire crop of fruit on the check trees was lost on account of the work of the larvæ, there being less than half a dozen apples on each tree, while the crop was unhurt on the sprayed trees.

EXPERIMENT II.—An apple orchard of the Rhode Island Greening variety, consisting of 120 trees about 40 years old, belonging to Mr. W. H. Woodruff, Benton Harbor, Mich., was also used for ex-

[1] Lime-sulphur solution was found to act as a strong repellent against certain other lepidopterous larvæ in other experiments conducted during the season.

perimental spraying against the lesser bud moth in 1913. Previous to that year the orchard had been badly neglected, not having been cultivated, pruned, or thoroughly sprayed for several years. The owner reported that no crop had been harvested from the orchard during the preceding eight years, although it is not known that this was due to the work of the lesser bud moth. However, last season it was noted by the senior author that almost every bud was infested with this insect, resulting in a total loss of the crop. The experimental spraying was done with a gasoline-power sprayer equipped with nozzles of the Vermorel type. The orchard was divided into six plats, each containing not less than 14 trees. The treatments and dates of application are shown in Table VI.

TABLE VI.—*Treatments and dates of applications of sprays for the lesser bud-moth, Mr. W. H. Woodruff's apple orchard, Benton Harbor, Mich, 1913.*

Plat No.	Treatment at—		
	First application, Apr. 7. (Trees dormant.)	Second application, Apr. 12. (Buds swelling.)	Third application, Apr. 29. (Cluster buds open.)
I	Lime-sulphur solution (1 : 8)	None	None.
II	Lime-sulphur solution (1 : 8)	None	Lime-sulphur solution (1½ : 50).
III	Soluble-oil solution (1 : 15)	None	Do.
IV	Blackleaf 40	None	Do.
V	None	Arsenate of lead (2 : 50)	Lime-sulphur solution (1 : 50) and arsenate of lead (2 : 50).
VI	Check (unsprayed)		

As the trees in this orchard were too large for counts to be made of the infested and uninfested buds, the results were determined only by observation and by comparing the amount of the fruit that set on the sprayed and unsprayed trees. While the infestation was not as heavy in this orchard this year as last, the larvæ were numerous enough materially to affect the crop, and at the time of blossoming quite a contrast could be noted between certain sprayed plats and the unsprayed plat.

Entirely satisfactory results were obtained on Plat I, which received only an application of lime-sulphur solution at the rate of 1 gallon to 8 gallons of water when the trees were in the dormant state. Only a few larvæ could be found on these trees at blossoming time, and there was practically no loss of fruit from their work, the trees bearing a good crop. Plat II received the same treatment, with the exception of an additional application of lime-sulphur solution at the rate of 1½ gallons to 50 gallons of water when the cluster buds opened. The results were the same as on Plat I. Plat III, sprayed in the dormant state with soluble oil at the rate of 1 gallon of the oil to 15 gallons of water, and Plat IV, receiving a dormant application of blackleaf 40 at the rate of 1 gallon of this insecticide to 800 gallons of water, gave no noticeable results. Both of these plats received an application of lime-sulphur solution at the rate of 1½ gallons to 50 gallons of water when the cluster buds opened, chiefly for the purpose of controlling apple scab. Plat V received two applications of arsenate of lead at the rate of 2 pounds to 50 gallons of water when the buds were swelling and when the cluster buds opened. The results on this plat were satisfactory, being practically the same as where the dormant application of lime-sulphur solution was used.

More than 50 per cent of the fruit buds on the unsprayed trees were infested with the larvæ, and the trees set less than half a crop of fruit.

Observations were made throughout the vicinity of Benton Harbor, Mich., to determine the extent of infestation of the lesser bud moth. It was noted that practically all unsprayed apple and peach orchards were badly infested, while all apple orchards which were thoroughly sprayed for the San Jose scale in the dormant state and followed up by later sprayings were free from infestation. No apple orchards were found which received only the dormant application, so that the effect of this one spraying could not be determined. However, the peach orchards in this section are sprayed with lime-sulphur late in the spring, just before the buds open, for control of the San Jose scale and leaf-curl, and in only a few cases do they receive any other application of spray. In these orchards, which receive only the dormant application of the lime-sulphur solution, the lesser bud-moth is thoroughly controlled, while unsprayed peach orchards are moderately to badly infested.

RECOMMENDATIONS FOR CONTROL.

The foregoing experiments, as well as general observations made throughout the infested section at Benton Harbor, Mich., show that the lesser bud-moth can be controlled by thoroughly spraying the trees in the dormant state with lime-sulphur solution at 32° Baumé used at the rate of 1 gallon to 8 gallons of water. Lower testing material should be used at increased strengths. The spraying should be done just before the buds swell, or preferably when the buds are swelling. This treatment is especially to be recommended, as it involves no extra application where it is necessary to spray during the dormant season for other insects, such as the San Jose scale, oyster-shell scale, scurfy scale, and blister-mite, and for the peach leaf-curl.

In cases where it is not expedient to use the lime-sulphur solution two early applications of arsenate of lead at the rate of 2 pounds to 50 gallons of water should be made. This should be applied first when the buds are swelling and again when the cluster buds open. This latter application coincides with the first apple-scab treatment. In case of a bad infestation it would be advisable to make another application of arsenate of lead when the buds are half open or bursting. It should be borne in mind that thorough control of this insect by use of an arsenical necessitates keeping the buds covered with poison as nearly as possible from the time they begin to swell until they are open.

LITERATURE CITED.

1776. SCHIFFERMÜLLER, I. Systematisches Verzeichnis der Schmetterlinge der Wiener Gegend, Wien, 1776.

Original description of *Tinea nanella*, C. 68. Original description of *Euota pruniella*, C. 75.

1794. FABRICIUS, J. C. Entomologia Systematica, v. 3, pt. 2, Hafniae, 1794.

Original description of *Tinea aleella*, p. 317.

1796(?) HÜBNER, JACOB. Tineæ, pl. 39, fig. 267.

Figures *Tinea nanella* Schiff., fig. 267; figures *Euota pruniella* Schiff., fig. 175.

1816. HÜBNER, JACOB. Verzeichniss Bekannter Schmetterlinge, Augsburg, 1816.

Lists *Trichotripis nanella* Schiff., p. 425, No. 4143; lists *Euota pruniella* Schiff., p. 408, No. 3930.

1827. CURTIS, J. British Entomology, v. 4, London, 1827.

Lists *Anacampsis nana* from Haworth's MSS., No. 189.

1829. HAWORTH, A. H. Lepidoptera Britannica, v. 4, London, 1829.

Gives *Tinea nanella* Hüb. and *Tinea aleella* as synonyms of *Recurvaria nana* Haw., p. 554.

1829. STEPHENS, J. F. A systematic catalogue of British Insects, pt. 2, London, 1829.

Gives *Tinea nanella* Hüb. and *Recurvaria nana* Haw. as synonyms of *Anacampsis aleella* Steph., p. 197, No. 7214.

1834. STEPHENS, J. F. Illustrations of British Entomology. Haustellata, v. 4, London, 1834.

Noted in gardens on trunks of apple trees in June, p. 215.

1853–1855. HERRICH-SCHÄFFER, G. A. W. Systematische Bearbeitung der Schmetterlinge von Europa, v. 5, Regensburg, 1853–1855.

Lists as *Gelechia nanella* Hüb., p. 167, No. 416.

1854. STAINTON, H. T. Insecta Britannica. Lepidoptera: Tineina, London, 1854.

First account of habit of larva of feeding on pear, p. 129.

1854. WOOD, WILLIAM. Index Entomologicus, London, 1854.

Noted as common in gardens near London in June, p. 176, fig. 1213.

1870. HEINEMANN, H. VON. Die Schmetterlinge Deutschlands und der Schweiz. . . . Zweite Abteilung, Kleinschmetterlinge, Bd. 2., hft. 1, Braunschweig, 1870.

Description of *Recurvaria nanella*, p. 280, No. 417.

1871–72. RÖSSLER, A. Beobachtungen über einige in Gärten vorkommende Kleinschmetterlinge. Jahrb. Nassau. Ver. Naturk., Jahrg. 25/26, p. 424–425, 1871–72.

Describes larvæ attacking fruit trees in large numbers.

1895. MEYRICK, E. A handbook of British Lepidoptera, London, 1895.

Description of adult and larva of *Aphanaula nanella*, p. 580.

1901. STAUDINGER, O., and REBEL, H. Catalog der Lepidopteren des Palaearctischen Faunengebietes, 3. aufl. des. Cataloges der Lepidopteren des Europäischen Faunengebietes, Berlin, 1901.

Distribution of *Recurvaria nanella*, pt. 2, p. 155, No. 2874.

1903. BUSCK, AUGUST. A revision of the American moths of the family Gelechiidæ. Proc. U. S. Nat. Mus., v. 25, p. 767–938, 1903.

Description of *Recurvaria crataegella*, p. 811.

1903. HOUGHTON, J. T. Contribution to the life-history of *Gelechia* (*Recurvaria*) *nanella*, Hb., from an economic point of view. Ent. Mo. Mag., v. 39 (ser. 2, v. 14), p. 219–221.

Most complete account of life-history of the species.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

DIV. INSECTS.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 118.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
July 14, 1914.

(PROFESSIONAL PAPER.)

EXPERIMENTS IN THE DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

By F. C. Cook, *Physiological Chemist, Bureau of Chemistry*, R. H. Hutchison, *Scientific Assistant, Bureau of Entomology*, and F. M. Scales, *Assistant Mycologist, Bureau of Plant Industry.*

INTRODUCTION.

The great activity in antifly campaigns in recent years, together with the recognition of the fly as a disease carrier, has created such widespread demand for some means of destroying the fly that this investigation has been undertaken for the purpose of finding a chemical that would destroy this pest in its principal breeding place, namely, horse manure, without injuring the bacteria or reducing the fertilizing value of the manure. This work was undertaken in 1913 at the suggestion of Dr. L. O. Howard to Dr. C. L. Alsberg, who has heartily cooperated in this study and secured the cooperation of Dr. W. A. Taylor. The entomological work was done under the direction of Mr. W. D. Hunter and the bacteriological work in cooperation with the laboratory of Mr. K. F. Kellerman. It is the purpose of this paper to review some recent experiments, the results of which point to an economical, practical, and effective way of destroying fly larvæ by the chemical treatment of manure. A consideration of the larvicidal powers of a number of chemicals more or less effective as larvicides, together with an account of their effects on the value of manure so far as may be estimated by chemical and bacteriological analyses, is included.

HISTORICAL.

American workers were the first to attack the problem of the chemical treatment of manure with a view to destroying fly larvæ. Pioneer work of this nature was begun in 1897 by Dr. L. O. Howard, who showed that kerosene emulsion, while effective with small amounts of manure, was not practical for use on a large scale. Chlorid of lime, however, was found to be a good maggot killer, but its action on the bacteria was not studied. Dr. Howard (1911)[1] published an account of his own experiments and of the work of other investigators.

Prof. S. A. Forbes (Howard, 1911, p. 197), State entomologist of Illinois, found that lime, borax, borax and sodium arsenate mixture, iron sulphate, and carbon bisulphid—the last in closed-box tests—were effective larvicides.

Herms (1910) claims that many of the common insecticides are more or less effective if used in proper concentrations and amounts, but none of these can be applied with safety, as they are poisonous, inflammable, or corrosive.

In 1912 Prof. R. I. Smith (Smith, 1912, p. 64), then State entomologist of North Carolina, found that 2 gallons of kerosene sprinkled over 25 square feet of a manure pile gave no indication of any larvicidal action. Acid phosphate proved entirely worthless from the standpoint of killing the maggots, even when used at the rate of 400 pounds to every 2,000 pounds of manure. Finely ground phosphate rock (floats) had no effect on the larvæ. A 4 per cent formaldehyde solution thoroughly applied to heavily infested manure piles did not destroy any maggots.

This seems to be the extent of the experimental work, as reported in the literature, up to the year 1913. It is evident that the chemical treatment of manure has not received the attention which it deserves. Moreover, Dr. Howard (1911) has pointed out that all these experiments have left unanswered the question as to what effect the treatment will have on the manure itself. No analyses were made to determine how the chemical composition of the manure was affected by the larvicides; nor were any field experiments carried out to ascertain whether the fertilizing value of the manure was altered in any way.

MANURE: ITS RÔLE IN FLY BREEDING.

As stable manure is one of the most valuable fertilizers known, a large number of investigations have been carried on to determine the best means of utilizing as well as preserving it. In addition to its content of nitrogen, phosphorus, and potash the value of manure depends on the number and species of bacteria present, as well as on its content of organic material which the bacteria convert into plant food. Manure, when undergoing fermentation in the open, loses some of its valuable nitrogenous constituents, especially ammonia and

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[1] Authors and dates in parentheses refer to "Literature cited," p. 26.

gaseous nitrogen, the extent of the loss depending on the nature of the fermentation, the aerobic fermentation, due to the rapidity of combustion, producing a greater loss than the anaerobic. To prevent this loss of plant food in the course of fermentation, various chemicals have been used, either to retard bacterial action or to fix the volatile constituents. Among the various substances used for this purpose may be mentioned ground phosphate rock (floats), kainit, various lime compounds, carbon bisulphid, formaldehyde, and ferrous sulphate.

The house fly is attracted to horse manure, possibly by its odor, and on alighting crawls an inch or so under the surface and there lays its eggs. On account of the temperature of the manure the eggs hatch within one day. The larval or maggot stage continues from four to five days, during which the larvæ migrate to the sides of the pile and toward the base, feeding on the manure during their journey. The pupæ are found, after a few days, congregated in the outer edges of the manure near the ground, as seen in Plate I. It is therefore about 10 days from the time the eggs are laid until the mature fly emerges.

GENERAL PLAN OF EXPERIMENTAL WORK.

Experiments were carried out at the Experimental Farm of the Bureau of Plant Industry at Arlington, Va., and continued during the autumn at the Experiment Station at Audubon Park, New Orleans, La., under a cooperative arrangement entered into by the Bureau of Entomology, the Bureau of Chemistry, and the Bureau of Plant Industry.

CAGE EXPERIMENTS.

An idea of the structure of the 15 cages, which were designed by Mr. W. D. Pierce, of the Bureau of Entomology, may be gained from the accompanying photograph (Pl. II). Each cage has an inside measurement of 2 by 2 by 4 feet. The bottom of the cage consists of a galvanized-iron pan 1 foot high. Above this pan bronzed wire screening (16 meshes to the inch) is tacked both on the inside and outside of the framework. These two layers of screening are 2 inches apart. In this way manure once put into the cages was protected from further infestation from the outside. In order to prevent the larvæ from escaping from the sides of the cages through this screening it was found necessary to fasten sheets of tin on the inside above the galvanized-iron base. These strips are 1 foot high, and thus there was afforded a space of 8 cubic feet from which larvæ had little chance to escape. In the bottom of the cage nine small holes were made which permitted excess liquids to drain off. Some larvæ found their way out through them, but these were caught in the pan below and a record kept of the numbers thus escaping.

The top of the cage is a wooden door which is fastened down tightly with hinges and hasps. In the center of this door is an opening 5 inches in diameter and above this a board provided with two openings of the same size. Cone-shaped flytraps are fitted into these openings. This board is placed in grooves so that either one of the two traps may be brought over the opening in the door by merely sliding the board.

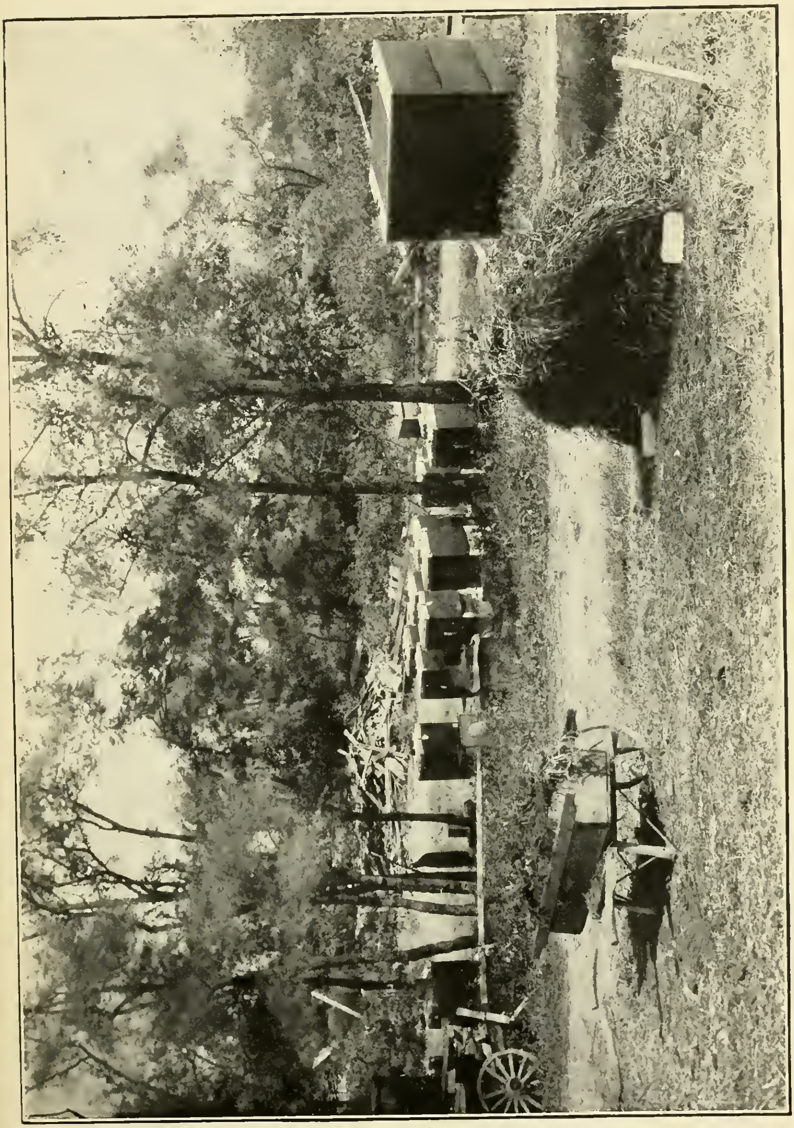
On one side of the cage is a small trapdoor 5 inches square through which samples of manure may be taken out for examination.

Each cage stands on legs 4 inches high and in a galvanized-iron pan 3 feet square with sides 4 inches high. This pan serves to collect drip water and escaping larvæ, and to isolate the cage from such predatory insects as ants.

Eight bushels of manure were used in each of the cage experiments. It was dumped in at the top and the chemical, in solution, was sprinkled on with a watering can. After two preliminary experiments it was found necessary, in order to insure thorough penetration, to use 10 gallons of the liquid per 8 bushels; that is, at the rate of 1 gallon to 1 cubic foot. Usually the sprinkling was done in three layers by putting 2 bushels of manure in the cage and applying $2\frac{1}{2}$ gallons of the solution. This was repeated in the second layer of 2 bushels. Finally, the remaining 4 bushels were added and the last 5 gallons of the solution applied. When a chemical was applied in dry condition it was scattered over the surface of the manure, which was treated in three layers as in the case of the solution; 10 gallons of water were afterwards added.

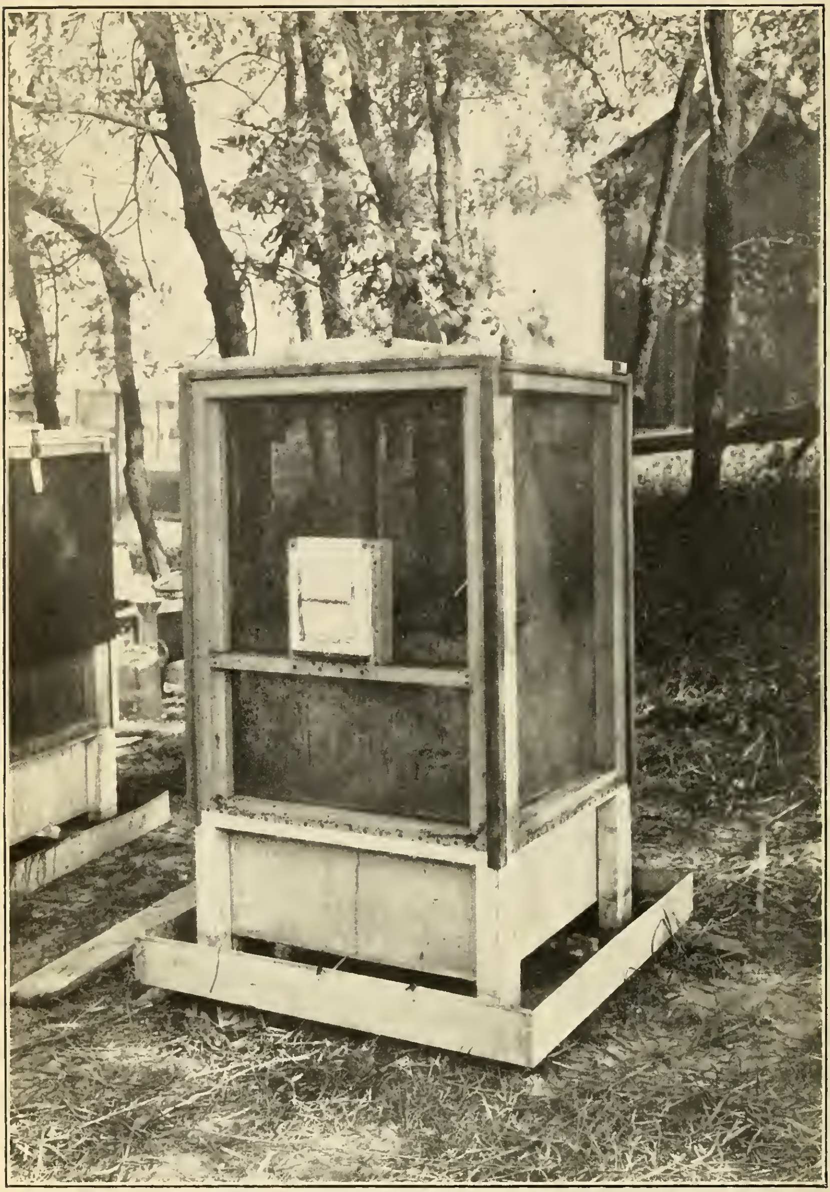
The manure in the control cages was sprinkled with water equal to the volume of the solutions of the chemicals used. In this way the moisture content of the manure was made as nearly as possible the same in all cages. It will be understood that 10 gallons of solution were applied to 8 bushels of manure in all the cage experiments mentioned below, unless some other explanation is given. After treatment in this way the doors of the cages were closed and the flytraps put in place. The cages were examined every day. The escape of any larvæ into the drip pan was noted, and the volume of the drip water measured and a sample analyzed. A quart sample of manure was removed through the small door at the side of the cage after a day or two and the percentage of living and dead maggots determined. The larval counts of quart samples were very unsatisfactory so far as indicating the comparative larvicidal value of the chemicals, but the results of some of these counts are given in the tables.

After five to seven days flies began to emerge. and then it was necessary to darken the cages with black cloth tacked on the sides, as seen



DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

View of manure pile cut in half. The places where the fly pupæ are found, just above the ground and around the edges of the pile, are indicated by the two pieces of white cardboard. (Original.)



DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

Cage used in the chemical treatment of manure, showing the flytraps at the top, the small door at the side through which samples of manure can be removed, the pan for collecting drip water, and other details of the structure. (Original.)

DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

A view of some open-pile experiments to show the size of the piles and the method of treatment. No. 1 has been treated with dry powdered borax, No. 2 with a solution of borax, and No. 3 is the control pile, which is sprinkled with water only. (Original.)

on the cage to the left in Plate II. In this way the only light came from the opening into the flytrap at the top, and flies very soon after emerging made their way up into the trap. The flies caught in the traps were chloroformed and counted daily. At the end of each experiment the total numbers of flies from each cage were compared. The difference between the total numbers of flies from a cage of treated manure and from the control cages is taken as an index of the effectiveness of the chemical. In any one set of experiments the manure used was all from the same source and, being in fresh condition, contained only eggs and larvæ. It was mixed before transferring to the cages, but it is evident that under the conditions we could not be sure of an equal infestation in all cages. Therefore the chemicals were not regarded as having any larvicidal power if the differences in the totals were small.

OPEN-PILE EXPERIMENTS.

In order to simulate natural conditions a parallel series of experiments was carried out by treating manure piles on the ground. Here again 8 bushels were used for each treatment, but repeated applications of both manure and chemicals were made. At the beginning of an experiment a quantity of fresh manure was divided into piles of 8 bushels each. Chemicals to be tested were tried at the rate of 10 gallons to 8 bushels except as otherwise noted. One pile was sprinkled with water only and was used as a control. On the following day another lot of fresh manure was similarly divided and piled on top of that of the previous day, and the treatment repeated. At the end of four days there was a pile of 32 bushels which had received four applications of chemicals. Plate III gives an idea of the size of the piles and shows that the experiments were carried out on a practical scale.

Eight to ten days after the fourth and last treatment the piles were opened and gone over carefully in search of pupæ. The pupæ were collected from the edges of the piles (compare Pl. I), spread on a large sheet of paper, counted, and the numbers compared. Chemical and bacteriological examinations were made of certain of these open piles.

METHODS OF SAMPLING.

Manure consists of urine and dung more or less intimately mixed with straw, wood shavings, sawdust, peat, or other absorbent. When first carried from the stable it is not uniform in composition, as the dung may predominate in one part of the mass and the straw or other absorbent in another part. Thorough mixing will help greatly in making it more uniform, but as the eggs and larvæ in the manure are readily shaken out, it can not be mixed as thoroughly as desired, and consequently there is no way under ordinary field conditions by which a small sample may be obtained that will be truly representative.

The errors due to sampling are necessarily large, and the differences in the results from the controls show the extent of this variation. This is unavoidable and must be recognized in all work on manure, and applies to the bacteriological results as well as to the chemical data, but is not so pronounced in the former cases, as the difference between the counts of the controls and treated samples is so much greater than for the chemical results.

In order to secure the most uniform samples under these conditions for bacteriological and chemical analyses, the following procedure for obtaining samples was adopted. Approximately an inch of material was first removed from the top and then half a pound of the underlying manure weighed on a spring balance; another half pound was then weighed from the center of the pile, and finally the same quantity was taken from the bottom. The three samples were all put in the same container for transportation to the laboratory, where the whole sample was spread out on a clean sheet of wrapping paper and then cut into small pieces and thoroughly mixed. When the material appeared quite uniform the sample was quartered. One quarter was then cut into half-centimeter lengths with clean shears. The straw or shavings were cut with the other material. When this was completed the sample was again thoroughly mixed. As the bacterial content of manure is very high, no attempt was made to work under absolutely sterile conditions because the contamination arising from ordinary handling of the material was of no importance when compared with the great number of organisms present. However, precautions were taken to prevent excessive contamination by using clean paper, shears, etc., for each sample. The carefully prepared quarter sample was put in a clean Mason jar.

BACTERIOLOGICAL EXAMINATION.

Two 10-gram samples of the manure, prepared as described above, were taken for each bacteriological determination. A sterile spatula was used to convey the sample from the jar to the tared watch glass on the balance pan. One of the 10-gram samples was dried at 100° C. for one hour to determine the percentage of solids. The other sample was brushed into a 2-liter flask containing 1 liter of sterile water. The cotton plug was thereupon replaced by a clean rubber stopper which had been lightly flamed. The flask was then vigorously shaken for five minutes and again, after a five-minute interval, for three minutes. A 1 c. c. sample was then withdrawn and run into 100 c. c.

of sterile water. Five dilutions were prepared, ranging from 1 part in 10,000 to 1 part in 100,000,000. A duplicate series of Petri dishes was then prepared from these dilutions and standard beef agar. After five days' incubation at 28–30° C. the plates were counted. The average counts of the duplicate plates were taken and converted into equivalents for 1 gram of dry manure by the use of the figures obtained from the duplicate 10-gram samples that had been dried at 100° C.

The results obtained by plating on the standard beef agar are comparative and serve to show the germicidal action of the chemicals on the majority of the bacteria present in the manure. The total bacterial counts on this medium include not only some of the bacteria that increase the value of the manure by their metabolic processes, but also many that may decrease its value in the same way by destroying nitrogen salts available for plant food. For this reason the total bacteriological counts on beef agar are not considered as entirely indicative of the fertilizing value of the manure. It is even possible that the germicidal effect of formaldehyde, calcium cyanamid, and potassium cyanid in the manure might prove highly beneficial, as Russell and Buddin's (1913) results with formaldehyde, toluene, cresol, phenol, etc., in the soil indicate.

CHEMICAL EXAMINATION.

The method of taking the samples was described above, but the samples for chemical examination were twice run through a sausage grinder after cutting with shears and were placed in screw-capped Mason jars provided with rubbers and analyzed as soon as possible. Samples for chemical examination were taken from the control cages immediately after the experiments were started, and from all 15 cages after 10 days. In this way it was thought an idea of the change which had taken place in the various samples could be obtained, the changes in the controls being taken as an index of the normal rate of decomposition of the manure.

The manure samples were analyzed for solids, ash, ammonia, and nitrogen, using the methods of the Association of Agricultural Chemists (Wiley, 1908). The total nitrogen determinations were made by the nitrogen laboratory of the Bureau of Chemistry. The results obtained by the magnesium oxid distillation method for ammonia, although much higher, showed the same general tendencies as the results obtained on the water extracts.

Water extracts of the manure were prepared from each sample by taking 25 grams of the finely divided manure and adding 500 c. c. of distilled water, allowing them to stand for one hour, with occasional shaking. The solutions were filtered through S. & S. folded filters No. 588, and the following determinations were made: Water-soluble nitrogen, ammonia, amino nitrogen, nitrites, nitrates, and reaction.

Ammonia was extracted by the Folin and Macallum (1912) aeration method and nesslerized. The amino nitrogen was determined by the Van Slyke method (Van Slyke, 1911), but as very little nitrogen in this form was present in the extracts, the figures are not given. Nitrites were determined with the sulphanilic acid reagent and nitrates by the reduction method with aluminum foil (American Public Health Association, Laboratory Section, 1912). Nitrites and nitrates were not usually found in the samples examined, because the manure had not stood sufficiently long. The reaction was determined by taking 20 c. c. of the water extract, diluting with 200 c. c. of carbon dioxid free water, and titrating with N/20 acid, using Alizarin red as indicator. Fehling's solution was not reduced by any of the 20 or more water extracts tested.

GENERAL ACCOUNT OF CHEMICALS USED.

In the course of the season 24 different chemicals were tried in various concentrations. Of these only seven have shown any effective larvicidal action in the strengths used. In the following paragraphs some of the chemicals which gave negative results are first noted, and later in the paper those which appeared to have the greatest value are described in more detail.

CHEMICALS WHICH GAVE LOW LARVICIDAL RESULTS.

KEROSENE EMULSION.

Kerosene emulsion, prepared according to the Riley-Hubbard standard formula, was used in strengths varying from 1 part emulsion in 5 parts water to 1 part emulsion in 50 parts water. In no case were results obtained which showed any appreciable larvicidal action. Even from the cage subjected to the strongest dosage 956 flies were taken, the average from the two control cages being 1,355 flies.

No chemical analyses of the manure were made. The bacterial count, where the strongest emulsion (1–5) was used, was 16,600 million per 1 gram of dry manure as compared with 6,130 million in the controls. These counts were made eight days after treatment with the chemical, but as the bacterial content of manure varies greatly and only one determination was made no conclusion can be drawn.

Kerosene emulsion was not used on any open-pile experiments. We have already called attention to the fact that Dr. Howard in his tests found that this reagent was ineffective when applied on a large scale.

KAINIT.

Kainit, which consists of potassium chlorid and magnesium sulphate, furnished us by Dr. F. Zerban, of New Orleans, was used in two cage experiments and in one open-pile test. In the cage experiments 4 pounds of kainit were used. The total number of flies obtained from the treated cages averaged 2,194, and from the two controls 3,104 flies. In the open-pile experiment three applications of 4 pounds per 8 bushels were made, and after 10 days about 12,000 pupæ were found. The corresponding control pile contained about 20,000 pupæ.

In the two cage experiments no chemical or bacteriological examinations were made. In the open-pile experiment the bacterial count was high, 17.5 million, as compared with 5.9 million in the control. One hundred c. c. of water extract, equivalent to 5 grams of the manure, from the treated pile contained a trace of nitrites and nitrates. No nitrites or nitrates were found in the kainit, nor did the control manure show any. The ammonia nitrogen in the kainit-treated manure was 12.3 per cent and in the control manure but 8.8 per cent of the total nitrogen. The high bacterial count and the increased amount of NH_3 obtained, as well as the fact that nitrates were found in the kainit-treated and not in the control manure, suggests that this compound may have a stimulating action on the bacteria, but no conclusions are justified from this one test. This chemical may be used to reenforce manure, but possesses little larvicidal power.

PYROLIGNEOUS ACID.

Pyroligneous acid was used in commercial form without dilution. Certain claims have been made in some districts of the South, especially in North Carolina, that pyroligneous acid is of value as a repellent, and in our experiments special attention was given to this point. Two piles of fresh manure of 8 bushels each were sprinkled with 10 gallons of pyroligneous acid. Before treatment no eggs were to be found anywhere on the surface of either pile. Two hours later fresh batches of eggs were found on both piles. The pupæ collected numbered about 6,000 and 8,000. Further observations showed that fly eggs were deposited on other piles of manure treated with the pyroligneous acid. Evidently the pyroligneous acid has little, if any, value as either a repellent or a larvicide. The bacterial counts showed a great increase, rising from 25 million in the control to 653 million in one of the pyroligneous acid piles.

ISTHMIAN CANAL COMMISSION'S LARVICIDE.

The Isthmian Canal Commission's larvicide, which has been successfully applied in the Canal Zone for the purpose of killing mosquito larvæ, is prepared according to the following formula: 150

gallons of carbolic acid are heated to 212° F. and to this 150 pounds of finely broken resin and 30 pounds of caustic soda are added and the mixture kept at 212° F. till a dark emulsion without sediment is formed. The resultant emulsion is a good larvicide, 1 part to 10,000 parts of water killing mosquito larvæ in less than half an hour. However, we did not find it effective against house-fly larvæ. The results of three cage experiments are given in Table I, Series A, Nos. 1, 2, and 3. Compared with the corresponding controls (Nos. 7, 8, and 9) it seems as if few, if any, fly larvæ were destroyed, but the fact that a considerable number of larvæ were found in the drip water from the control and only a few from the three treated cages should be considered.

The chemical analyses, given in Table I, show variation in the total nitrogen of the treated and control manures. This is true of many of the samples analyzed and shows the normal variations. The water extract of the treated manure showed more nitrogen and ammonia present than did the water extract of the control manure. The reactions of the water extracts varied considerably. No nitrites or nitrates were present either in the larvicide treated or in the control manure.

Unfavorable action on the bacteria is shown where the numbers are progressively decreased as the volume of the larvicide was increased. The highest count for the larvicide-treated samples is considerably lower than the lowest control count.

Several open-pile experiments were also carried out. One of these was started September 15 and the treatment repeated on four successive days. From the resulting pile of 32 bushels of manure about 10,000 pupæ were taken on September 26. The control pile contained about 7,000 pupæ. This was a typical experiment and is sufficient to show that even with repeated daily applications this reagent is of no value as a maggot destroyer.

IRON SULPHATE.

The results of three cage experiments with iron sulphate are given in Table I, Series A, Nos. 4, 5, and 6. The controls for these are Nos. 7, 8, and 9. The total number of flies caught from these cages shows that the manure was rather lightly infested. However, a comparison of the total number of flies that emerged and the number of larvæ found in the drip pan from treated and untreated cages indicates that this chemical may have had some larvicidal power. However, in three other cage experiments not shown in the table no larvicidal action was evidenced.

Iron sulphate was not used on open piles. The chemical and bacteriological findings in Table I show an injurious action on the manure. The number of bacteria was noticeably reduced, varying inversely with the strength of the solution used. The amounts of water-soluble nitrogen were materially lowered in the iron-sulphate-treated manure, depending on the amount of iron sulphate employed. The iron sulphate evidently acts as a precipitant for some of the water-soluble nitrogen compounds. The ammonia was fully doubled, due possibly to the reduction of alkaline reaction, two of these three samples showing a faint acidity. Iron sulphate blackened the manure and deodorized it, as noted by Forbes. On the whole, we find iron sulphate less effective as a larvicide than Forbes's experiments seem to indicate. It is important, however, to note that the amount of iron sulphate used by Forbes was much greater than that used in these tests.

TABLE I.—*Destruction of fly larvæ in horse manure—Results with ineffective larvicides—Cage experiments at Arlington, Va., summer of 1913.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever solution was applied.	Larval mortality, 1 quart sample of manure 2 days after treatment.		Flies emerged.	Larvæ killed.	Larvæ in drip pan.	Bacteria per 1 gram of manure, dried at 100° C.	Manure, total nitrogen.	Water extract.		
									In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4 per 100 c. c. (5 grams of manure).
		Alive.	Dead.						Nitrogen.	Ammonia nitrogen.	
				Number.	*Per cent.*	*Number.*	*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*
Series A:											
1	Canal larvicide, 1-75 (7½ gallons)	0	5	113	0	6	3,700	0.73	35.62	6.58	12.00
2	Canal larvicide, 1-75 (10 gallons)	0	6	110	0	1	2,600	.61	34.43	3.93	5.50
3	Canal larvicide, 1-75 (12½ gallons)	......	......	179	0	0	1,600	.53	32.08	3.96	5.75
4	Iron sulphate, 1½ pounds per gallon	2	0	73	32.4	0	700	1.05	10.48	5.05	1.50
5	Iron sulphate, 1 pound per gallon	6	1	171	0	0	970	.67	16.42	6.72	[1]0.62
6	Iron sulphate, ½ pound per gallon	1	0	81	25.0	0	2,800	.76	22.37	6.84	[1]1.25
7	Control (water only)	32	0	146	0	15	5,200	.84	26.19	2.62	10.50
8	do	22	0	102	0	127	6,000	.68	25.00	3.09	6.50
9	do	5	0	76	0	221	5,100	.65	18.46	2.46	5.00
Series B:											
1	Sodium chlorid, 2½ pounds per gallon	28	1	141	55.5	0	2,550	.51	32.94	7.65	4.40
2	Sodium chlorid, 1 pound per gallon	110	0	217	30.0	100	....	.45	28.67	3.78	7.50
3	Copper sulphate, 1 pound per gallon	5	2	101	67.4	0	648	.69	9.71	3.78	2.75
4	Copper sulphate, ½ pound per gallon	4	0	132	57.4	Few.	4,070	.75	14.93	2.40	7.75
5	Control (water only)	48	0	322	0	100	3,060	.55	23.45	2.55	7.75
6	do	12	0	298	0	30	4,800	.72	21.11	2.08	7.50

[1] Acidity.

SODIUM CHLORID (TABLE SALT).

The results of two cage experiments with manure treated with sodium chlorid are given in Table I, Series B, Nos. 1 and 2. The corresponding control cages are numbered 5 and 6. The average number of flies from these two controls is 310. Presuming that the infestation of the manure at the start of the experiment was the same in all cages, it appears from the table that sodium chlorid used at the rate of 2½ pounds per gallon killed 55 per cent of the larvæ. The 1-pound per gallon application showed a 30 per cent destruction of the maggots. The chemical results of the salt-treated manure are not very different from those of the untreated manure except that there is an apparent increase in the nitrogen and ammonia in the water extract of the treated samples. Only one bacterial examination was made and this showed that the strongest salt solution reduced the number of bacteria somewhat.

COPPER SULPHATE.

Nos. 3 and 4 of Series B, Table I, give the results of two cage experiments with copper sulphate. When compared with the controls it would seem that the dosage of 1 pound per gallon killed 67 per cent of the maggots and the one-fourth pound strength 57 per cent.

The bactericidal power of copper sulphate is well known. When added at the rate of 1 pound per gallon sufficient copper sulphate remained in solution to kill 87 per cent of the bacteria. Their number was not affected by the smaller quantity of this chemical.

The chemical analyses show an injurious effect from the heavier application of copper sulphate, which reduced the amount of soluble nitrogen and the alkaline reaction of the water extract. With the weaker strength the only apparent effect is a slight reduction of water-soluble nitrogen. No open-pile experiments with copper sulphate were carried out.

LIME-SULPHUR MIXTURE.

Lime-sulphur was used in three cage experiments, but in no open piles. There is no evidence that the lime-sulphur possessed any larvicidal power, for more flies developed from the cage receiving a 1–5 treatment than from the control. The bacteria do not appear to be affected by this treatment. From two other experiments where lime-sulphur was used in strengths of 1–15 and 1–30 fewer flies emerged than in the control, but this was probably due to differences of infestation.

In addition to the chemicals mentioned, acid phosphate, a proprietary fertilizer, and several proprietary disinfectants were tested with negative larvicidal results.

PARTIALLY EFFECTIVE LARVICIDES.

In Table II, page 15, some results obtained with potassium cyanid, Paris green, and formaldehyde, which were found to possess some larvicidal action, are recorded. Each of these three substances in the heaviest application, and formaldehyde in all cases, reduced the number of bacteria.

POTASSIUM CYANID.

Potassium cyanid gave favorable results in three cage experiments. These results are given in Table II, Series C, Nos. 1, 2, and 3, the control being No. 4. Quart samples of manure two days after treatment showed a large percentage of dead larvæ for the two stronger applications. The total numbers of flies developing were very much reduced. It appears that the two higher concentrations killed 93 per cent of the larvæ. The chemical results of analyses of these three samples of manure show considerable variations, but there is no evidence that the manure had been injured by the application of the potassium cyanid. The increased alkalinity results of the control and of No. 2 may be explained by the large amount of water-soluble nitrogen in these two cases. No open piles were treated with potassium cyanid. This reagent, when used in proper concentrations, will undoubtedly be found a very effective maggot killer, but its extremely poisonous nature makes it objectionable and dangerous. The bacterial counts show that potassium cyanid in the manure had no very definite bactericidal effect. A stimulating action is rather indicated in the two higher dilutions, but as the difference in the number of bacteria between the three treated samples is no greater than that between some of the controls, no conclusions can be drawn from this experiment.

PARIS GREEN.

Paris green was used in three cage experiments, the results of which, together with those of the corresponding controls, are given in Table II, Series D. The Paris green was not all dissolved, but was applied in the form of a suspension. The suspended particles were deposited on the surface and only the part in solution filtered into the deeper parts of the manure. It appears from these experiments that Paris green killed from 70 to 90 per cent of the larvæ.

The bacteriological counts vary considerably and inversely with the strength of the solution used. The most concentrated solution was strongly bactericidal and reduced the number of organisms by about 50 per cent. The higher dilutions showed the general stimulating action of poisons in small quantities. The effect in general is the same as that of potassium cyanid, but is much more marked.

The water-soluble nitrogen varied with the amount of Paris green used, and was lowest where the strongest application of Paris green was made, due probably to the precipitating power of the copper, and about equal to the control where the two weaker applications were made.

FORMALDEHYDE.

Formaldehyde solution was used in six cage experiments, but on no open piles. Three concentrations were tried, by mixing 1 part of the commercial 40 per cent formalin with 3, 6, and 12 parts of water, respectively. The results of three of these tests are given in Table II, Series E, together with the corresponding controls. In three experiments not given in the table the infestation of the manure was so slight that it was not possible to form any judgment as to the larvicidal action of this chemical. Even in the experiments which are given in the table, the manure was lightly infested. However, all the concentrations show considerable larvicidal action. Taking the average total number of flies of the controls it is evident that from 75 to 85 per cent were killed. It is probable that if this treatment had been made in closed boxes or receptacles to retard the loss of formaldehyde by evaporation, the larvicidal action would have been still higher.

As might be expected, the formaldehyde in these dilutions caused a great reduction in the number of bacteria. The highest dilution (1–12) killed 99.6 per cent of the bacteria that would grow on beef agar. The chemical results show a decreased alkalinity of the water extract. The ammonia results average slightly higher than those obtained on the control samples, but in No. 2, where the dilution of formaldehyde used was 1–6, the bacterial count, the water-soluble nitrogen, the ammonia, and the alkalinity are higher than in either of the other two treated samples. The fact that formaldehyde produces an acid reaction, either by conversion to formic acid or by combining with amino acids, a reaction used by Sörensen (1907) for the quantitative estimation of the amino acids, may explain the reduced alkalinity of these extracts. Nitrites and nitrates were detected in all three cases of the manure treated with formaldehyde. It is interesting in this connection to note that Russell and Buddin (1913) carried out some experiments on the action of various volatile antiseptics in the soil, and found that formaldehyde increased the production of nitrates and ammonia. While formaldehyde is extremely disagreeable to work with on account of the irritating action which it has on the mucous membrane, nevertheless further work with this chemical will be undertaken.

TABLE 11.—*Destruction of fly larvæ in horse manure—Results with partially effective larvicides—Cage experiments at Arlington, Va., summer of 1913.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever solution was applied.	Larval mortality, 1 quart sample of manure 2 days after treatment.		Flies emerged.	Larvæ killed.	Larvæ in drip pan.	Bacteria per 1 gram of manure, dried at 100° C.	Manure, total nitrogen.	Water extract.		
									In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4 per 100 c. c. (5 grams of manure).
		Alive.	Dead.						Nitrogen.	Ammonia nitrogen.	
				Number.	*Per cent.*	*Number.*	*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*C.c.*
Series C:											
1.......	Potassium cyanid, 0.1 per cent solution.	2	9	82	93.6	......	5,250	0.68	19.85	3.09	10.25
2.......	Potassium cyanid, 0.02 per cent solution.	11	21	86	93.3	100	7,260	1.00	23.60	2.90	14.50
3.......	Potassium cyanid, 0.004 per cent solution.	11	4	251	80.6	350	7,620	.63	20.48	Trace.	10.00
4.......	Control (water only).....	64	1	1,287	0	400	6,130	1.12	24.11	3.57	17.65
Series D:											
1.......	Paris green, 1-20.........	0	2	92	70.3	Few.	1,740	.70	13.43	2.71	9.00
2.......	Paris green, 1-40.........	......	......	35	88.7	Few.	7,300	.59	22.88	1.86	7.50
3.......	Paris green, 1-80.........	0	1	32	89.7	Few.	19,950	.56	25.00	4.64	6.00
4.......	Control (water only).....	48	0	322	0	100	3,060	.55	23.45	2.55	7.75
5.......	.....do...................	12	0	298	0	30	4,800	.72	21.11	2.08	7.50
Series E:											
1.......	Formaldehyde,[1] 1-3 solution.	0	7	20	81.5	1	14	.58	18.97	3.62	.75
2.......	Formaldehyde, 1-6 solution.	3	1	16	85.2	22	14	.46	21.74	4.57	2.00
3.......	Formaldehyde, 1-12 solution.	165	15	27	75	0	22	.60	18.33	2.83	.75
4.......	Control (water only).....	32	0	146	0	15	5,200	.84	26.19	2.62	10.50
5.......	.....do...................	22	0	102	0	127	6,000	.68	25.00	3.09	6.50
6.......	.....do...................	5	0	76	0	221	5,100	.65	18.46	2.46	5.00

[1] Nitrites and nitrates were found in Nos. 1, 2, and 3, Series E.

SODIUM FLUORID.

Sodium fluorid was used in two cage experiments. In one it was applied at the rate of 2 pounds per gallon, and 454 flies developed. In the other 1 pound per gallon was used, and 1,053 flies developed. From the two control cages the totals were 6,152 and 5,870. Thus the stronger concentration destroyed over 90 per cent of the maggots, and the weaker strength 84 per cent. No open piles were treated.

No bacteriological or chemical analyses were made of the manure treated with sodium fluorid. From the limited number of tests with this chemical, it is evident that it may possess some value as a larvicide, and further experiments will be conducted, using commercial sodium fluorid, although the cost (5 pounds, $1) may prohibit its general use.

AMMONIACAL GAS LIQUOR.

Ammoniacal gas liquor, which is a by-product of the manufacture of illuminating gas, evidenced some larvicidal effect when used in the strengths of 1–5 and 1–25. From the cage treated with the stronger dosage 206 flies were caught and 179 flies from the other. The control cages showed 1,508 and 1,287 flies. The gas liquor in the 1–5 strength was strongly bactericidal, reducing the number of bacteria as shown in the control from 6,130 million to 92.8 million. In view of the fact that the gas liquor showed a bactericidal action and that the transportation of a liquid in large amounts is expensive, it was not studied further, although it possesses certain advantages, as it contains a considerable amount of nitrogen, practically all of which is in the form of ammonia. This nitrogen is, however, all in soluble and volatile form and easily lost.

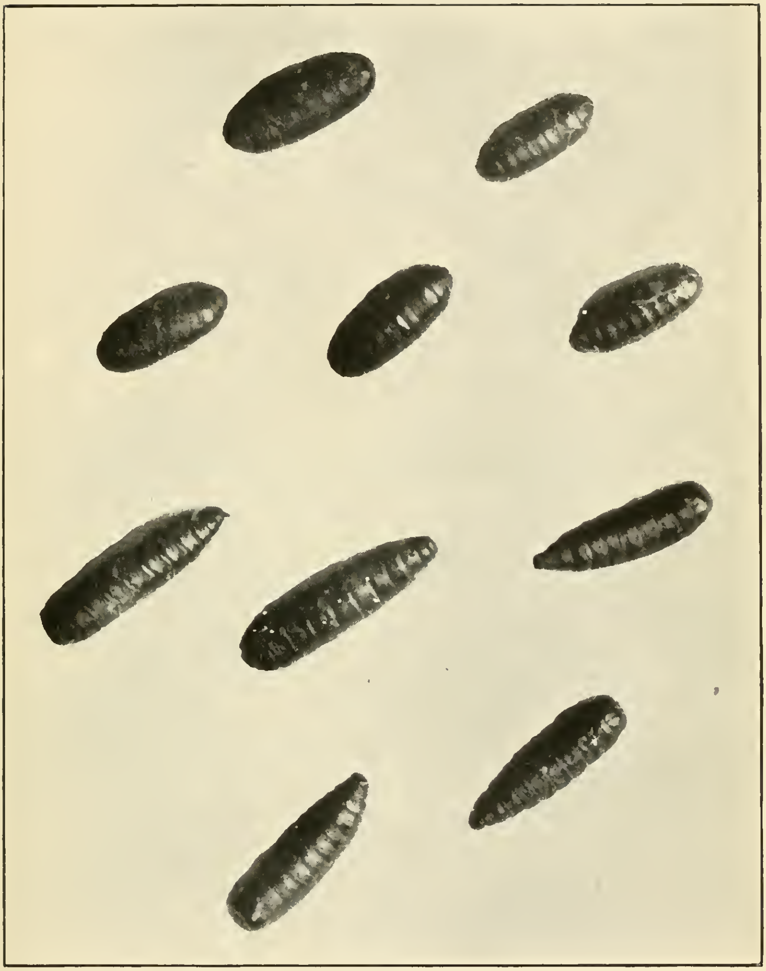
CALCIUM CYANAMID.

The treatment with calcium cyanamid was tried at the suggestion of Dr. Alsberg. It has been used in cage experiments at Arlington, Va., and the results obtained are recorded in Table III.

TABLE III.—*Destruction of fly larvæ in horse manure—Larvicidal results with calcium cyanamid—Cage experiments at Arlington, Va., summer of 1913.*

No.	Treatment of 8 bushels of manure with 10 gallons of water.	Larval mortality, 1 quart sample of manure 2 days after treatment.		Flies emerged.	Larvæ killed.	Larvæ in drip pan.
		Alive.	Dead.			
Series F:				*Number.*	*Per cent.*	*Number.*
1	Calcium cyanamid, 20 pounds	1	2	7	99.5	6
2	Calcium cyanamid, 5 pounds	0	4	52	96.3	....
3	Control	22	0	1,508	0	12
4	.....do	64	1	1,287	0	400
Series G:						
1	Calcium cyanamid, 5 pounds	4	0	92	20.0	30
2	Calcium cyanamid, 4 pounds	4	1	761	....	20
3	Calcium cyanamid, 3 pounds	....	....	56	51.3	25
4	Control	82	0	25	0	50
5	.....do	22	0	204	0	10

The calcium cyanamid was scattered over the manure in powdered form and in all cases water was added. From the table it appears that the 20-pound application killed over 99 per cent of the larvæ. The 5-pound applications gave varying results, as seen in the table, and in one cage experiment not shown 58 per cent of the larvæ were destroyed. This gives an average larvicidal power of 58 per cent for this amount of the calcium cyanamid. In one cage test not shown where 4 pounds were applied, 40 per cent were killed, but in the cage experiment given in Table III no larvicidal action was apparent. Since calcium cyanamid is used to some extent as a fertilizer and is a means of adding nitrogen to the manure, and thus to the soil, it is highly desirable that a further study of this chemical be made, not only to determine more exactly its larvicidal action, but also to de-



DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

On the left larvæ are shown which have been killed by borax. They were in the process of changing to pupæ. On the right normal pupæ are seen. (Original.)

termine by field experiments whether the amount of nitrogen thus added compensates for the cost of treatment. The cost of the cyanamid in 100 or 200 pound lots is about 3½ cents per pound.

The results of two typical open-pile experiments with calcium cyanamid are given in Table IV. The 5-pound application killed 82 per cent of the larvæ and reduced the number of bacteria markedly. The 4-pound application killed 71 per cent of the larvæ and reduced the bacteria 50 per cent. In both cases the water-soluble nitrogen, ammonia, and alkalinity were considerably increased.

TABLE IV.—*Destruction of fly larvæ in horse manure—Results with calcium cyanamid—Open-pile experiments (three applications) at New Orleans, La., November, 1913.*

No.	Treatment of 8 bushels of manure with 10 gallons of water.	Total number of pupæ found after 8 to 10 days.	Larvæ killed.	Bacteria per 1 gram manure, dried at 100° C.	Manure.		Water extract.		
							In per cent of total nitrogen.		Alkalinity, N/20 H_2SO_4 per 100 c. c. (5 grams manure).
					Solids.	Total nitrogen.	Nitrogen.	Ammonia nitrogen.	
			Per cent.	*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*
Series H:									
1	Calcium cyanamid, 5 pounds	3,500	81.6	43	31.30	0.72	44.44	8.89	7.35
2	Calcium cyanamid, 4 pounds	5,500	71.0	75	30.47	.59	47.46	13.56	8.15
3	Control	19,000	0	158	27.14	.43	19.54	6.51	5.30

EFFECTIVE LARVICIDES (BORATES).

The most favorable results were obtained by the use of borax (sodium borate) and calcined colemanite (crude calcium borate). Both substances possessed a marked larvicidal action and appeared to exert no permanent injury on the bacteria. These two borates have been used in a large number of experiments and the results all uniformly show a very high larvicidal action, both in cages and open piles, and whether applied in dry form or in solution.

A comparison of the total number of flies or of pupæ from borax-treated manure with the totals from control manure shows a larvicidal power of over 99 per cent in nearly all trials. One of the reasons why borax is so effective in reducing the number of flies is due to its toxic effect on the eggs, which do not hatch after contact with this chemical. The piles in one experiment, started on September 13, 1913, were examined for pupæ on September 25. At this time large masses of eggs of the house fly, perhaps 600 to 800, were found in a borax-treated pile. They were not empty, collapsed shells, but had normal shape and evidently had not hatched. They were somewhat discolored, many having a bluish tinge. Some of these were taken to the laboratory and examined daily under a microscope. None of these hatched after a week at room temperature and favorable moisture conditions. On October 6, in going over a pile, last treated with borax solution on September 28, batches of a thousand eggs or more were found. They had a bluish tinge. A mass of these eggs with surrounding manure was kept in a jar in the laboratory for a week and examined daily. None had hatched at the end of this time. Similar observations were made on other borax-treated piles. No such masses of unhatched eggs were ever found on control piles, nor on piles treated with other chemicals after the first three or four days of exposure.

Calcined colemanite, being largely insoluble, did not show this effect on the eggs. Borax acts very effectively through its toxic action on the eggs, but its action is not confined to the egg stage, as larvæ are also killed. In nearly all cases examinations of open piles showed the presence of dead larvæ as well as pupæ. In Table V it will be noted that in some piles large numbers of pupæ were found, but these were black, shrunken, wrinkled, and were not normal in shape, having more nearly the form of the larvæ than of the pupæ. Pl. IV.) When kept in the laboratory for a long time 1 per cent or less hatched. The borax had evidently killed them just at the time of transformation from larvæ to pupæ. This may be explained in several ways. (1) It may be that the larvæ, in the younger stages, resisted the action of the borax they had ingested but became very sensitive to it at the time of the breakdown of larval tissues. (2) The action of the borax may be cumulative and so may not evidence its toxic action until toward the end of the larval stage. (3) It may be that the larvæ in their earlier stages were found some distance in from the surface where the borax had not penetrated, but that, when ready to pupate, they migrated to the outer lower edges of the manure pile where the concentration of the borax was greatest and were killed by it. The migration of the larvæ in the cages and open piles has already been referred to on pages 3 and 5, and is discussed more in detail by Mr. Hutchison (1914).

The fact that small quantities of borax are not detrimental to the normal fermentation of manure is further shown by some temperature determinations.

The manure piles were made with no attempt to pack the manure, because it was believed that the higher temperatures prevailing where aerobic fermentation was in progress would be an attraction to the flies. Three series of experiments were used for these tests. The temperatures were taken by inserting a thermometer about a foot deep in the top of the piles. As the piles were small the temperatures at this depth were very nearly the maximum. The three controls attained their highest temperature, 66° and 67° C. (150.8° and 152.6°

F.) in from five to seven days after the experiment was started. At the same time the borax-treated piles reached their maximum of 58° to 63° C. (136.4° to 145.4° F.). Even where one-eighth pound of borax was used the temperature was slightly suppressed, as it reached only 61° C. (141.8° F.). This effect, however, may have been due to the borax preventing the growth of organisms which produce firefanging. The effect of borax in entirely preventing this condition has been reserved for a future investigation. However, it was found that in three cases the control piles showed evidences of firefanging and the presence of a white powdery mold in the interior. This condition was never found in the borax-treated piles. After attaining a maximum, the temperature of all the piles declined rapidly. The treated ones continued lower than the controls.

One manure pile treated with 5 pounds of calcined colemanite showed a steady decline in temperature from the beginning of the experiment. The bactericidal effect of this large dose is further shown by a comparison of the bacterial count obtained from a sample of this pile and that of the control; a decrease of 64 per cent in the number of bacteria occurred.

The data of the borax-treated manure are recorded in Tables V and VI. The open-pile experiments, which are recorded in Table V, show marked variations in numbers of bacteria, but whether this is due to a variation in the penetration of the borax because of different natural factors, or because the samples were not representative of the pile, although taken in the usual manner (see page 5), can not be stated at this time. There is a reduction in the number of bacteria in Series J, Nos. 1 and 2, and Series L, Nos. 1 and 2, where colemanite was used. There are marked increases in Series I, Nos. 1 and 2, and Series K, Nos. 3 and 4. In Table VI, where the results are recorded for the manure experiments made in cages, an increase in the number of bacteria is seen in all the borax-treated samples.

The manure from the open-pile experiments, Table V, indicates an increase of water-soluble nitrogen and ammonia in the borate-treated samples. The reaction of the water extract is increased in all of these cases. Further, in four of the open-pile experiments nitrites and nitrates were both found. In no case did the control manure give a reaction for nitrites or nitrates. The presence of nitrites and nitrates in the borax-treated piles is very interesting and if it is obtained in all cases where the borax-treated manure has been allowed to stand for several weeks a strong argument will be presented for its use in addition to the effective larvicidal action which it is seen to possess. There are considerable variations in the water-soluble nitrogen and ammonia results for the open-pile experiments as well as for the bacterial counts as noted on page 6.

TABLE V.—*Destruction of fly larvæ in horse manure—Results with borates—Experiments on open piles, New Orleans, La., November, 1913.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever liquid was added.	Number of applications.	Total number of pupæ found after 8–10 days.	Bacteria per gram manure, dried at 100° C.	Manure.		Water extract.		
					Solids.	Total nitrogen.	In per cent of total nitrogen. Nitrogen.	In per cent of total nitrogen. Ammonia nitrogen.	Alkalinity, N/20 H_2SO_4 per 100 c. c., 5 grams manure.
Series I:				*Millions.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*
1.......	Na-borate,[1] 2½ pounds dry (no water added)	4	[2] 5,000	141	39.59	0.60	36.67	7.33	11.05
2.......	....do.[1]	4	[2] 4,200	172	39.14	.55	29.09	8.18	10.60
3.......	Control (water)	4	10,000	105	34.54	.46	30.43	8.69	5.90
Series J:									
1.......	Na-borate, 2 pounds dry (no water)	4	30	.659	42.51	.67	44.78	12.54	10.20
2.......	....do	4	39	.577	43.29	.68	39.71	11.03	10.90
3.......	Control (water)	4	2,500	316.	42.43	.63	30.16	8.89	6.50
Series K:									
1.......	Na-borate in solution, ¼ pound per gallon	3	[2] 985	2	36.69	.52	25.00	8.27	12.45
2.......	....do	3	[2] 575	5	43.08	.56	21.43	7.50	7.85
3.......	Na-borate [1] in solution, ⅛ pound per gallon	3	[3] 1,700	38	34.72	.47	34.04	11.91	8.55
4.......	....do.[1]	3	[3] 1,900	36	43.01	.53	26.42	11.13	7.35
5.......	Control (water)	3	20,000	6	34.04	.49	24.49	8.78	6.10
Series L:									
1.......	Calcined colemanite, 3 pounds plus water	3	[4] 2,600	38	30.58	.49	30.61	16.33	7.05
2.......	....do	3	[4] 3,200	26	30.77	.44	31.82	9.09	7.20
3.......	Control (water)	3	19,000	158	27.14	.43	19.54	6.51	5.30

[1] Nitrites and nitrates present.
[2] Approximate. Of pupæ from borax-treated piles about 1 per cent hatch.
[3] Of all these only 10 flies emerged after many days in the laboratory.
[4] Abnormal in shape and color. Only 1 fly developed in sample of 500 pupæ.

TABLE VI.—*Destruction of fly larvæ in horse manure—Results with borax—Cage experiments at New Orleans, La., November, 1913.*

No.	Treatment of 8 bushels of manure with 10 gallons of liquid.	Larval mortality, 1-quart sample manure 2 days after treatment. Alive.	Larval mortality, 1-quart sample manure 2 days after treatment. Dead.	Total number of flies emerged.	Larvæ in drip pan.	Bacteria per 1 gram manure, dried at 100° C.	Total nitrogen in manure.	Water extract. In per cent of total nitrogen. Nitrogen.	Water extract. In per cent of total nitrogen. Ammonia nitrogen.	Water extract. Alkalinity, N/20 H_2SO_4, per 100 c.c. (5 grams manure).
Series M:						*Million.*	*P. ct.*	*P. ct.*	*P. ct.*	*C. c.*
1.......	Borax, ½ pound per gallon	5	0	15	12	7,392	0.51	33.33	9.41	19.50
2.......	....do	2	0	18	15	3,003	.55	18.18	10.18	16.50
3.......	Borax, ¼ pound per gallon	35	0	38	3	7,452	.58	27.59	11.55	13.00
4.......	....do	5	4	22	6	5,800	.58	37.93	10.86	13.75
5.......	Control (water)	82	0	25	50	2,204	.74	16.22	4.46	8.30
6.......	....do	22	0	204	10	3,484	.84	14.29	1.79	7.50

In the cage tests, Table VI, the water-soluble nitrogen, ammonia, and reaction were lower for the controls than for the borax-treated manure. The low water-soluble nitrogen and ammonia results of the controls may possibly be due to the unusual fermentation going on in these two samples, as indicated by the peculiar odor. The fact that, after grinding, the manure tended to cake or lump may have prevented the usual amount of material from going into solution. The bacterial counts in the cage experiments are higher than the controls, and also higher than those of the open piles. This is undoubtedly due to the artificial conditions of the cage experiments. The increase of water-soluble nitrogen, ammonia, and alkalinity has been found in all the borax-treated manure, both cage and open-pile tests, at Arlington and New Orleans.

In Table VII additional cage experiments showing the larvicidal action of borax, dry and in solution, and calcined colemanite with water, are recorded. Borax in small amounts, such as 1¼ pounds per 8 bushels of manure, destroyed 98 to 99 per cent of the maggots, and calcined colemanite, even when 2 pounds per 8 bushels of manure were used, showed the same percentage of larvicidal action.

TABLE VII.—*Cage experiments showing larvicidal action of borates on fly larvæ in horse manure.*

No.	Treatment of 8 bushels of manure; 10 gallons used whenever liquid was added.	Total number of flies emerged.
Series N:		
1	Na-borate, dry powder, 2½ pounds (no water added)	12
2	Na-borate in solution, ¼ pound per gallon	1
3	.....do	2
4	Control (water)	6,152
5	.....do	5,870
Series O:		
1	Na-borate in solution, ⅛ pound per gallon	5
2	.....do	13
3	.....do	68
4	Na-borate in solution, ⅛ pound per gallon	46
5	.....do	50
6	Calcined colemanite, 4 pounds plus water	55
7	Calcined colemanite, 3 pounds plus water	165
8	Calcined colemanite, 2 pounds plus water	29
9	Control (water)	3,069
10	.....do	3,140

RECENT EXPERIMENTS TO DETERMINE MINIMUM AMOUNTS OF BORAX AND CALCINED COLEMANITE WHICH ARE EFFECTIVE AS LARVICIDES.

Some recent tests at New Orleans to determine the minimum amounts of borax and calcined colemanite which are effective have shown that 0.62 pound of borax and 0.75 pound of calcined colemanite are effective as larvicides, but when smaller amounts of either are used their larvicidal value is reduced. It is therefore apparent that 0.62 pound of borax and 0.75 pound of calcined colemanite to 8 bushels of manure (10 cubic feet), with the addition of 2 to 3 gallons of water, are the minimum quantities of these borates that will destroy practically all the fly maggots in manure.

ADVANTAGES AND COST OF BORAX.

The great demand for borax, due to its uses in the arts and in the household, has made this substance available in all parts of the country. It has the further advantage of being comparatively nontoxic, noninflammable, and easily transported and handled, as it is a powder. Thus borax is superior to most of the substances that have been tested as larvicides. Several investigators (see Haselhoff, 1913) have shown that in small amounts borax has a stimulating effect on plant growth, while larger amounts are toxic.

Borax is prepared from colemanite (calcium borate), which is mined in California, and has the following composition: Boron trioxid, 50.9 per cent; calcium oxid, 27.2 per cent; water, 21.9 per cent. The crude colemanite was tested for its larvicidal action, but this was so slight, undoubtedly due to its insolubility, that it was discarded in favor of borax and calcined colemanite. Calcined colemanite is prepared from crude colemanite by simply subjecting it to high temperatures.

The crude colemanite is not sold as such, but a considerable amount of the calcined colemanite is used in various industries. The calcined colemanite is a gray powder and is largely, but not entirely, insoluble in water. It costs about 2 cents per pound in large shipments, and in smaller amounts sells at approximately 4 cents per pound. Borax ($Na_2B_4O_710H_2O$) is prepared from colemanite by treatment with soda ash. It retails at about 10 cents per pound, but can be obtained in 100-pound lots or more in Washington at 5 to 6 cents per pound. Borax is readily soluble in water.

EFFECTS OF BORAX-TREATED MANURE ON PLANTS.

The chemical analyses and bacterial counts to which references have been made throughout this bulletin do not indicate any permanent deleterious effects of the borax on manure. On the contrary, a beneficial effect is suggested. This was especially the case with the chemical results where an increase of ammonia was obtained in all cases and no apparent reduction in the total nitrogen was evident. Nitrites and nitrates were found in several of the open piles where borax had been applied. In order to be certain of the effect of borax-treated manure on plants, extensive experiments have been performed both in the greenhouse and in open plats. The field work was conducted at four points in the South, as well as on the Arlington farm, and the pot tests were conducted in the greenhouses of the department at Washington. The following plants were tested: Wheat, tomatoes, peas, beets, radishes, kohl-rabi, oats, corn, cucumber, lettuce, as well as apple seedlings and rosebushes. Such elaborate experiments seem to be necessary on account of the known toxic effects of large applications of boron upon the growth of plants, as shown by several investigators. In this connection it is important to note that investigations of Russell and Buddin (1913) in England have shown that the application of very small amounts of volatile and some nonvolatile disinfectants have eventually resulted in the stimulation of plant growth. This same effect is indicated in some of the experiments with borax.

In the field and pot experiments no deleterious effects were observed from the application of borax at the rate of 0.62 pound per 8 bushels (10 cubic feet) of manure, except possibly on wheat. Larger doses of borax produced a discoloration of the tips of some other plants. In our field experiments with winter wheat the plants when 4 inches high showed a decided yellowing of the tips where very heavy applications of borax were made, but at the start of the growing period in the spring the yellowing of the tips decreased and the wheat was nearly normal in appearance. These effects vary with the plants and the amount of moisture present in the soil. Where rainfall is heavy the effects disappear quickly. At Orlando, Fla., for instance, where the experiment was conducted during a drought and larger amounts of borax than 0.62 pound per 8 bushels were used, injurious effects were much more evident than in other localities. In all these cases, however, except at Orlando, recent observations have shown that the plants have practically recovered—so far as can be determined without estimating the actual yields, which can not be done at the present time. From these experiments it is believed that no injurious effects will follow the application of the minimum amount of borax found necessary to destroy the larvæ, namely, 0.62 pound per 8 bushels of manure, which may be applied to the field at the rate of 15 tons per acre. If more is necessary, untreated manure may be used. Some recent pot tests have indicated that the addition of slaked lime in amounts equal to half that of the borax present tends to offset the toxic action which results from heavy applications of borax. Some questions relating to the effects of borax on the growth of plants remain to be determined, notably its possible cumulative action, and these will be reported later. It is expected that interesting results will follow from the experiments now under way with calcined colemanite, which, though cheaper than borax, is effective in destroying fly larvæ when applied at the rate of 0.75 pound per 8 bushels.

SUMMARY.

CLASSIFICATION OF CHEMICALS TESTED.

The substances used in the experiments dealt with in this bulletin may be arranged in two classes, as indicated below. The term "satisfactory" is used to indicate destructive action on fly larvæ, noninjurious effect on manure, and lack of extremely poisonous properties. Among the unsatisfactory or partially satisfactory substances are included several which when used in large amounts may kill fly larvæ but are placed in this class because of the large amount required or because of their extremely poisonous properties.

Iron sulphate has been used as a larvicide and in considerable amounts is stated to be effective. However, no studies of the effects of iron sulphate on the fertilizing value of manure have been reported. Our experiments indicate injury to the manure even from small applications of iron sulphate (see p. 10). Paris green and potassium cyanid are effective as larvicides, but are objectionable on account of their extremely poisonous nature.

UNSATISFACTORY OR PARTIALLY SATISFACTORY SUBSTANCES.

Kerosene emulsion.
Kainit.
Isthmian Canal Commission larvicide.
Iron sulphate.
Several proprietary disinfectants.
Potassium cyanid.
Formaldehyde.
Calcium cyanamid.
Pyroligneous acid.
Sodium chlorid (table salt).
Copper sulphate.
Lime-sulphur mixture.
Paris green.
Sodium fluorid.
Ammoniacal gas liquor.

SATISFACTORY SUBSTANCES.

Borax.
Calcined colemanite.

By far the most effective, economical, and practical of the substances is borax in the commercial form in which it is available throughout the country.

Borax increases the water-soluble nitrogen, ammonia, and alkalinity of manure and apparently does not permanently injure the bacterial flora. The application of manure treated with borax at the rate of 0.62 pound per 8 bushels (10 cubic feet) to soil does not injure the plants thus far tested, although its cumulative effect, if any, has not been determined.

DIRECTIONS FOR TREATING MANURE WITH BORAX TO KILL FLY EGGS AND MAGGOTS.

Apply 0.62 pound borax or 0.75 pound calcined colemanite to every 10 cubic feet (8 bushels) of manure immediately on its removal from the barn. Apply the borax particularly around the outer edges of the pile with a flour sifter or any fine sieve, and sprinkle 2 or 3 gallons of water over the borax-treated manure.

The reason for applying the borax to the fresh manure immediately after its removal from the stable is that the flies lay their eggs on the fresh manure, and borax, when it comes in contact with the eggs, prevents their hatching. As the maggots congregate at the outer edges of the pile, most of the borax should be applied there. The treatment should be repeated with each addition of fresh manure, but when the manure is kept in closed boxes less frequent applications will be sufficient. Where the calcined colemanite is available, it may be used at the rate of 0.75 pound per 10 cubic feet of manure, and is a cheaper means of killing the maggots. In addition to the application of borax to horse manure to kill fly larvæ, it may be applied in the same proportion to other manures, as well as to refuse and garbage. Borax may also be applied to floors and crevices in barns, stables, markets, etc., as well as to street sweepings, and water should be added as in the treatment of horse manure. After estimating the amount of material to be treated and weighing the necessary amount of borax a measure may be used which will hold the proper amount, thus avoiding subsequent weighings.

WARNING IN CONNECTION WITH THE USE OF BORAX-TREATED MANURE.

While it can be safely stated that no injurious action will follow the application of manure treated with borax at the rate of 0.62 pound for 8 bushels, or even larger amounts in the case of some plants, nevertheless borax-treated manure has not been studied in connection with the growth of all crops, nor has its cumulative effect been determined. It is therefore recommended that not more than 15 tons per acre of the borax-treated manure should be applied to the field. As truckmen use considerably more than this amount, it is suggested that all cars containing borax-treated manure be so marked, and that public-health officials stipulate in their directions for this treatment that not over 0.62 pound for 8 bushels of manure be used, as it has been shown that larger amounts of borax will injure most plants. It is also recommended that all public-health officials and others in recommending the borax treatment for killing fly eggs and maggots in manure warn the public against the injurious effects of large amounts of borax on the growth of plants.

COST OF BORAX TREATMENT.

The amount of manure from a horse varies with the straw or other bedding used, but 12 or 15 bushels per week represent the approximate amount obtained. As borax costs from 5 to 6 cents per pound in 100-pound lots in Washington, it will make the cost of the borax practically 1 cent per horse per day. And if calcined colemanite is purchased in large shipments the cost should be considerably less.

LITERATURE CITED.

AMERICAN PUBLIC HEALTH ASSOCIATION, LABORATORY SECTION.
1912. Standard Methods for the Examination of Water and Sewage. 2d ed. New York, Amer. Pub. Health Assoc., 144 p. (Cover title: Standard Methods of Water Analysis. A. P. H. A. 1912.)

FOLIN, OTTO, AND MACALLUM, A. B.
1912. On the determination of ammonia in urine. *In* Jour. Biol. Chem., v. 11, no. 5, p. 523–525, June. See p. 523.

HASELHOFF, E.
1913. Landwirtschaftlichen Versuchs. vols. 79 and 80, p. 399.
1913. Uber die Einwirkung von Borverbindungen auf das Pflanzenwachstum. *In* Landw. Vers-Stat., Bd. 79 u. 80, p. 399–429, pl. 4–7, 1913.

HERMS, W. B.
1910. How to control the common house fly. Cal. State Board of Health Bul., May 5, no. 2, p. 269–277.

HOWARD, L. O.
1911. The House Fly—Disease Carrier. New York, Frederick A. Stokes Co., 312 p., illus. See p. 196 and 197.

HUTCHISON, R. H.
1914. The migratory habit of house-fly larvæ as indicating a favorable remedial measure, An account of progress. U. S. Dept. Agr., Bul. 14. 11 p. Feb. 28.

RUSSELL, E. J., AND BUDDIN, WALTER.
1913. The action of antiseptics in increasing the growth of crops in soil. *In* Jour. Soc. Chem. Ind., v. 32, No. 24, p. 1136–1142, Dec. 31.

SMITH, R. I.
1912. The house fly (*Musca domestica*). No. Car. Agr. Expt. Sta., Col. Agr. & Mech. Arts, Ann. Rpt. 34, p. 62–69, figs. 13–14. See p. 64.

SÖRENSEN, S. P. L.
1907. Enzymstudien. *In* Biochem. Ztschr. Bd. 7, Hft. 1/2, p. 45–101, Dec. 6.

VAN SLYKE, D. D.
1911. A method for quantitative determination of aliphatic amino groups, Applications to the study of proteolysis and proteolytic products. *In* Jour. Biol. Chem., v. 9, No. 3/4, p. 185–207, May.

WILEY, HARVEY W., editor.
1908. Official and provisional methods of analysis, Association of Official Agricultural Chemists. U. S. Dept. Agr., Bur. Chem., Bul. 107 rev. 272 p.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 124

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
August 28, 1914.

THE ALFALFA CATERPILLAR.

By V. L. WILDERMUTH,
Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

The alfalfa butterfly, *Eurymus eurytheme* Boisd. (fig. 1), is one of the most beautiful and interesting of the group of butterflies known as "the yellows"; beautiful because of its golden and orange colors which contrast so conspicuously with the bright green of alfalfa fields, and interesting because of the wide individual variation, extending from the white or albino forms to those that are deep orange. To the alfalfa grower in the Southwest, however, its chief interest lies in the great destructiveness of the larvæ (fig. 2.) One seeing the yellow butterflies darting here and there over a green alfalfa field would hardly suspect that a few weeks hence they would cause the same field to appear as brown, dead stubble. Yet this is what happens nearly every year to a greater or less degree in the Imperial Valley of California and in the Salt River Valley of Arizona.

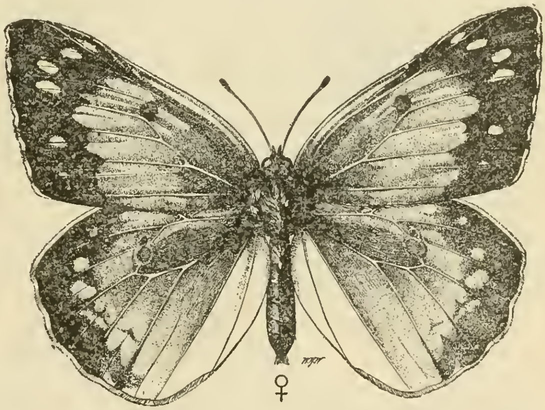

FIG. 1.—The alfalfa caterpillar (*Eurymus eurytheme*); Female in the adult, or butterfly stage. One-half enlarged. (Author's illustration.)

It was not until 1910 that this butterfly was known to entomologists as a serious pest. Previous to that time reports received from

NOTE.—This bulletin is especially applicable to the Southwest, where the alfalfa caterpillar occurs in destructive numbers in irrigated alfalfa fields.

the Southwest, placing on this species the blame for injury to alfalfa, were doubted. In the spring of that year, however, the writer was detailed to investigate these reports in the Imperial Valley and discover whether the butterflies bore any relation to the destruction of alfalfa by a "green worm." His observations showed that the accusations were well founded, for in July, 1910, the butterflies were seen to lay the eggs that hatched into the green larvæ which ate up the alfalfa crop, causing a loss of thousands of dollars.

At the end of the first year's investigation, experiments and observations had been completed which were thought to be of immediate benefit to the ranchers in controlling the pest, and a preliminary report was made and published as Circular 133 of the Bureau of Entomology. During the three years subsequent to this preliminary

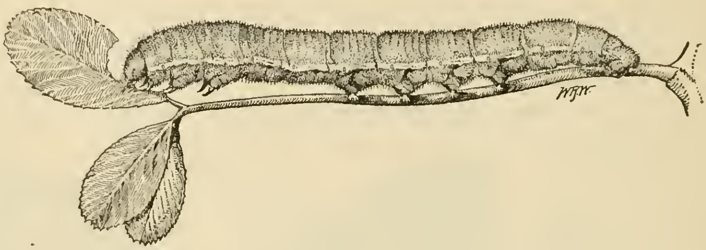

FIG. 2.—The alfalfa caterpillar: Full-grown larva. Enlarged about three diameters. (Original.)

investigation the writer and others have made a more exhaustive study of the species, its habits, and natural or artificial methods of control, and the object of this bulletin is to record these observations as they have been interpreted.

GENERAL DISTRIBUTION.

According to Scudder[1] this insect is well distributed over the United States, but is found in its greatest numbers in the Mississippi Valley (see map, fig. 3) and to the westward. In only a few cases does it appear east of the Allegheny Mountains, but its range extends northward into Canada, even as far as Hudson Bay. In 1911 Mr. R. A. Vickery made observations on the species at Brownsville, Tex., thereby considerably extending the southern range from that included in Scudder's map. In past years the species has been especially abundant throughout the alfalfa-growing sections where irrigation is extensively developed.

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, pp. 1131–1132.

ECONOMIC HISTORY OUTSIDE THE BORDERS OF ARIZONA AND CALIFORNIA.

In regions outside of Arizona and California this species has at various times been suspected, both by agents of the Bureau of Entomology and others, of doing more or less injury to alfalfa. In 1906 a correspondent of the Department of Agriculture reported the caterpillars as infesting lucerne fields in Brigham County, Wyo. In the same year another correspondent, writing from Dell, Oreg., reported the butterflies in "countless thousands playing on the alfalfa blossoms."

In 1909 Mr. C. N. Ainslie found eggs and larvæ on alfalfa at Springer, N. Mex., but not in sufficient numbers to be doing any apparent damage. In July, 1913, on nearly the same ground, the writer found larvæ quite abundant. It is apparent that the reason Mr. Ainslie did not find them in numbers was the lateness of the season. In the same year, 1909, Mr. E. O. G. Kelly, at Wellington, Kans., reported the larvæ as rather numerous on alfalfa plants and feeding freely; and the following year, at the same place, Messrs. T. H. Parks and H. T. Osborn observed the larvæ feeding upon alfalfa, and reared parasites therefrom.

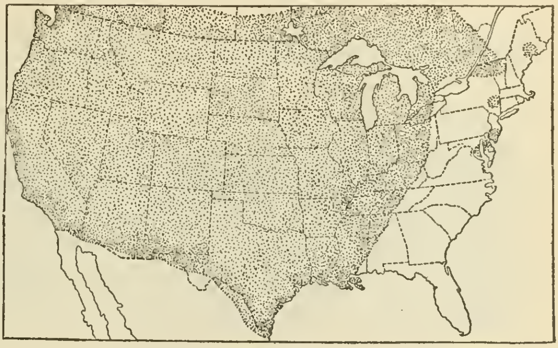

Fig. 3.—Map showing distribution of the alfalfa caterpillar. (Original.)

In 1910 Mr. R. A. Vickery, at Brownsville, Tex., reported the species as being abundant in the alfalfa fields as late as November. He states: "These larvæ are the most numerous and injurious of the several species of caterpillars that are injuring alfalfa now."

In the summer of 1911 the species was found in a number of localities, and reported by different members of the Bureau of Entomology as injuring alfalfa at the following places: Cokeville, Wyo., Idaho Falls and Blackfoot, Idaho (T. H. Parks); Ely, Nev. (C. N. Ainslie). In July, 1911, Prof. S. B. Doten, of the Nevada Agricultural College, received from The H. F. Dangberg Land & Live Stock Co., Minden, Nev., a letter reporting damage from this worm, an extract of which follows: "We are this day mailing you under separate cover a species of worm which at the present time is doing a great deal of damage in our alfalfa fields. They seem to congregate on different parts of the field, and wherever they are the crops are totally destroyed." The same month Mr. Frank C. Jones, of Gardnersville, Nev., reported: "The caterpillar of the yellow butterfly is seriously damaging the alfalfa fields of Carson Valley. It seems to develop most abundantly about the time of the first cutting and feeds on the young shoots, retarding the growth perhaps two weeks."

During the season of 1913 the species was reported by Mr. E. H. Gibson as doing slight damage at Jackson and Nashville, Tenn., and at Greenwood, Miss. Here the butterflies were abroad from early April until late November and, while everywhere present, never seemed to do a great amount of damage. Mr. W. H. Larrimer, also working at Nashville, reported larvæ in considerable numbers.

ECONOMIC HISTORY IN CALIFORNIA AND ARIZONA.

It was Henry Edwards [1] who, in 1877, reported the occurrence at various times of what since has proved to be one of the many color forms of this species. No account can be found in which he treats the species as of economic importance, but he says: "This * * * is an abundant insect in clover and alfalfa fields from July to September," thus intimating that its numbers might be great enough to cause damage. Most of his records were for California.

In 1899 Prof. T. D. A. Cockerell,[2] in studying the insects of the Salt River Valley of Arizona, noted the abundance of these butterflies, but did not stress the probability of damage to alfalfa. He says: "I never saw these butterflies so extraordinarily abundant as they were last October at Phoenix. * * * These caterpillars being very numerous must eat a great many leaves and so reduce the crop, but it is probable that their ravages would not be very noticeable under favorable conditions of moisture and temperature. At all events, it is not practicable to take any measures against them." We have here the first record of the insect as actually destructive to alfalfa.

It would seem that after this, as irrigation in the warm valleys of southern Arizona and southern California began to be more highly developed and alfalfa became a more important crop, the damage became more noticeable each year. In 1907 Mr. Geo. G. Carr, writing to the Department of Agriculture from Hanford, Cal., reports considerable damage to alfalfa. An extract from his letter follows:

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[1] Edwards, Henry. Pacific Coast Lepidoptera, No. 24. Notes on the genus Colias, with descriptions of some apparently new forms. *In* Proc. Cal. Acad. Sci., v. 7, p. 4, Feb. 5, 1877.

[2] Cockerell, T. D. A. Some insect pests of Salt River Valley and the remedies for them: Ariz. Expt. Sta. Bul. 32, p. 286–288, Dec., 1899.

FIG. 1.—ALFALFA PLANTS STRIPPED OF LEAVES BY ALFALFA CATERPILLARS. (ORIGINAL.)

FIG. 2.—HERDING TURKEYS AS A METHOD OF REDUCING THE NUMBERS OF DESTRUCTIVE INSECTS. (ORIGINAL.)

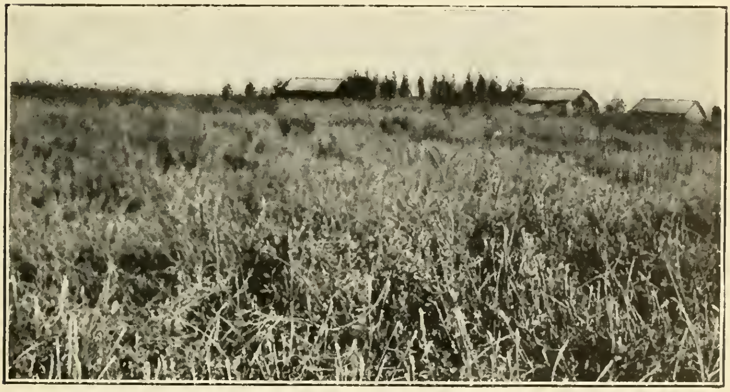

FIG. 3.—FIELD SHOWING IMPROPER CUTTING. THE ALFALFA CATERPILLAR THRIVES IN THE LONG STUBBLE. (ORIGINAL.)

THE ALFALFA CATERPILLAR.

As to the "cutworms," they result from the yellow butterfly, which is often noticed in the alfalfa fields in this valley. The butterfly lays an egg which hatches into the so-called "cutworm" [fig. 2]; the latter goes into the chrysalis state [fig. 6], which eventually results in another butterfly. Seemingly there are several crops of worms which hatch in one season. Whereas we have noticed these worms and butterflies in moderate numbers for years, yet never before have they attained the present great numbers.

In the fall of the year 1909, after a severe outbreak in the Imperial Valley of California during the summer, Mr. J. A. Walton, the owner of a large ranch in that valley, appealed to the Secretary of Agriculture for methods of handling the pest. Mr. W. E. Packard, of the California Experiment Station, reports that the worms are often quite numerous during certain years and cause more or less damage in the Sacramento Valley, and in the irrigated alfalfa regions of south-central California. Several fields that came under the writer's observation in 1910 made an entire failure of the third crop, while many others suffered a 40 to 60 per cent loss in a single hay crop, so that the damage for the year could be conservatively estimated at more than $500,000. (See Pl. I, fig. 1.) During that year (1910) there was also considerable damage in the Salt River Valley of Arizona, but compared with the damage in the Imperial Valley it was slight. In fact, as is explained in later paragraphs, injury was rarely as severe in any other locality as in the Imperial Valley.

During 1911 the bureau was unable to make any studies in the Imperial Valley, but Mr. Packard, who was continually on the ground, told the writer in the fall of that year that little damage was accomplished, the larvæ never being present in great numbers. As noted in a separate paragraph, the destruction of the larvæ in wholesale numbers the summer before by an apparently contagious disease had so checked the species that it was unable to make any headway during that season, and, in fact, as will be seen later, it required two years to readjust itself to conditions.

Throughout the season of 1911, during the writer's absence, Mr. E. G. Smyth, in the Salt River Valley, noted that while there was some damage the species was not numerous enough at any time to necessitate protective measures against it.

In 1912 the writer was again located in the Salt River Valley, and that year, although considerable damage was done by the alfalfa caterpillar, the work of the disease just referred to and of parasites was able to keep the species pretty well within bounds, so that only an occasional field was seriously damaged. The following quotations are from the writer's own field notes:

July 10, 1912: Butterflies are very numerous at this time and in many fields are actively depositing eggs.

July 22: Butterflies are very numerous now, filling the air everywhere. They are even flying around over town in great numbers. Over an alfalfa field north of town they are simply swarming. Millions of them present over the blooming alfalfa where they are feeding. A field just across the road that had been recently cut had the alfalfa covered with eggs. These are adults of the third generation.

Aug. 1: Eurymus larvæ are very abundant now and in a few fields beginning to do considerable damage. On Mr. Aepli's farm 1 mile south of town the caterpillars were exceptionally numerous and damage considerable. However, Mr. Aepli cut his crop of hay and stopped their work by disking. There were 257 larvæ to the square yard counted in this field.

In the Imperial Valley in 1912 the fourth hay crop, about August 1, was nearly one-third lessened by the feeding of the caterpillars, but the damage, although heavier than in the previous year, in no way compared with that of 1910 or 1913. During July, 1913, Mr. Walter Packard wrote to the author, telling him of a great outbreak around El Centro and suggesting that something should be done at once, as practically all of the third crop had been destroyed. As the writer was in northern New Mexico, engaged on other work, Mr. R. N. Wilson was instructed to proceed to Imperial Valley and investigate the outbreak. Upon his arrival there he found the damage to be very heavy, but over for the year, as the species had again been checked by the disease. The conditions are best told in his original field notes, which follow:

El Centro, July 14, 1913: Some of the fields [alfalfa] were visited this morning, and it immediately became obvious that if the bacterial disease is as prevalent in all of the fields in the valley as in those visited this morning it is now too late to try cultural methods, brush dragging, disking, etc., as most of the larvæ are dead. I am told that last week was very warm during the entire week and that the humidity was high. This was probably just the right condition for the disease to spread, and hence the cause of the death of millions of the larvæ. Many of the fields about El Centro have been cut recently and so show nothing now as to *Eurymus* conditions; many are also being pastured, and in these the caterpillar attack is slight. In some fields which have not been either pastured or cut the damage is considerable, but very few healthy larvæ or pupæ can be found at present. Butterflies are numerous everywhere, and in some fields they rise in clouds before the sweepnet. That the damage from larvæ to the present crop is about over is almost certain. * * * A few farmers cut the crop after it had been stripped by larvæ, and the hay was of such poor quality that it was not even gathered. Much of the hay that was gathered was of such poor quality and some of it was so foul with diseased larvæ that it was of little value.

On July 16 Mr. Packard said that he noticed the "worms" in some numbers in the second crop at cutting time, about the last of May. The real outbreak came in July, however, when the third generation of worms began to eat the third crop of alfalfa. He noticed the bacterial disease in the fields about the first week in July, when a large amount of damage had already been done by the larvæ, but the disease did not become widespread or really effective until after the hot, humid weather of last week.

During the season of 1913 in Arizona the outbreak was heavier in the Salt River Valley than it has been for several years—at least the heaviest since the bureau began its investigations four years ago. The report of the outbreak for this year is taken from the notes of Messrs. R. N. and T. Scott Wilson, both of whom were located at Tempe, in the Salt River Valley, this past year. The greatest amount of damage was done to the fourth crop, although the third crop was considerably reduced. The species reached destructive numbers in the eastern part of the valley, especially in the vicinity of Chandler, earlier than in other parts, so that the third crop was considerably damaged and in some fields totally destroyed. On July 22 Mr. T. Scott Wilson reported considerable damage to a field on Mr. Knepper's ranch, and stated that in large spots, perhaps as large as 50 to 100 yards across, the alfalfa was completely defoliated. On July 29 the same observer states: "Mr. Lang's field, 3 miles north of Chandler, shows more damage than any other field I have seen this year. * * * The entire field is damaged, but on spots where the land is rather poor the alfalfa did not grow as rapidly as in other places, and after irrigation it came up quickly and at this tender stage the worms attacked it, completely stripping it of leaves." Mr. R. N. Wilson had previous to this, on July 25, made a similar but more general note in which he says: "The butterflies are now very numerous, and the larvæ have stripped large patches in several fields. * * * The most serious damage began in the central part of the valley about a week or two weeks later than that described in the foregoing notes and was much more severe. On July 30 Mr. T. Scott Wilson reported very serious damage 6½ miles south of Tempe. This field had about 25 to 50 per cent of the alfalfa destroyed." Then, on August 7: "In Mr. Harmon's field, 1½ miles south of Tempe, there are a great many pupæ and larvæ. The alfalfa is almost completely bare of leaves." And on the same date he noted that Mr. Olsons's alfalfa in an 80-acre field, 1 mile south of town, was almost destroyed. Of course he meant the crop then present. On August 14 he mentions seven different ranches that had almost the entire fourth crop destroyed by Eurymus. A day later Mr. Wilson visited several fields south of Phoenix and found the fourth crop here completely defoliated. It is thus seen that the damage ran into thousands of dollars just to this one crop alone. One can hardly anticipate exactly what would have been the resulting damage had these caterpillars gone on unmolested and produced another generation of butterflies. Fortunately, however, the disease already mentioned appeared at this time and prevented a large percentage, possibly 90 to 95 per cent, from ever reaching the pupal stage.

We thus have a history of the several outbreaks during the last few years in these two larger valleys of southern Arizona and California.

There has also been damage in a smaller way, but just as important to the individual farmer, in other valleys of these States. In the Yuma Valley, near the town by that name, both the writer and Mr. R. N. Wilson have noted the occurrence of the caterpillars in destructive numbers, and in the Buckeye Valley they have made similar observations. Mr. Long reported serious damage in the Buckeye Valley, and in 1913, on the Wessex ranch 2 miles west of the town of Buckeye, Eurymus larvæ entirely stripped a 20-acre field, reducing the alfalfa to mere stubble. In the Gila River Valley, between Thatcher and Safford, Ariz., Mr. R. E. L. Wixon, a deputy State nursery inspector, reports occasional devastation and often entire fields destroyed.

In California Mr. T. D. Urbahns has at various times during 1913 reported outbreaks and very serious damage at several towns in the San Joaquin Valley. We quote the following from his notes: July 9, Corcoran: "Considerable injury where crops were left in field too long." September 13, Tulare: "Farmers generally reported heavy loss to their alfalfa crops from the 'alfalfa worm,' and on some fields the alfalfa was completely destroyed in July, then resuming its growth after the pests had subsided from natural control." September 14, Fresno: "While out a short distance north of town I observed fields yellow with butterflies. The leaves were nearly all badly eaten by the larvæ, of which many were still present." September 15, Dos Palos: "Larvæ present in moderate numbers, but causing much injury." September 16, Merced: "A 10-acre field of alfalfa south of town literally covered by larvæ and adults. Stems had been stripped of their leaves." September 17, Modesto: "West of town farmers consider the alfalfa worm a serious pest to their midsummer crops in July and August. Adults and larvæ were still present in large numbers."

At Indio, in the Coachella Valley, Mr. Bruce Drummond, of the Bureau of Plant Industry, has informed the author that considerable damage is done by these caterpillars and that at times it becomes quite severe.

It is thus seen that what was once considered merely a thing of beauty has now become one of the worst enemies to alfalfa culture, causing between $500,000 and $1,000,000 of damage annually to this crop in these southwestern sections alone. That the energetic and up-to-date farmer can greatly reduce and at times totally eliminate this damage is to be shown in the following pages.

DESCRIPTION.

All stages of *Eurymus eurytheme* have been fully described by Edwards and Scudder, and since this paper is purely economic in purpose, no detailed description will be given, but instead a brief outline, such as would enable the casual observer to recognize the different forms.

THE ADULT.

The typical wing color of the adults is an orange-yellow with a black outer border above, and a lighter yellow color on the underside with the black outer border wanting. There is a black discal spot in each of the four wings and a double discal spot of orange in each hind wing. The lower surface of the wing is the one noticed when the butterfly is at rest. The male (fig. 4.) may be distinguished from the female (fig. 1) by the fact that the outer border of the wings is solid black in the former, but broken by a line of yellow dots in the latter. A white or albino female form is frequently found with other color markings, the same as in the yellow form. The wing expanse is about 2 inches.

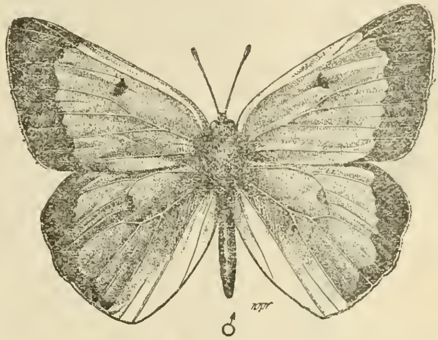

FIG. 4.—The alfalfa caterpillar: Male in the adult, or butterfly, stage. One-half enlarged. (Author's illustration.)

EGG.

The egg (fig. 5) is small, only 0.06 of an inch long, with from 18 to 20 slightly raised longitudinal ridges or ribs broken by cross lines. It is elongated, white when laid, but turning reddish brown after the second day, and is deposited upright, with the basal end attached usually to the upper surface of the leaf.

FIG. 5.—The alfalfa caterpillar: Egg, greatly enlarged. (Redrawn from Scudder.)

LARVA.

The newly hatched larva is a tiny, dark brown, cylindrical object which soon after feeding takes on a green color. Growth is rapid and the larva (fig. 2), after having shed its skin or molted four times, is a little more than an inch in length and is of a dark grass-green color, with a white stripe on each side of the body, through which runs a crimson line. Beneath this stripe on each segment or division of the body is a black spot. There is often an intermediate, narrower, broken, and less distinct white line just above each of the lateral lines. This may be wanting. In some specimens a black or dark green median dorsal line is also present.

PUPA.

The pupa (fig. 6) is yellowish green, with a conspicuous row of black dots just within the margin of each wing pad and three black dots on each side of the abdomen. It is free, having no cocoon, and is found, head up, attached closely by the posterior end to an alfalfa stalk or other support, with the anterior end hanging loosely in a threadlike swing which is joined to the same support.

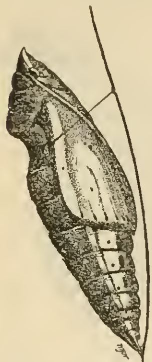

FIG. 6.—The alfalfa caterpillar: Chrysalis, or pupa. (Author's illustration.)

LIFE HISTORY AND HABITS.

The complete life cycle for this insect averages about 38 days for all generations, the minimum length being about 26 days for the third brood and the maximum 64 days for the first brood. (See Table III.) The time occupied by the different stages is as follows: Egg, 6 days; larva, 24 days; pupa, 7 days, and a resting and feeding period of 1 day following emergence of adults during which copulation takes place. Males usually complete the developmental period several days sooner than the females, and thus pass a longer period between emergence and copulation. Mr. W. H. Larrimer, working at Nashville, Tenn., made some interesting records on the life-cycle periods, as shown in Table I. It will be noted that these records were all made during the months of June and July and correspond with the tables for Arizona showing records made during weather of medium temperature.

TABLE I.—*Rearing records for the alfalfa caterpillar, Nashville, Tenn., 1913.*

Egg laid.	Egg hatched.	Egg stage.	Larva pupated.	Larval stage.	Adult emerged.	Pupal stage.	Food plant.
		Days.		*Days.*		*Days.*	
June 4[1]	June 7	3	June 26	19	July 2	16	Medicago sativa.
4[1]	7	3	July 1	24	8	7	Do.
4	7	3	3	26	10	7	Do.
27	30	3	16	16	23	7	Do.
27	30	3	16	16	23	7	Do.
July 2[1]	July 5	3	22	17	29	7	Do.
2[1]	5	3	23	18	29	6	Do.
2[1]	5	3	28	23	Aug. 1	5	Do.
2[1]	5	3	30	25	6	7	Do.
16[1]	19	3	Aug. 2	14	8	6	Trifolium hybridum.
27	30	3	13	14	20	7	Trifolium repens.
27	30	3	14	15	21	6	Do.
27	30	3	11	12	17	6	Vicia sativa.
27	30	3	12	13	17	5	Do.
27	30	3	11	12	17	6	Do.
27	30	3	15	16	21	6	Pisum sativum.
27	30	3	15	21	21	6	Glycine hispida.
1	4	3	July 28	24	2	6	Trifolium pratense.

[1] Reared under same conditions of light, moisture, temperature, and food supply.

	Days.
Average length of egg stage	3
Average length of larval stage	18
Average length of pupal stage	6½

EGG STAGE.

The egg stage varies under ordinary temperatures from 2 to 15 days, the normal period being about 6 days. The length of the egg stage as observed for the six generations during the season of 1912 is as follows: First generation, 14½ days; second generation, 4 days; third generation, 3 days; fourth generation, 3½ days; fifth generation, 3½ days; sixth generation, 5 days. In the summer of 1913 Mr. T. Scott Wilson had eggs under observation which hatched in two days during the month of August, but with an average mean temperature of 87° F., and this same season Mr. E. H. Gibson, at Nashville, Tenn., observed eggs to hatch in an equally short time, with an average mean temperature of 76° F. Mr. Gibson gathered three eggs on June 5 and noted that the time of oviposition was 3 p. m. He placed these in a box, and at 3 p. m., June 7, the larvæ were found emerging from eggshells. Thus the remarkably short period of 48 hours elapsed from oviposition to hatching.

The eggs are deposited upright, singly, on the upper surface of fresh, green alfalfa leaves. When first deposited they are white in color, but change in a few hours to reddish brown. Just before hatching the upper end becomes light colored or nearly transparent, and the caterpillar gnaws its way out.

LARVAL, OR CATERPILLAR, STAGE.

Upon hatching, the larva makes its first meal on the eggshells, often consuming the whole shell. It then feeds upon the leaf, at first gnawing out very small, tiny spots; but rapidly its appetite increases, and it is soon consuming the entire leaf, veins and all. Observations made by the writer and by Mr. Watts, a former agent of this bureau, show that one larva consumes about 25 to 30 leaves during its lifetime. Its growth increases just as fast as its appetite. and often within 12 days the larva is full grown, having cast its skin, or molted, four times and having passed through five instars, or periods between molts, and increased from less than one-tenth inch to nearly 1½ inches in length. The duration of these various instars (see Table II) is influenced greatly by temperature, and during cold or cool weather they are protracted considerably, so that often the complete larval period will cover a month or even more, the general average period for all temperatures being about 24 days.

The larva in feeding stretches itself along an alfalfa stalk and is often rather hard to find, the green color of its body proving to be exactly the same shade as the alfalfa upon which it is feeding.

TABLE II.—*Duration of larval instars and pupal stages of the alfalfa caterpillar, Tempe, Ariz.*

[The records for 1912 are by the author; those for 1913, by Mr. T. Scott Wilson. Records all made in vials under unnatural conditions.]

Cage No.	Larva hatched.	First molt.	Length of first instar.	Second molt.	Length of second instar.	Third molt.	Length of third instar.	Fourth molt.	Length of fourth instar.	Pupation.	Length of fifth instar.	Length of larval stage.	Adult emerged.	Length of pupal stage.	Sex.	Average mean temperature.
	1912.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*		*Days.*		*°F.*
1	Apr. 7	Apr. 14	7	Apr. 19	5	Apr. 22	3	....	....	May 3	11	26	May 13	10	Male	63
2	May 31	June 3	3	June 5	2	June 7	2	June 10	3	[1]	....	....	....	....	....	82
3	31	3	3	5	2	8	3	12	4	June 17	5	17	June 25	8	Female	83
4	June 28	30	2	July 5	2	July 5	3	July 8	3	July 11	3	13	July 16	5	do	81
5	28	30	2	2	2	5	3	7	2	10	3	12	15	5	Male	80
6	28	30	2	2	2	5	3	8	3	12	4	11	17	5	Female	81
7	July 25	July 28	3	Aug. 3	6	Aug. 15	12	Aug. 21	6	[1]	....	....	....	....	....	84
8	25	28	3	July 31	3	3	3	5	2	[1]	....	....	....	....	....	85
9	25	28	3	31	3	2	2	5	3	[1]	....	....	....	....	....	85
	1913.															
7	June 10	June 11	4	June 18	4	June 20	2	....	....	June 27	[2] 7	17	....	....	....	83
12	10	14	4	18	4	20	2	June 23	3	25	2	15	June 29	4	Male	83
13	10	11	4	[3]	[3]	[3]	[3]	[3]	[3]	25	....	15	30	5	do	83
14	11	14	3	[3]	[3]	[3]	[3]	[3]	[3]	25	....	14	July 1	6	do	83
15	11	14	3	[3]	[3]	[3]	[3]	[3]	[3]	25	....	11	[1]	....	....	83
17	11	14	3	June 18	4	June 20	2	June 21	1	25	4	14	June 30	5	Male	83
18	11	15	4	18	3	20	2	22	2	[1]	....	....	....	....	....	83
26	12	17	5	19	2	[3]	[3]	[3]	[3]	June 28	....	16	[1]	....	....	83
32	12	16	4	18	2	[3]	[3]	[3]	[3]	25	....	13	July 2	7	Male	83
34	12	15	3	18	3	June 20	2	June 23	3	27	4	15	1	[1]	....	83

[1] Died. [2] Combined length, fourth and fifth instars. [3] No record.

PUPAL, OR CHRYSALIS, STAGE.

As has been stated before, the pupæ are found hanging, head up, attached to alfalfa or other stems, and as their color blends with their environment they are often hard to see and will be overlooked unless searched for. Often, too, instead of pupating on a bare stem the larvæ will crawl to a leafy stem and pupate there, thus protecting themselves still further from their enemies and from the rays of the sun. The average length of the pupal period for ordinary field temperatures is about 7 to 10 days, but varies considerably with the temperature. Records made by the writer at Tempe, Ariz., from March to September, 1912, showed a variation of from 5 to 10 days, and records made at the same place in 1913 showed a variation of from 5 to 7 days, while Mr. W. H. Larrimer, at Nashville, Tenn., secured records during the summer of 1913, from July 2 to August 21, in which the pupal stage varied from 5 to 7 days, averaging for 18 specimens $6\frac{1}{3}$ days. There is no doubt that the pupal period may be lengthened to 12 or 15 days, or even more, if the temperature is low enough.

ADULT, OR BUTTERFLY, STAGE.

The process of emergence from the pupa is one of short duration and usually occurs early on a bright morning. The butterfly crawls up a stalk, soon spreads and dries its wings, and is off looking for bloom upon which to feed. Copulation often takes place within a day or sometimes on the same day, and the female begins ovipositing on the day following. A large number of eggs is usually laid by one female. In the Southwest the number per individual is greater during spring and fall than during the extreme hot weather. At Tempe never more than 200 eggs were recorded for one female, the number often being as low as 50. At Tempe, also, the total number was often deposited in a single day, while specimens sent to New Hampshire deposited as many as 500 during a laying period of 11 days. This shows the relation of temperature to egg production.

The sending of gravid female moths from Tempe, Ariz., to Prof. John H. Gerould, at Hanover, N. H., a railroad trip of several days, was a matter of interest and shows well the hardiness of the butterflies. The butterflies were placed inside a tin box securely lined with moist blotting paper, and the box was then wrapped carefully and mailed. Vigorous specimens were secured and only a few to a box. While not every attempt was successful, a great many were so. Through the kindness of Prof. Gerould I quote from a letter written October 7, 1913:

> The third female from Arizona produced from one laying of eggs 214 males and 206 orange-yellow females. She was mailed at Tempe on June 6 and re-

ceived at Hanover in strong active condition on June 10. She began to lay on June 11 and continued until June 22. Her 420 adult offspring represent only a part of her caterpillar progeny, for, besides the loss through disease and accident, 15 pupæ succumbed to excessive cold and other unfavorable conditions in a refrigerator while undergoing an experiment to determine the effect of cold upon color. Probably 500 eggs were laid.

The proportion of males to females in Arizona is about 2 to 1, but Gerould, in New Hampshire, finds them about equal. In the field at Tempe one will always be impressed with the superabundance of males. This difference in the proportion of the sexes as between Arizona and New Hampshire is probably due to the fact that in Arizona the intestinal disease kills a large number of the larvæ; and since males develop a few days sooner than females, it is likely that the majority of the larvæ killed would have developed into females, while those escaping the disease become males. In New Hampshire Prof. Gerould is often able to rear over 90 per cent from egg to adult in confinement, while at Tempe it is rare that 25 per cent of the eggs are reared. In a blooming alfalfa field the percentage of males to females is still higher, owing to the fact that females after feeding and mating leave this older alfalfa to seek new growth. In searching out this tender growth for egg deposition it seems as if they knew that if their eggs were laid on the older alfalfa it might be cut before the larvæ could mature. One can tell at a glance an ovipositing female. She has a hesitating flight and at intervals will drop down for a moment on an alfalfa leaf and, depositing an egg, will flutter on, soon repeating the operation and depositing as many as four or five eggs per minute.

Among the yellow butterflies in a field one notices many white or albino forms. These are of the same species as the yellow ones and, according to Prof. Gerould,[1] are merely color phases, as he has shown to be the case in *Eurymus philodice* (Godart).

FEEDING HABITS OF THE BUTTERFLIES.

The butterflies of *Eurymus eurytheme* feed upon nectar from the blossoms of a great many plants. Over a blooming alfalfa field one can often see them by the millions, visiting the blossoms and extracting the nectar therefrom. This habit has occasioned many remarks, farmers quite often being under the impression that these butterflies were producing some direct results upon the growth of the alfalfa crop. The bee-keeping farmer usually insists that they are robbing his bees by taking nectar that belongs to them. In Circular 133 of the Bureau of Entomology, published in 1910, the writer ventured the remark, since he had witnessed the tripping of the pollen trigger

[1] Gerould, J. H. The inheritance of polymorphism and sex in *Colias philodice*. Amer. Nat., v. 45, p. 257–283, May, 1911.

of alfalfa bloom by this butterfly, that possibly its feeding habits might be of some benefit in assisting pollination. As this statement occasioned some comment, further observations were made upon the butterflies during three consecutive years, but not another instance of tripping was noted. It seems, therefore, that in the cases observed, the trippings were effected accidentally by the feet. As these instances are probably exceptional it is not likely that the butterflies exert any material influence on seed production. However, the relation of bees and alfalfa to butterflies and alfalfa seems to be a complex one. Hermann Müller,[1] in 1873, came to the conclusion that butterflies probably effect explosion and cross-fertilization, while C. V. Piper,[2] in 1909, in his Report of the Committee on Breeding Forage Crops, gives the records from a considerable number of well-known plant breeders, no two of whom seem to agree as to the exact relation of butterflies to alfalfa pollination, but the majority of whom think that the butterflies exert no influence.[3] Whether the butterflies rob honeybees of their just food is a question. Prof. Cockerell[4] states, in 1899, that * * * "butterflies, sucking the nectar, but making no honey, must interfere with the success of the bees, especially when they become very numerous." As mentioned above, this robbing of the bees by butterflies is a common belief among beekeepers and has been suggested to the author many times.

NUMBER OF GENERATIONS.

Mr. W. H. Edwards[5] reports two broods of this species in the mountains of northern Colorado, the adults of which appear in June and again in the latter part of July and in August. In Nebraska and Illinois, according to the same author, three broods are recorded, while in the lowlands of California he reports the insect as being triple or quadruple brooded. Mr. J. Boll,[6] in 1880, reports four broods in Texas, and this, too, during a short season, for he

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[1] Müller, Hermann. Die Befruchtung der Blumen durch Insekten, Leipzig, 1873, p. 228–229.

[2] Piper, C. V. Report of the committee for breeding forage crops. Alfalfa and its improvement by breeding. Amer. Breeders' Assoc., v. 5, 1909, p. 94–115.

[3] Since this manuscript was submitted for publication, Bulletin No. 75 of this department, dated Apr. 8, 1914, treating of Alfalfa Seed Production; Pollination Studies, by Prof. C. V. Piper and his assistants, has been published.

In this document it is shown that tripping of alfalfa flowers may be automatic as well as effected by insects or other external agents. The authors state that this automatic tripping takes place more frequently in hot sunshine, although humidity is doubtless a factor. Also the statement is made that this automatic tripping, with consequent self-pollination, probably results in the setting of as many pods as does tripping by insect visitors, at least in the West.—F. M. W.

[4] Cockerell, T. D. A. Some insect pests of Salt River Valley and the remedies for them. Ariz. Agr. Expt. Sta. Bul. 32, p. 273–295, Dec., 1899.

[5] Edwards, W. H. The Butterflies of North America, second series, Boston, 1884, Colias IV.

[6] Boll, J. Ueber Dimorphismus und Variation einiger Schmetterlinge Nord-Amerikas. Deut. Ent. Ztschr., Bd. 24, Heft 2, p. 241–248, 1880.

states that the species æstivates during the summer months from June to November.

In the year 1910, in the Imperial Valley of California, there were four distinct generations up to July 15. The fourth generation, however, was almost entirely exterminated by the disease before mentioned, and, following this, later generations became so largely confused that it was impossible to separate them, since, unfortunately, no series of generation cages were then in use for this purpose. The first generation in 1913 covered the period from March 15 to April 30; the second generation from May 1 to May 28; the third generation from May 28 to June 20; and the fourth generation from June 20 to July 15. It seems quite probable that there were at least three generations during the rest of the season. As shown in Table III, during the year 1912, at Tempe, Ariz., there were six generations, adults of hibernating forms appearing in March and adults of the fifth generation disappearing in October, while a few adults of the sixth generation appeared during warm periods of the winter months.

TABLE III.—*Generations of the alfalfa caterpillar, Tempe, Ariz., 1912.*[1]

Generation.	Eggs laid.		Eggs hatched.		Length of egg stage.	Larva pupated.	Length of larval stage.	Adults issued.[2]	Length of pupal stage.	Total developmental period.	Number issued.	Average mean temperature.
	Date.	Number.	Date.	Number.								
	1912.				*Days.*		*Days.*		*Days.*	*Days.*		°*F.*
1st	Mar. 24	Many.	Apr. 7 8	12 31	14 15	May 11	34	May 19	8	56	17 females. 30 males.	63.5
2d	May 27	36	May 31	36	4	June 18	18	June 24	6	28	2 females. 1 male.	83.75
3d	June 25	Many.	June 28	Many.	3	July 13	15	July 19	5	23	3 females. 2 males.	86.5
4th	July 22	Many.	July 25	Many.	3½	Aug. 12	18	Aug. 19	7	28½	1 female. 1 male.	84.5
5th	Aug. 23	6	Aug. 26	6	3½	Sept. 9	16	Sept. 19	10	29½	3 females. 3 males.	80.0
6th	Sept. 28	Many.	Oct. 3	Many.	5	Nov. 18	45	These hibernated.				64.0

[1] The first half of this table does not give duration of time elapsing between emergence and oviposition.
[2] Date here is the day the last ones issued.

PERIODS AND DURATION OF GENERATIONS.

	Days.
First generation, Mar. 24 to May 27	64
Second generation, May 27 to June 25	29
Third generation, June 25 to July 22	26
Fourth generation, July 22 to Aug. 23	33
Fifth generation, Aug. 23 to Sept. 28	38½
Sixth generation, Sept. 28 to pupæ in hibernation.	

Mr. T. Scott Wilson, working at Tempe, secured records during the year 1913 of three distinct generations from late March to the latter part of July, his observations thus corresponding fairly well with those of the writer during the previous year. The dates of the three generations were as follows: First brood, March 27 to May 20; second brood, May 20 to June 23; and third brood, June 23 to

July 23. Following this the intestinal disease attacked the larvæ so generally that Mr. Wilson found it impossible to continue generation records. Nevertheless, he states in his field notes that a fourth generation was out by the latter part of August. We thus see that there are in the colder sections of the country two generations annually and in the extreme warmer sections at least six and possibly more generations each year.

FOOD PLANTS.

Alfalfa seems to be the favorite food plant, but there are quite a number of others. The two buffalo clovers, *Trifolium reflexum* and *T. stoloniferum*, were probably the original native food plants. For some years the species was thought not to live upon red clover (*T. pratense*), but Mr. E. H. Gibson, at Greenwood, Miss., and Mr. W. H. Larrimer, at Nashville, Tenn., proved conclusively that it does attack red clover. They collected both eggs and larvæ from red clover and reared them to adults. During the summer of 1913 the writer collected the larvæ feeding upon few-flowered Psoralea (*Psoralea tenuiflora*) at Koehler, N. Mex., and Mr. Larrimer, at Nashville, made some interesting experiments, besides those on red clover. Using larvæ that hatched indoors, he reared them from the following plants that had not already been reported as food plants: Alsike clover (*T. hybridum*), soja bean (*Glycine hispida*), Canadian field peas (*Pisum sativum*), and hairy vetch (*Vicia sativa*). Repeated attempts to rear them on cowpeas (*Vigna sinensis*) resulted in failure. He says: "On hairy vetch they seemed to thrive exceedingly well and completed their life history in a shorter period than on any other food plant." In July, 1910, the writer found larvæ feeding on sweet clover (*Melilotus alba*), which, strangely enough, they seemed to prefer to a patch of alfalfa growing close by. Eggs were observed to be very numerous upon the leaves of the sweet clover at the same time. Besides alfalfa and the buffalo clovers, Scudder[1] has recorded Hosackia, ground plum (*Astragalus caryacarpus*), and *A. crotalariæ* as food plants. The adults visit blooming plants for nectar, and they have been reported, doubtless erroneously, as feeding upon many of these. The butterfly is known to oviposit on toothed medicago or bur clover (*Medicago hispida*). Mr. E. H. Gibson, at Greenwood, Miss., reported females ovipositing on coffee weed (*Sesban macrocarpa*), which they curiously preferred to red clover growing near by.

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[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, p. 1132.

HIBERNATION.

According to earlier records by Edwards and those a little later by Scudder, which treat of the species in its northern rather than in its southern range, the alfalfa caterpillar hibernates as larvæ and adults, whereas G. H. French,[1] in his revised edition of Butterflies of Eastern United States, reports the species as hibernating as chrysalids. The writer has observed the species hibernating in all three forms, if it could really at all times be termed hibernation. Hibernating chrysalids were found upon weed and alfalfa stems by the writer at both Tempe, Ariz., and El Centro, Cal., and at Wellington, Kans., Mr. Kelly reported the finding of hibernating pupæ beneath fence rails. Just a few larvæ have been collected by sweeping at various times during the winter season at Tempe. During the last week in January, 1912, a single larva was taken, while in January, 1913, Mr. R. N. Wilson took a third-instar larva less than two weeks after a very severe cold spell, i. e., severe for the Salt River Valley, a temperature of 13° F. having been recorded on two successive nights. On warm days adults have been observed in flight several times during the winters when the species was under observation. In 1910 adults were taken at Tempe early in December, and Mr. W. E. Packard took them during the third week in December at El Centro, Cal. In the winter of 1911–12 adults were seen on the 20th of December and again in the middle of January. Larvæ have been collected in January and, pupating within a few weeks, have issued early in March. Pupæ collected in December have issued in February, but adults have never been noted to deposit eggs during the month of January. It is thus seen that at times hibernation amounts to nothing but a prolongation of one of the three stages, the usual activity for each respective stage being resumed on warm days that occur during the hibernation period.

According to Boll[2] the species æstivates in Texas as larvæ during the dry period in summer when the food supply has become exhausted. The writer has never witnessed the æstivation of this species in the Southwest. In fact, it has always occurred in most abundance during the hotest months of the year, notably July and August. Other bureau records likewise show no report of æstivation. It seems safe to assume that the change in habit from that early reported by Boll in Texas is due to recent irrigation of tracts of land well distributed over the arid regions of the Southwest. Originally the species had to æstivate during summer when clovers

[1] French, G. H. The Butterflies of the Eastern United States. New and rev. ed., Philadelphia, 1900, p. 130.

[2] Boll, J. Ueber Dimorphismus und Variation einiger Schmetterlinge Nord Amerikas. Deut. Ent. Ztschr., Bd. 24, Heft 2, p. 241–248, 1880.

were dried up, but now, in the thrifty-growing alfalfa fields of this once arid country, it finds a place to continue its activity throughout the summer, and, as has been mentioned before, it is this very change that has enabled the species to become the pest that it is to-day.

NATURAL CHECKS TO THE SPECIES.

Were it not for the fact that this species is preyed upon by a great many natural enemies it would indeed prove a much more serious pest than it is at the present time. Parasites and predaceous insects, fungous and bacterial diseases, birds, toads, and even domestic fowls, all play a large part toward keeping the species well within bounds during certain seasons of the year.

In 1889 Scudder[1] said: "Strange to say, not a single parasite has been reported to attack this common insect." However, the author and others, during the past three years, have reared as many as nine parasites from the various stages of this butterfly, and some of these at times are quite numerous. An example of the extent of parasitism may be gleaned from the following record of a collection of 154 pupæ made at Tempe, Ariz., on August 26, 1912:

	No. of pupæ.
Infested by chalcid parasites	82
Partially eaten by *Heliothis obsoleta*, etc	28
Rotten from intestinal disease	37
Infested by tachinid parasites	6
Alive and healthy	1
Total	154

This, of course, was an exceptional collection, but often collections were made from which as few as 5 per cent of the pupæ were reared to adults. The percentage of parasitism usually reaches the maximum during the month of August, so that rarely is much damage done by the caterpillar after that time.

PARASITES OF THE EGGS.

Only one egg parasite of *Eurymus eurytheme* was found. This is the very common *Trichogramma minutum* Riley (fig. 7), which is known as an egg parasite of a great many species of insects. In its relation to eggs of this species it was first found by Mr. Harry Newton, of the Bureau of Entomology, who was working at Tempe, Ariz., during the summer of 1913. On July 26 he found three eggs which were very dark in color, and two days later three of the tiny parasites issued from one of these. Two days previous to Mr. Newton's collection Mr. T. Scott Wilson collected 100 eggs. From three

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, p. 1132.

of these parasites issued several days later, or 3 per cent. On July 28 Mr. Newton, encouraged by his first efforts, collected 31 eggs that appeared to be parasitized. Twenty-six of these produced, in the course of five days, 76 parasites, or nearly 3 to each egg. Seventeen freshly laid eggs were exposed to female parasites by Mr. Newton on August 1, and on August 8 eight of these produced 24 adult parasites, showing the length of the combined egg, larval, and pupal stages to have been seven days. Nine failed to be parasitized, and one produced 5 parasites in six days. On August 16 Mr. Wilson collected 19 eggs, 60 per cent of which were parasitized.

FIG. 7.—*Trichogramma minutum*, a parasite of the eggs of the alfalfa butterfly, in act of oviposition in an egg of the brown-tail moth (*Euproctis chrysorrhœa*). Greatly enlarged. (From Howard and Fiske.)

It is thus seen that this tiny parasite is of considerable benefit in reducing the numbers of the alfalfa caterpillar. From the records it seems that the increase of the parasites from July to August was quite rapid. The fact that the life cycle is of so short duration is partially responsible for this, as it doubtless gives a chance for two broods of parasites upon the eggs of one generation of Eurymus.

HYMENOPTEROUS PARASITES OF THE CATERPILLARS AND CHRYSALIDS.

Four species of hymenopterous parasites of the caterpillars and chrysalids were found. Specimens of a Limnerium were reared

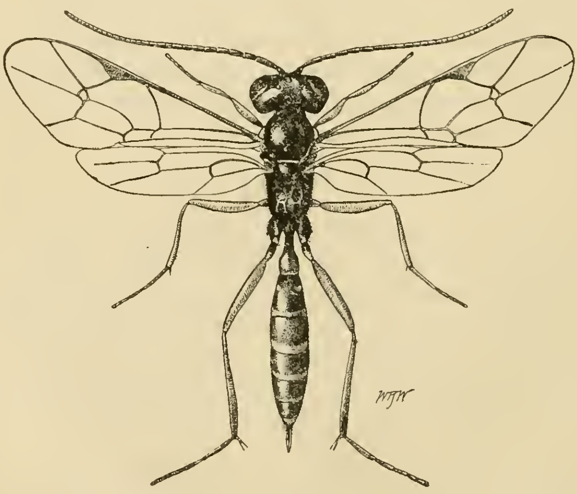

FIG. 8.—*Limnerium* n. sp., an ichneumonid parasite of the alfalfa caterpillar: Adult. Greatly enlarged. (Original.)

by the author at El Centro, Cal., in 1910, and what is supposedly the same species was reared in considerable numbers by Mr. L. P.

Rockwood at Salt Lake City in the summer of 1913 and has since been determined by Mr. A. B. Gahan, of this bureau, as *Limnerium* n. sp. (fig. 8). Mr. Rockwood found these parasites of material benefit in the suppression of outbreaks in Utah and always reared them from young and only partially grown larvæ. At Salt Lake City, during the summer of 1913, he also reared a goodly number of a small hymenopteron, *Apanteles* (*Protopanteles*) *flavicombe* Riley. This species is gregarious, but was not found to be sufficiently numerous to exert any marked effect upon the abundance of Eurymus. The common *Chalcis ovata* Say (fig. 9) was first reared from this species by the writer in 1910, at El Centro. Only one specimen was secured, but in 1912 the author reared many adults, and in 1913 the Messrs. Wilson reared adults from pupæ collected in both Arizona and California.

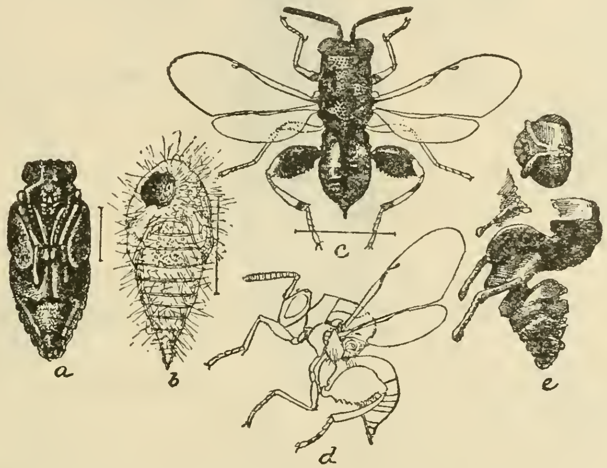

FIG. 9.—*Chalcis ovata*, a parasite of the pupa of the alfalfa caterpillar: *a*, Pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

PTEROMALUS EURYMI GAHAN.

The three parasites just mentioned are of minor importance, but the fourth is of great assistance in suppressing outbreaks of the alfalfa caterpillar. It is a new species, recently described by Mr. Gahan[1] as *Pteromalus eurymi* (fig. 10). Mr. H. T. Osborn, at Wellington, Kans., in September, 1910, reared 40 specimens of this species from a pupa of Eurymus, but the specimens were put into alcohol and not determined until November, 1913. When, therefore, Mr. R. N. Wilson secured a parasitized pupa in December, 1911, and

[1] Gahan, A. B. New Hymenoptera from North America. Proc. U. S. Nat. Mus., v. 46, p. 431–443, 1913. "*Pteromalus eurymi*, new species," p. 435–436.

reared this parasite, it was believed to be the first rearing record. During the following summer the parasites were so numerous that it was hard to understand why they had not been discovered before. Collections of pupæ of Eurymus were made by the writer in August,

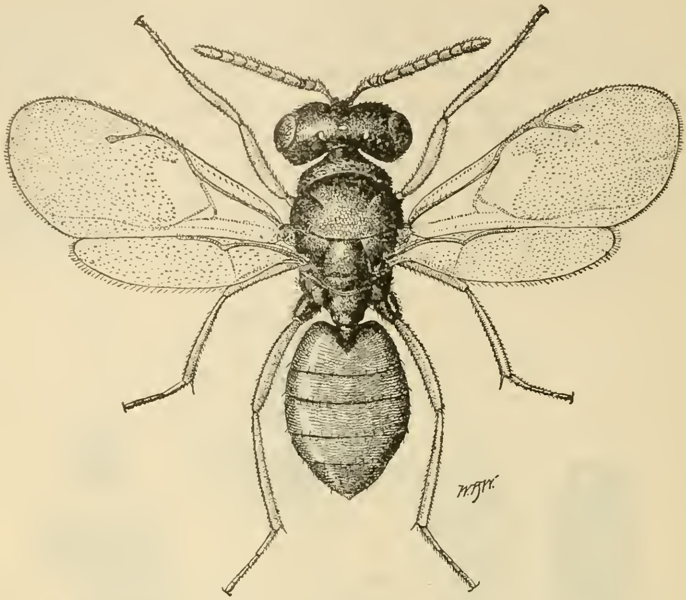

FIG. 10.—*Pteromalus eurymi*, a parasite of pupæ of the alfalfa caterpillar: Adult. Greatly enlarged. (Original.)

1912, and showed that 49 per cent were parasitized by this species. The record follows:

TABLE IV.—*Parasitism of pupæ of the alfalfa caterpillar by Pteromalus eurymi.*

Date.	Pupæ collected.	Infested with Pteromalus.	Per cent infested.
1912.			
Aug. 5	65	26	40
Aug. 14	39	17	43+
Aug. 19	11	7	63+
Aug. 26	154	82	53
Total and average	269	132	49

This insect thus seems to be exerting a larger influence than any other parasite toward the control of the alfalfa caterpillar.

In 1913 Mr. T. Scott Wilson did not find it nearly so numerous in the Salt River Valley as was the case the year before. Just why this was so, it is hard to say. The extremely cold weather during the preceding winter may have killed the hibernating Pteromalus larvæ (fig. 11). In the same year Mr. R. N. Wilson found the species quite numerous in the Imperial Valley of California. As many as 20 per cent of the Eurymus pupæ were parasitized by it.

This parasite seems to be distributed over a considerable area, for, besides being present in Arizona and California and, as stated, at Wellington, Kans., it has been reared during the season of 1913 and found to be quite abundant at Salt Lake City, Utah, by Mr. Rockwood, and at Nashville, Tenn., specimens were raised by Mr. Larrimer from a single pupa of Eurymus.

It seems almost certain that this parasite winters as a larva within the pupal shell of the host. The first lot collected in a pupa of the alfalfa caterpillar in December were discovered as larvæ in January and soon thereafter turned to pupæ (fig. 12), issuing as adults in March. The eggs are laid in pupæ of Eurymus, from 40 to 114 parasites developing in one pupa. About 80 to 90 per cent of these are females and the rest males, and the adults issue from one or more tiny holes in the pupa of their host. (See fig. 13.)

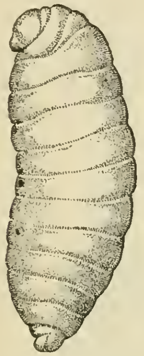

FIG. 11.—*Pteromalus eurymi:* Larva. Greatly enlarged. (Original.)

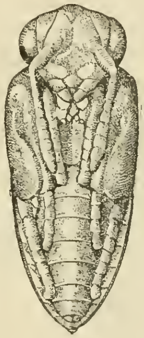

FIG. 12.—*Pteromalus eurymi:* Pupa. Greatly enlarged. (Original.)

FIG. 13.—*Pteromalus eurymi:* Adults issuing from chrysalis of alfalfa caterpillar. Enlarged nearly three diameters. (Original.)

The combined length of the egg, larval, and pupal stages in the warmer weather of August is from 12 to 15 days, while the pupal stage was found to cover 4 days in the month of August and 12 to 15 days in February, the variation being due to differences of temperature. Thus several generations are possible each season, and thus, with abundant egg production and high percentage of females, gives rise to a rapid increase in the number of parasites, so that by late August the multiplication of the host species is checked.

DIPTEROUS PARASITES.

Three tachinid flies, determined by Mr. W. R. Walton, of this bureau, have been reared from the larvæ and pupæ of this caterpillar. *Phorocera claripennis* Macq. (fig. 14) is the most important of these, its wide distribution and abundance of alternate hosts causing it to be always on hand. In 1910 at El Centro, Cal., the writer observed as many as 15 per cent of Eurymus larvæ with eggs of this species attached to them; while in 1913 Mr. T. Scott Wilson, at Tempe, Ariz., observed as many as 50 per cent of larvæ with eggs upon them, and in some cases there were as many as five or six to one caterpillar. Of course a great many of these eggs are shed in molting, but a majority of them hatch, and the maggot, entering the Eurymus larva. kills it in a short time. *P. claripennis* has been reared from this species at the following other places: Salt Lake City, Utah (E. J. Vosler and L. P. Rockwood); Wellington, Kans. (H. T. Osborn); Greenwood, Miss. (E. H. Gibson); Nashville, Tenn. (W. H. Larrimer). Three specimens of *Frontina archippivora* Will. were reared from a larva and pupa collected at El Centro, Cal., by Mr. R. N. Wilson, and a single specimen of the same species was reared by Mr. Rockwood at Salt Lake City, while at El Centro a single specimen of *Masicera* sp. was reared by the writer.

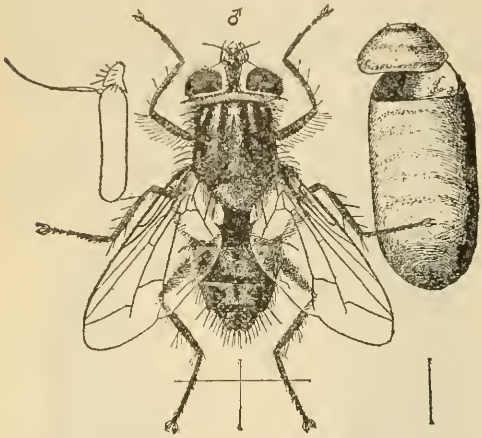

FIG. 14.—*Phorocera claripennis,* a parasite of the alfalfa caterpillar. Adult and enlarged antenna of same; puparium. Enlarged. (From Howard.)

FIG. 15.—*Aphiochæta perdita,* a phorid parasite of the pupa of the alfalfa caterpillar. Greatly enlarged. (Original.)

Besides these tachinid parasites, another small dipteron was discovered by Mr. T. Scott Wilson to be parasitic upon the pupæ. This was a small brown phorid (fig. 15) which has been determined by Mr. J. R. Malloch as *Aphiochæta perdita*, a species recently described by him[1] as new. This is supposedly a new record of habit for this species, but according to Mr. Wilson it was reared time and again from pupæ which were alive when collected; thus the flies could not be acting as scavengers, but must have been true parasites.

OTHER INSECT ENEMIES.

A large green caterpillar, known as the bollworm, *Heliothis obsoleta* Fab. (fig. 16), which can be distinguished from the alfalfa caterpillar because it is of a lighter green color, about one-fourth larger, hairy, and rough in appearance rather than smooth, with three black lines traversing its body lengthwise, is quite prevalent in the Imperial and Salt River Valleys, and is often mistaken for the alfalfa caterpillar by many farmers. As observed by the writer, and later by Mr. T. Scott Wilson, it was found to do very little damage to alfalfa, but to be a ravenous enemy of the alfalfa caterpillar, never eating alfalfa as long as it could find the larvæ or pupæ of Eurymus. Messrs. E. O. G. Kelly and T. H. Parks noted this species at Wellington, Kans., in the summer of 1909, and reported it as being of a predaceous habit.[2]

Fig. 16.—Bollworm (*Heliothis obsoleta*), an enemy of the alfalfa caterpillar. Twice natural size. (Author's illustration.)

The writer observed a bollworm larva to eat five large larvæ of Eurymus during a single day, and both the writer and Mr. T. Scott Wilson counted dozens of pupal cases with the contents eaten out (fig. 17) and many times with the Heliothis larva still feeding upon and devouring the pupæ. Mr. Wilson, on July 15, 1913, remarked in his field notes that "Heliothis was observed in great numbers feeding upon Eurymus pupæ, and in a few instances on Eurymus larvæ. The Heliothis makes a hole in the side of the pupa, through which he puts his head and eats out the contents of the pupa." The writer has observed the end of the abdomen eaten off the pupa; again, an opening would be made on the side, often the entire side being destroyed.

Fig. 17.—Chrysalis of alfalfa caterpillar that has been eaten out by a bollworm. Enlarged about two diameters. (Original.)

[1] Malloch, J. R. The insects of the dipterous family Phoridæ in the United States National Museum. Proc. U. S. Nat. Mus., v. 43, p. 459–460, 1912. "*Aphiochæta perdita*, new species," p. 459.

[2] This cannibalistic habit has also been observed in Texas by Quaintance and Brues. (U. S. Dept. Agr., Bur. Ent., Bul. 50, p. 79–80, 1905.)

The malachiid beetle, *Collops vittatus* Say (fig. 18), is rather numerous in the alfalfa fields of Arizona and was suspected of bearing some relation to Eurymus. Mr. T. Scott Wilson found both adults and larvæ feeding upon pupæ of the alfalfa caterpillar. He observed as many as 20 beetles feeding upon as many pupæ in a single day. This beetle seems to feed upon either live or dead Eurymus larvæ and pupæ and does not appear to have much choice between the two. It attacks a pupa or larva and, piercing it, sucks the juices that exude. In this way a hole is gradually made in the host, which, of course, is killed. Being small, the beetle does not consume much of its prey, but wanders off, and the next time it is hungry it attacks a new pupa or larva and thus kills many. Larvæ were taken in the act of feeding upon Eurymus pupæ, placed in vials, and reared to adult Collops.

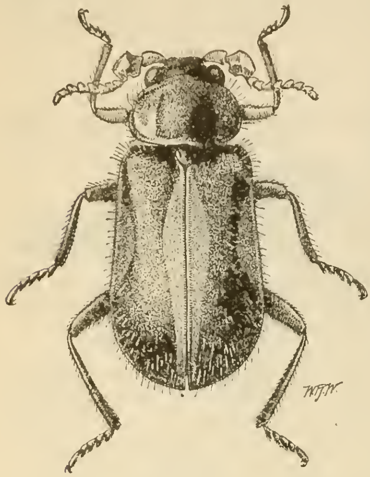

FIG. 18.—*Collops vittatus*, a beetle that preys upon the alfalfa caterpillar. Greatly enlarged. (Original.)

Two species of ants, *Pogonomyrmex barbatus* Smith and *Cremastogaster lineolata læviuscula* var. *clara* Mayr (?) were observed to attack Eurymus larvæ and kill them. Several species of robber flies have been observed to catch the adult butterflies and feed upon them. The writer took *Proctacanthus milbertii* Macq. with a butterfly in its claws, and Mr. H. E. Smith, at Koehler, N. Mex., observed the butterflies being carried off by *Stenopogon picticornis* Loew (fig. 19).

FIG. 19.—*Stenopogon picticornis*, a robber fly that preys upon alfalfa butterflies. Not quite natural size. (From C. N. Ainslie.)

A FUNGOUS ENEMY.

A fungus was found to attack the pupæ in the Salt River Valley in 1912. This is sometimes quite common, but never abundant, although more prevalent about August than at other times, probably owing to higher humidity. Dr.

Flora W. Patterson, of the Bureau of Plant Industry, has determined this as a Fusarium. In her letter she says: "The fungus, which bears strong evidence of being parasitic, has quite filled the body cavity and is either a Fusarium or Microcera," and states that the majority of similar fungi are reported upon scale insects. Later she says, "Cultures of the above fungus, parasitic upon *Eurymus eurytheme*, have developed in the most satisfactory manner, and it is probably an undescribed parasitic Fusarium."

A DISEASE.

As has been mentioned earlier in this paper, a disease which is probably bacterial and resembles flacherie of the silkworm is quite common upon larvæ and pupæ of Eurymus. At times, evidently during periods of higher humidity accompanied by warm weather, as in July and August, it becomes so widespread as to kill a great majority of a brood and often nearly annihilates it. This disease is by far the greatest natural check against which the alfalfa caterpillar has to contend and is one of the most important factors looking toward its control.

The dead worms, which are nothing but soft decayed masses found hanging to the alfalfa stalks, are sometimes so numerous as to make sweeping with an insect net impossible, the net in a few sweeps becoming so foul as to render other insect specimens of little value. The disease has proved a great detriment to the successful carrying on of life-history experiments and the rearing of parasites, owing to the fact that large percentages of larvæ taken to the laboratory and confined often die from it. Frequently, where a hay crop is not totally destroyed by a brood of caterpillars before they are killed by this disease, the decayed remains on the hay become so foul as to render the hay quite unpalatable for horses and hence of low value.

As has been suggested, the development of the diseased condition in either larvæ or pupæ—for it attacks both—depends largely upon moisture. The disease is present at all times, and a few larvæ from each brood are killed, but it is only when a period of high humidity accompanied by warm weather occurs that it becomes so prevalent as to attack the worms in large numbers. It has been found that at certain times these conditions of moisture may be produced artificially by irrigation, and, as is discussed in a later paragraph, the disease, thus fostered, is utilized as a factor in controlling the pest. That the disease does not at all times keep the caterpillar in check is doubtless due to the dry climate of these southwestern countries, and a comparison of the conditions in the Imperial Valley of California with those in the Salt River Valley of Arizona supports this view. The Imperial Valley is unique in location, being below sea level and having an average annual rainfall of probably less than 2 inches, while the Salt River Valley has an elevation of some 1,200 feet and an annual rainfall of about 8 inches. A study of the outbreaks of Eurymus in the two valleys shows them to vary inversely with the rainfall. In the dryer Imperial Valley the outbreaks are more numerous and severe and the resultant damage is greater than in the Salt River Valley with its greater rainfall and its longer period of humid weather during the hot summer months.

The worms when first attacked take on a lighter green color and become sluggish; but in a few hours they change to a brownish black and melt down into a decaying mass. A first sign of the breaking down of tissues may often be noted when the worm is still active, a slight exudation at some small broken place, usually in front; and the writer has noted specimens with the anterior end blackened and the posterior end still slightly moving, showing that life was not yet extinct. The attack upon a pupa is similar, except that the stronger pupal covering usually prevents the melting down of the specimen, and later the decayed contents of the interior dry up, leaving the empty black shell still intact.

BIRDS AND DOMESTIC FOWLS.

Few records are available showing the relation of wild birds to the alfalfa caterpillar. Several times the writer has observed birds with larvæ in their bills, but he was unable to capture these, not having the necessary firearms. Domestic fowls, however, play an important part in the history of this insect. In alfalfa adjoining farmhouses where chickens or turkeys have the run of the field one rarely finds alfalfa caterpillars in numbers, whereas fields adjoining chicken lots inclosed with wire fence, keeping the poultry out of the alfalfa, suffered severe damage. In Mr. R. N. Wilson's notes for 1912 he reports that "Mr. Carlos Stannard, living 4 miles northeast of Glendale, Ariz., killed a young rooster and found 24 Eurymus larvæ in the rooster's crop." Mr. T. Scott Wilson was informed by Mr. Everett, living near Tempe, that he and his wife had found a dozen larvæ in a chicken's crop, the chickens having access to an alfalfa field growing near the house. By the same observers, turkeys have been noted feeding greedily upon the larvæ, a flock in traveling across an alfalfa field eating hundreds of them. Mr. T. Scott Wilson, on July 21, 1913, at Chandler, Ariz., made the following note:

> I observed one dozen turkeys in a half acre of alfalfa on the lots of the United States power house feeding upon Eurymus larvæ. The alfalfa is about 12 inches high and is tender. I find only a few Eurymus feeding upon this alfalfa, while in a large field just across the fence the alfalfa is almost destroyed, except that in that portion next to the house where the tur-

keys likewise feed there are few Eurymus to be found, and consequently no damage. * * * I also observed several chickens feeding upon Eurymus larvæ.

From these observations it is seen that chickens may be utilized in small fields to keep down the numbers of alfalfa caterpillars, and that turkeys, because of their roving nature, can be used to advantage in larger fields. Mr. Charles Springer, of Cimarron, N. Mex., informs the writer that he hires a boy to herd an immense flock of turkeys on the range, so that they may feed upon the grasshoppers destroying the grama grass and other range grasses (see Pl. I, fig. 2, p. 4). It seems that the same method could be employed in outbreaks of the alfalfa caterpillar.[1] There is always a good demand for fattened turkeys, and with the cheap labor of a Mexican boy for herding the turkeys, if this additional expense is really necessary, the caterpillars could be kept within bounds at a very small cost per acre, or possibly even at a profit.

OTHER ENEMIES.

Quite a few observations have been made upon the food habits of toads. These batrachians have been found to feed upon both adults and larvæ of Eurymus, as many as 45 adults and 1 larva having been found in a single stomach on one occasion, while on another 15 Eurymus larvæ were found, besides 4 of Heliothis, 3 geometrids, 3 larvæ not classified, a cricket, and the remains of a few beetles. As toads are quite numerous throughout the alfalfa fields of the Salt River Valley, they must exert a considerable influence toward the suppression of outbreaks of the alfalfa caterpillar.

THE CONTROL OF THE ALFALFA CATERPILLAR.

PASTURING VERSUS HAYING.

It was first noted by the writer in 1910, during his early study of the subject, that fields in pasture are never troubled as much by the alfalfa caterpillar as are haying fields. Since then this has been clearly verified, not only by the writer but by others connected with the work. On July 14, 1913, Mr. R. N. Wilson makes the following note, which bears out this statement:

Many of the fields about El Centro have been cut recently and so show nothing now as to Eurymus conditions. Many are also being pastured, and in these the caterpillar attack is slight. In some fields which have not been either pastured or cut the damage is considerable.

There are several factors which explain this. At first it was thought to be owing entirely to the lack of bloom for the butter-

[1] Of course care should be exercised not to allow the turkeys in the alfalfa after it has become too high and rank, nor should too great a number be used in any one field, as in such cases the alfalfa might be badly trampled.

flies to feed upon and to the fact that the greater part of the fields was kept closely grazed, making the alfalfa less favorable for the laying and development of the eggs. Under such conditions the number of eggs deposited in a given field is greatly reduced. Many of the eggs laid on the young growth under such conditions are destroyed by the grazing of the stock, and the percentage that develops is kept at a minimum. Later on it was noted that on the stock ranches visited the disease previously mentioned, which is common to lepidopterous larvæ, was more prevalent in pastured ranches than in hay ranches. The prevalence of the disease in such fields is due to the fact that usually a few days after stock are turned in the alfalfa becomes trampled. The ground and the alfalfa are very moist, there being more or less dew every morning, and droppings from the cattle bring about a foul condition in the field, thus assisting in the retention of moisture, which, in turn, is conducive to the development of the disease.

If fields can be systematically and carefully pastured, damage from the caterpillar will accordingly be at a minimum. Cattle should never be allowed on a field when wet nor for too long a period, say from 24 to 35 days, and disking or renovating should always follow so as to loosen the soil and place it in a receptive condition for future irrigation.

It is on ranches and fields from which successive crops of hay are taken that the height of the damage is reached. In such fields the conditions for the development of the species are as nearly ideal as possible, and here the worms are ordinarily unmolested in their feeding and growth. The period elapsing from the time that one crop is cut until another is ready for harvesting so nearly coincides with the length of the period necessary for the development of any one generation of the butterfly that the cutting of the hay, as ordinarily carried on, does not reduce their numbers or disturb their work, since the worm will likely be in the advanced stage, or, perhaps, have passed into the pupal stage, before the crop is cut.

CONDITIONS AFFECTING INJURY.

As has been pointed out, this insect is ordinarily kept in control by its natural enemies, such as insect parasites and diseases, and it is only upon the occurrence of conditions unfavorable to the development of these enemies that serious outbreaks occur. It has also been noted time and again, both by the writer and others, that the seriousness of the damage quite often depends upon the farming methods used by the individual whose fields are attacked, or upon certain other conditions, such as character of soil, quantity of water for irrigation, location of land, etc. The former are conditions that the individual may remedy by changing his methods, while the latter may be practically alleviated by proper handling of the farm in question.

The damage in some alfalfa fields is quite often apparently correlated with the condition of the soil. A field seriously damaged often reveals a poor soil—at least a soil not well adapted to alfalfa culture, and consequently producing a slow-growing crop. Of course not all of the fields damaged were of poor soil; some of the very best alfalfa fields were seriously ravaged, but in these cases this was often attributable to other factors. Sandy loams or light soils are the best for alfalfa production, and consequently are the least damaged, owing to the fact that the alfalfa, growing more rapidly, is often able to recover from insect attacks and be ready for harvest before any noticeable damage has been done. A heavy soil can be improved and the growth of the alfalfa increased by deep plowing and thorough preparation of the seed bed at time of seeding the crop and then by renovating the alfalfa several times a year, either by disking or by the use of an alfalfa renovator. By such a procedure in irrigated regions the soil will more readily take water, and thus plant growth will be stimulated.

A farmer who attempts to use up-to-date and proper cultural methods is unfortunate indeed when his alfalfa fields, for which he is caring properly, are just across the fence from fields that are run down, and hence are breeders of insects. No matter how careful his efforts, some damage may be done owing to reinfestation of his fields from the butterflies supplied by his neighbor's field. Nevertheless enough may be accomplished through his own efforts to pay many times.

Again, the amount of water applied is often insufficient, sometimes because of neglect on the part of the rancher, and sometimes because of scarcity of supply. The former case is under the rancher's control; he should use care in applying the water and should eliminate waste. Sufficient water should be used to provide for the prompt development of the alfalfa crop, for in this way the farmer can reap his crop earlier and before the caterpillars have effected much damage.

Soon after agents of the Bureau of Entomology began observations and experiments looking toward the control of the species it was noticed that damage to alfalfa was often, although not always, associated with careless methods of farming and a lack of appreciation on the part of some ranchers of the benefits to be derived from careful, clean cultural methods. This is sometimes due to the fact that the rancher is trying to cultivate more land than it is possible for one man to farm successfully with the limited amount of labor and capital at his disposal. A great many times poor management is responsible for a failure where other methods would have meant success.

CLOSE CUTTING AND CLEAN CUTTING.

In harvesting the hay crop ranchers usually have to depend upon labor that, while often the best obtainable, is not by any means of the best class, and thus cutting is often done in a careless manner, stubble is left high and ragged, bunches of hay are left uncut at turning rows or on borders, ditch banks and fence rows are rarely or never cut, and the field presents the spectacle shown in Plate I, figure 3, page 4, and Plate II, figure 3. Thus any caterpillars that may still be present have a considerable amount of alfalfa upon which to feed and develop, and soon do so, so that the butterflies from these are ready for the next crop. Such places also afford bloom which attracts adult butterflies from other fields, and these lay eggs on the new alfalfa that soon springs up. If such neglected fields are treated as are those shown in Plate II, figures 1 and 2, there will be no food to enable any remaining caterpillars to complete their development; besides this, there will be no protection for them from an early irrigation or the rays of the hot sun, either one of which will kill them. Heat of the midday sun, accompanied by prompt irrigation immediately following such clean cutting, will nearly always kill Eurymus larvæ, especially in the warm Southwest. This is such an important item that one should not hesitate to go to the necessary expense in order to secure such a condition of cleanliness. In two cases in the Imperial Valley in 1910 it became necessary, because the hay had lodged badly, to remow a field at a cost of from 30 to 50 cents per acre, and in each case the results obtained in the following crop more than paid for the cost of the experiment.

EXPERIMENTS AND OBSERVATIONS IN CALIFORNIA.

In California, in 1910, 10 fields were selected in which good cultural conditions were to be created and in which methods were to be inaugurated that would not further the development of the caterpillars. The thing done in these fields was to put them under a system that would remedy as far as possible all or part of the defects recorded on a previous page. During that season (1910) a large part of the damage was due to the caterpillars of the third and fourth generations, the first and second not being numerous enough to assume any serious aspect. The task, then, was to keep their numbers below the point at which they could do any considerable damage. The time to start this control work was naturally with the earlier generations. The 10 fields mentioned (no two of which had had the same conditions of culture previous to that year, and which had all suffered more or less damage the year before, namely, in 1909) were given what might be termed clean culture, or careful management. Just as soon as possible after removing a crop of hay

FIG. 1.—FENCE ROW BORDERING ALFALFA FIELD, SHOWING CLEAN CUTTING, WHICH HELPS TO REDUCE THE ALFALFA CATERPILLAR AS WELL AS OTHER INSECT PESTS. (ORIGINAL.)

FIG. 2.—ALFALFA FIELD SHOWING CLOSE, CLEAN CUTTING NECESSARY FOR REDUCING A GENERATION OF ALFALFA CATERPILLARS. (ORIGINAL.)

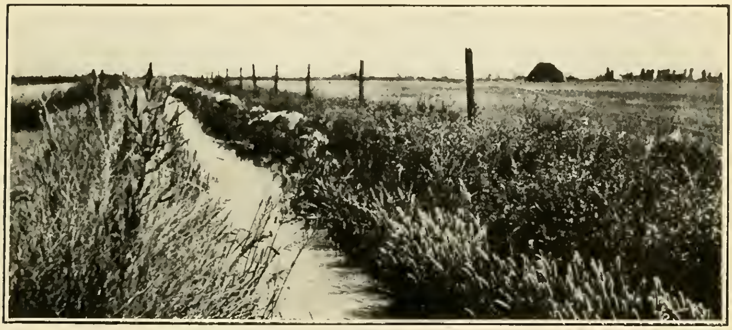

FIG. 3.—FENCE ROW AND DITCH BANK SHOWING NEGLECTED GROWTH OF ALFALFA AND GRASS, WHICH OFFERS PROTECTION AND HIBERNATING QUARTERS FOR THE ALFALFA CATERPILLAR AND OTHER INSECT PESTS.

CLEAN CULTURE AND THE ALFALFA CATERPILLAR.

the field was irrigated thoroughly, thus starting the growth quickly. The field was again irrigated as soon as the dry condition of the crop required, and thus the growth was forced and not allowed to be checked.

It requires about 28 days to produce a hay crop in the Imperial Valley—a little longer than this in the spring and fall, and a few days less in warmer weather. It also takes practically the same period of time, as has been shown on a previous page, for the butterflies to develop from egg to adult. Now, if the crop of hay be forced by frequent watering, or because of good soil conditions, the worms will not have gone into the resting stage at time of cutting, but, instead, will still be feeding on the green alfalfa, and when the hay is cut and removed conditions will be unfavorable for their development and their food supply will be reduced. The hay in these fields was cut just as it was coming into bloom, which is a few days sooner than it is generally thought advisable to cut it. The advantage of this early cutting is often very important, for if worms are present in damaging numbers they will take a whole field in a short time. In this case not only will the hay be saved, but a major portion of the larvæ, if clean cultural methods are used, will find a lack of the food necessary for their complete development, and this, associated with hot weather and irrigation following the removal of the cured hay, will cause them ultimately to perish.

Of the 10 fields handled according to these methods only 1 was damaged to any considerable extent. The other 9 were not entirely free from larvæ, but the numbers were so reduced as to preclude any chance of noticeable injury to the alfalfa. In the one exceptional field the damage was due to the fact that irrigation had been delayed for nearly two weeks after the cutting of the second crop, owing to a new ditch which was under construction. Being a thrifty field naturally, the alfalfa had made a start, assisted by the moisture still present in the ground, and butterflies coming in from an outside field deposited eggs on this new growth, thus enabling the worms to destroy the best of the crop after it was finally irrigated. As a result almost an entire crop was lost. A field adjoining on the south, which had been irrigated immediately after cutting, was not in the least damaged. This was a lesson in itself, as it indicated the necessity for prompt work.

These observations in California in 1910 have been further supplemented by observations at Tempe, Ariz., and El Centro, Cal., in 1912. This year (1912) the writer made two trips into the Imperial Valley. Several ranchers had kept records of their methods of handling alfalfa, and these records show conclusively the same results as those of 1910. Two ranchers especially were found who had practically controlled the pest in the last few years, and they have accomplished it altogether by such methods as have just been described. One of these men, Mr. Henry Stroven, whose ranch is north of Holtville, says that he has had a minimum of damage. His ranch evidences his careful and systematic cultural methods. Ditch banks and fence rows are clean, and there is scarcely a weed noticeable on the entire ranch. Mr. Stroven informed the writer that he always renovates twice a year and sometimes oftener and also aims to keep his alfalfa abundantly watered in order to get a quick, thrifty growth. The other rancher, Mr. William Mansfield, of Brawley, practices the same methods in use by Mr. Stroven, and his ranch also shows this. Neither of these ranchers aims to allow his alfalfa to stand longer than five years in a certain field. Instead, he plows it up, raises some other crop for a year, and then reseeds to alfalfa, thus bringing into play a system of crop rotation which not only keeps the soil in excellent condition, but prevents insect increase. Mr. Mansfield told the writer that in 1908 he had considerable damage when his May cutting was getting a little more than two-thirds grown. One day he noticed that damage from the caterpillar was very apparent. The next day the effect was much more noticeable. So he mowed the alfalfa, taking it up at once, and irrigating as soon as possible. He thus saved by far the greater part of the crop infested and, besides, was not troubled again that year.

The following observations, made by Mr. R. N. Wilson in July, 1913, also bear out the foregoing statements:

> One farm was examined near Meloland, Cal., to-day. This is a dairy farm belonging to Mr. Cook. In order that the hay may be in the best condition, Mr. Cook cuts it just as it comes into bloom. He in this way gets two more cuttings of hay per year than his neighbors, who allow their fields to come to full bloom before cutting. His crops have never been badly injured by Eurymus, while his neighbors have more or less injury every year. He also keeps his alfalfa in a thrifty condition, and the rapid growth is another element in Eurymus control.

These three examples show the practicability and the success of the methods proven by observation and experimentation to be means of controlling outbreaks of the alfalfa caterpillar.

EXPERIMENTS AND OBSERVATIONS IN ARIZONA.

Observations similar to those in California were made in Arizona by the author in 1912 and in 1913 by Mr. T. Scott Wilson. The same relation has been noted to exist between clean culture and good farming methods in general and damage by the alfalfa caterpillar as existed in California. But in Arizona, as the soil conditions are somewhat different from those in California, it is necessary for the application of water to be even more timely. In many parts of the

Salt River Valley there is a layer of subsurface water. This is lacking in the Imperial Valley. Thus when a crop has been removed in the former place alfalfa soon sprouts, and eggs are laid sooner and have made some headway when irrigation has finally been accomplished. While there is a limit to the promptness with which a crop can be removed from the ground after being cut, and consequently a limit to the promptness with which the ground can be irrigated, yet these measures should always be carried out just as soon as possible, thus avoiding damage by reason of the difference noted.

In 1912 Mr. Peter Aepli, living a mile south of Tempe, began cultural methods especially meant to control outbreaks of the alfalfa caterpillar. It is to be noted that even previous to this time Mr. Aepli had carried on a system of crop culture that would secure the maximum returns from his land; so that about the only change in his methods was an addition of factors that take into consideration the status of the alfalfa caterpillar at the time of each cutting; that is to say, he cuts at a time that will do the most harm to any larvæ that may be present and before any damage is done to the alfalfa. August 1, 1912, it was found that a considerable number of caterpillars were present in Mr. Aepli's field and that he would have to cut earlier than he had intended in order to save it from serious damage. On August 3 he cut the hay, doing a fine clean job. On August 5 he removed the hay from the ground and then followed this with disking and irrigation. The worms were all killed, the present crop saved, and no further damage was done to the alfalfa in that field that year. The effect of these careful and painstaking methods was also noted in the field the year following. From Mr. T. Scott Wilson's notes of August 4, 1913, is quoted the following:

> An 80-acre field of alfalfa across the fence from Mr. Aepli's is almost completely destroyed, while Mr. Aepli's is damaged but very little. Mr. Aepli is cutting his hay to-day. The larvæ are not full grown yet, so he is taking their food from them before they mature. He usually cuts his hay close to the ground and before it gets too ripe, hence Eurymus do not bother him much.

Another example of the effect a careful system of clean cultural methods will have upon caterpillar devastations is noted in a 640-acre ranch just south of Tempe, Ariz. Here the clean-up methods are accomplished by a combined system of haying and pasturing and are quite successful. The ranch should really be termed a cattle ranch, but after the owners' young steers that have been raised on their range in northern Arizona are fed out in the winter and spring, several crops of hay are made, stacked up in the field, and fed the next winter. The hay from such crops is cut often, not allowed to get overmatured, and as the owners employ a large force of men it is hastily stacked and then, following this, 40 to 60 head of steers are turned in for about three days, during which time they clean up every growing sprig in the field. They are then sent to another field, and so on and on, the owners in this way keeping their alfalfa ahead of the butterflies, and by the clean-up method few larvæ are allowed to develop to adults. Of course, not everyone can have stock available at just the right time, but this is another example of what clean-up methods will do.

IRRIGATION AS A FACTOR IN CONTROL.

As has been stated in a previous paragraph, moisture is conducive to the development of the disease which plays an important part in the control of this insect. A number of experiments were therefore tried by which, with the use of irrigation water, an attempt was made to supply moisture artificially so that the worms would become diseased. This was found to be quite successful. In fields where clean methods of cutting are used at haying time and this is immediately followed by irrigation, there seems little doubt that a part of the mortality of the larvæ is due to the effect of irrigation. The beating sun, of course, kills a great many, and then, as has been shown, under such a procedure the food supply is cut off and the decayed remains of larvæ are found hanging in great numbers to the alfalfa stubs about two days after such a procedure. This led the way for other experiments; accordingly, during the summer of 1913, Mr. T. Scott Wilson made a number of observations on irrigation of alfalfa at a time when the worms were beginning to appear numerously, and he found that invariably this gave the disease the necessary moisture and the worms soon died. For a rancher to take advantage of this would, of course, mean that he must have water available any time he wants it, which is not the case in all irrigated regions, as water is usually distributed in turn. However, in cases where the time for irrigation corresponds with the occurrence of an outbreak the water can be utilized and the worms killed.

VALUE OF DISKING AND RENOVATION.

It has been suggested before that an alfalfa field should be disked or renovated annually, or oftener, in order to keep the sod in good loose condition, so that it will take water readily and be aerated, and also to kill weeds. If teams are available, the best procedure would be to renovate several times, or at least twice a year. The usual method is to renovate once, and this during the winter. Now, if the alfalfa can be renovated in August, immediately after the third crop is removed, not only will the ground be placed in an excellent condition and weeds killed, but any larvæ or pupæ on the ground will be killed and future crops protected from damage. Some ranchers do this already and claim great results for it, and a few even renovate oftener. Mr. Stroven, of Holtville, Cal., renovates just as often as it is possible for him to do so, and in 1911 this was four times. Leaving the matter of insects entirely out of consideration, enough benefit is derived from renovation to pay many times for the cost of the work. If a disk harrow is used, it should not be set at an angle, as this would be likely to cause injury to the crowns, but should be run straight and forced into the ground by weights.

DIRECT METHODS OF CONTROL.

INSECTICIDES.

In dealing with insect pests affecting cereal and forage crops it has proved possible in only a few instances to control them by the use of any of the various insecticides or poisons. The reason for this lack of success lies largely in the fact that such crops are distributed over a wide area, and the expense of application of any insecticide as a control measure is necessarily high, while a lack of thoroughness is likely to arise when one tries to keep the expense of treatment down to an economical basis.

Since the alfalfa hay is fed to stock, it is not possible to use any of the arsenical poisons against the caterpillar of the alfalfa butterfly. A few experiments, however, were tried with pyrethrum, or "buhach." As this is not a poison, and since its fatal effect upon the larvæ of butterflies is produced externally through their breathing pores, there would be no danger to stock. Pyrethrum was used in one case in 1910 in full strength, and in another instance it was diluted with equal proportions of flour. An application was made by dusting this substance from a cheesecloth sack, following the primitive method of applying Paris green to potato vines, at the rate of 3 pounds of pyrethrum to the half acre, which in the case of diluted material would make 1½ pounds of pyrethrum to the half acre. This first test was made on July 8, 1910, and no results were obtained, because of the fact that just two days later practically all of the worms in the field where the test was being made were destroyed by the malady before mentioned. The same experiment was repeated, however, on September 22, and in this case the results were negative, not a caterpillar being killed. It would seem, therefore, that the application was not sufficiently heavy to kill the worms, and that to have increased the amount of pyrethrum applied might have resulted in the eradication of the pest; but as the cost of pyrethrum at the rate of 3 pounds to the acre is already nearly $2, without considering the expense of application by hand, this could not be considered from an economic point of view.

In 1913 some additional experiments were tried with the same material by Mr. T. Scott Wilson at Tempe, by using it full strength. This killed about 50 per cent of the larvæ, but the cost of application was again too high, and a large enough number of worms were not killed to justify the expense incurred.

ROLLING AND BRUSH DRAGGING.

At the time a field is being damaged by the worms the hay that remains undestroyed can be cut and then either a brush drag or a roller run over the ground, by which a great many of the larvæ will be destroyed. Some experiments tried along this line by Mr. T. Scott Wilson were quite successful. On August 15, in a 5-acre patch a brush drag was used and a great many larvæ were killed. This field was overrun by Bermuda grass, which protected many larvæ that would have been killed. A roller here would doubtless have

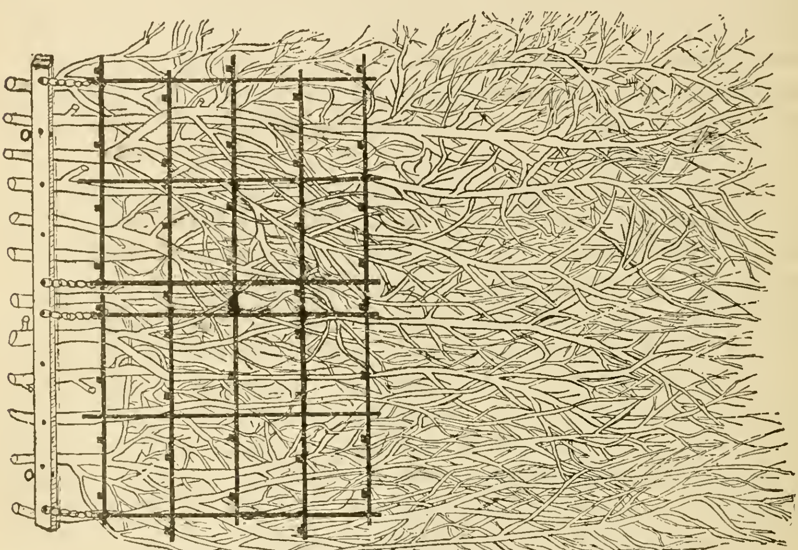

FIG. 20.—Brush drag used to crush alfalfa caterpillars in the fields. (Original.)

mashed all larvæ. On the 26th of August another test was made, using the same drag. In this case the larvæ were about full grown, and 55 per cent were killed by the operation. The latter experiment, however, was carried on in alfalfa of considerable height, and consequently the larvæ were afforded much protection and as large a percentage was not killed as would have been the case had the dragging immediately followed cutting.

A good brush drag and one that is well adapted to dragging alfalfa is shown in figure 20. The plan for constructing this, as given by Mr. E. S. G. Titus, in Bulletin No. 110 of the Utah Agricultural Experiment Station, is as follows:

The drag is made by laying the butts of rather short brush, five or six feet long, in a row on a plank twelve or fourteen feet long, then another row should be laid upon the first, consisting of longer brush, with the butts trimmed a little further back so that you will have in effect two brush harrows, one following the other. Another plank should then be laid on the brush butts and bolted to the under plank. In weighting this drag, lay an ordinary tooth harrow, with the teeth down, directly on the brush drag. This makes a very even weight, at the same time it is so flexible that the drag will work its way down into the small depressions as well as over the larger elevations of the fields.

A larva exposed to dust and hot sun soon dies. On September 4 three larvæ were placed in a dusty spot by Mr. Wilson, and within a few minutes all were dead. The next day the experiment was repeated, and all larvæ died. In all about 50 larvæ were exposed to the dust and sun, and of this number only 1 was able to crawl back to alfalfa, the rest dying before they had crawled 10 inches on the dust and dry dirt. The sun was very hot, and the temperature, 4 feet from the ground, was 97° F. These experiments show why so many larvæ die following careful methods of haying. They have no protection from the hot sun when such methods are carried on.

CONCLUSIONS REGARDING CONTROL.

Keep the ranch in the best possible cultural condition. Irrigate it often and thoroughly and as soon after cutting as the crop of hay can be removed from the ground.

Renovate every winter and during the month of August, or even oftener if possible, either by disking or by the use of an alfalfa renovator, thus disturbing any pupæ that may be present, and putting the land and alfalfa in condition for good growth of succeeding crops.

Cut the alfalfa close to the ground and clean, especially along the ditch banks, borders, and turning rows, as well as in the main part of the field.

Cut the alfalfa earlier than is the general rule. The proper time is when it is just coming in bloom or is one-tenth in bloom. Watch for caterpillars in the early spring crop, and if many are observed about grown, cut the hay a few days before it is in bloom, and thus save the next and future crops.

A minimum amount of damage occurs in fields that are systematically pastured all or a part of the time.

A field should never be abandoned because the caterpillars threaten the destruction of a crop of alfalfa before the hay can possibly mature. Mow it at once, cutting it low and clean, thus saving part of the present crop, and in so doing starve, and allow the heat of the sun to kill, a great many of this generation of worms. Follow this by disking and then by either rolling or brush dragging, and a great majority of any remaining larvæ will be killed. The ground should then be thoroughly irrigated, and by these efforts the coming crop will be assured.

Turkeys and chickens when allowed the run of a field will keep the numbers of the caterpillars at a minimum.

The protection of toads should be encouraged, as they eat many of these insects, as well as other injurious forms.

It has been noted that a carrying out of only part of these recommendations will not at all times save one's crop. The best results come to the one who is thorough in methods.

Cooperation among all farmers is necessary to suppress an insect attack completely. An occasional outbreak has been known to occur upon a farm or ranch that is under the best possible condition of crop culture, but in each case it was noted that the careless methods of a neighbor were responsible for the reinfestation.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 131

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
September 10, 1914.

REPELLENTS FOR PROTECTING ANIMALS FROM THE ATTACKS OF FLIES.[1]

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INTRODUCTION.

During the warm season of the year cattle, horses, and mules suffer a great deal of annoyance and more or less injury as the result of the attacks of various biting flies, and numerous requests are received in this department concerning methods of relieving the animals from these attacks. The flies that cause the greatest annoyance to domestic animals are the stable fly (*Stomoxys calcitrans* L.) and the horn-fly (*Lyperosia irritans* L.). The horseflies (Tabanidæ) are of some importance and individually their attacks are sanguinary, but they are not the cause of as much injury as either of the two species of muscids that have been mentioned. The bot flies (Œstridæ) affecting horses, cattle, and sheep are not biting flies and only visit these animals to deposit their eggs. The larvæ of these flies, however, are parasitic and are the cause of considerable annoyance and more or less loss, and for this reason repellents are sometimes applied to animals to prevent the adults from depositing their eggs. In the case of the horse and the ox, parasiticides are applied to the skin to destroy the eggs of bot flies that have already been deposited.

The screw worm (*Paralucilia macellaria* Fab.) likewise is not parasitic in its adult state, and visits animals only to deposit its eggs in wounds where the larvæ, when they emerge, may find nourishment and complete their growth. There are also various other species of flies that may deposit their eggs in wounds and whose larvæ become parasitic.

In the United Kingdom and Holland a bluebottle fly (*Lucilia sericata* Meig.) deposits its eggs on the soiled wool about the anus,

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[1] The investigations reported in this paper were undertaken by the Bureau of Animal Industry incidentally during the progress of other investigations concerning stock dips. Although comparatively few repellents were tested, it is believed that the data obtained concerning substances which may be applied to live stock to protect them from flies are of interest and value to the live-stock industry.

[2] Resigned, April 16, 1914.

chiefly in young sheep, sometimes in adult sheep when badly kept, and the larvæ hatching from the eggs become parasitic in the skin. In Australia several species of blowflies (*Calliphora oceanicæ* Desv., *C. villosa* Desv., and *C. rufifacies* Desv.) produce a similar condition in sheep. Recently a cutaneous invasion of sheep with dipterous larvæ occurring at Cobham, Va., was reported to this department, but the fly responsible for the trouble has not been identified. The application of repellents and parasiticides is indicated in case sheep are subject to the attacks of such flies.

The house fly (*Musca domestica* L.) commonly visits wounds on animals to suck up the exudates that occur there. It is the cause of considerable annoyance to animals in this way; it prevents wounds from healing and may introduce into a wound agents of infection adhering to its body. Repellents are therefore indicated and are frequently used on wounds to keep house flies away and also to keep away such flies as may deposit their eggs in wounds, such, for example, as the screw-worm fly.

The use of fly repellents is resorted to largely for the purpose of relieving animals of the torment of biting flies or of preventing infestation with the larvæ of flies, without any reference to the control or eradication of such pests. In the case of such flies as the stable fly and the hornfly, the use of repellents can be of only secondary importance as an eradicative measure, since a much more effective means of getting rid of these pests lies in preventing them from breeding. This may be done by preventing access of the flies to materials such as manure, etc., in which they deposit their eggs, and by destroying the young stages that may be present in such materials. However, the eradication of these flies in most instances, or even a reduction in their numbers in many cases, is out of the question, so that it is necessary to resort to the use of repellents or other means to give relief to animals.

In the case of the horseflies, preventing them from biting is probably as important a factor as can be taken advantage of in bringing about control, yet it must be admitted that this means can be of only very little importance. In the case of the bot flies and the screw-worm flies, the use of repellents against the adults and of parasiticides against the eggs and larvæ is an important method of eradication as well as a valuable means of protecting animals.

INJURY CAUSED DOMESTIC ANIMALS BY BITING FLIES.

Aside from the transmission of various animal diseases by biting flies, a matter of much less importance in this country than in the Tropics, flies are generally assumed to be responsible for enormous losses to farmers and stockmen. Because of the great numbers in which flies occur, the irritation they cause animals, the blood they abstract, the movements they cause animals to make in fighting them, and the unfavorable influence they have on the temper of dairy cows, it is believed by both scientist and layman that flies are responsible for very great financial losses.

According to Delamare (1908), a German professor named Lehmann is stated to have established that the supplementary expenditure of energy corresponding to the agitation caused horses by the attacks of flies amounts to a pound of oats a head per day. Moore (1903), of the South Dakota Agricultural Experiment Station, says: "When we consider the intimate relationship existing between the milk yield and the physical comfort of the cow, no question can be raised as to the benefit obtained by mitigating so far as possible the annoyances of these pests." Hopkins (1891) states that the hornfly so annoys cattle by its bite that the cows fail in milk and other cattle fail in flesh. Garman (1892) says: "The injury done to cattle has been greatly overestimated in some instances; yet there can be no doubt that the yield of milk from cows greatly worried by hornflies is much reduced, and growing and fattening stock are doubtless retarded by their attacks." Marlatt (1910) states: "During the first years of the hornfly, when it was a new and little understood menace to cattle, the losses occasioned by it were undoubtedly much exaggerated. Nevertheless, the loss when the fly is abundant is still very considerable, showing in reduced vitality, lack of growth, or lessened yield of milk, the production of milk often being cut down from one-fourth to one-half. In Canada the late Dr. James Fletcher estimated the loss in Ontario and Quebec at one-half the product of meat and milk." Bishopp (1913) describes an unusual outbreak of the stable fly in 1912 in northern Texas and refers to various other outbreaks that have occurred in the United States. In referring to the injury due to the fly he states that many horses and cattle became so weak that they gave up the fight against the pest. In a few cases in which the animals were not protected they succumbed in a short time. Texas fever was rekindled in an acute form in cattle that became weakened as a result of the flies, and in many cases death resulted. The influence of the flies on the milk production was marked, the reduction being from 40 to 60 per cent, and in some cases cows were completely dried up. Horses and mules lost 10 to 15 per cent in weight during the outbreak. Cattle likewise suffered a great reduction in weight. It is estimated that in northern Texas over 300 head of cattle, mules, and horses were killed directly or indirectly as the result of the fly attack. This loss is estimated at $15,000, and the loss in the milk production is placed at $10,000, and other losses are stated to surpass these.

Fuller (1913) has described an outbreak of the stable fly along the east coast of South Africa. All classes of animals are said to have suffered greatly from worry and anemia. Many cattle were killed, and horses and cattle stampeded into the sea and into rivers to obtain relief. The outbreak followed heavy rains.

The experimental evidence with regard to the losses due to flies that is available in this country does not seem to indicate that they are as a rule of such serious consequence as the foregoing statements would lead one to believe. The seriousness of such outbreaks as Bishopp and Fuller refer to can not be questioned. Carlyle (1899), at the Wisconsin Agricultural Experiment Station, conducted an experiment relative to injury due to flies in which two lots of seven cows each were used. Lot No. 1 was kept during the day in a paddock provided with shade trees, while lot No. 2 was protected from flies by being kept in a screened stable. The cattle in both lots were kept on the pasture during the night and taken off at 9 o'clock in the morning. The experiment was continued for a period of four weeks. The cattle in the lot protected from flies ate 835 pounds more green corn than those that were unprotected. All the cows lost in weight, but the protected cows lost nearly three times as much as the others. In comparing the milk and butter production of the first two weeks of the experiment with that of the two weeks just preceding the experiment it was noted that there was a decrease in both milk and butter. The milk reduction was greater for the protected animals and the butter reduction was greater for the unprotected animals. The conclusion reached was that the greater amount of butter yielded by the protected lot was not sufficient to pay for the increased trouble and expense entailed in stabling the cows during the greater part of each day.

Kent (1903), in an experiment at the Oregon Agricultural College and Experiment Station, used a proprietary repellent on four dairy cows. Four untreated cows served as controls. The treated cows gained a total weight of 265 pounds while the untreated ones gained 212 pounds. In comparing the milk and butter records of two cows from each lot that were in about the same stage of lactation with the records of the same cows during the two months just preceding the experiment it was found that the treated cows lost about 10 per cent less than the cows not treated.

Beach and Clark (1904), at Storrs Agricultural Experiment Station, Conn., tested a proprietary fly repellent which the manufacturers claimed would effect a tremendous saving during the fly season. The experiments covered a period of two seasons and the cows were sprayed thoroughly once a day. The conclusions reached by the authors are as follows: "1. The annoyance of cows by flies seems to be overestimated. 2. Certain proprietary ointments known as 'fly removers' will protect the animal to a greater or less extent, but their use has little or no effect on the milk or butterfat secretion."

Eckles (1905) carried on experiments for two seasons at the Missouri Agricultural Experiment Station with a proprietary repellent for the purpose of determining whether the use of a repellent on dairy cows would have any influence on the amount of milk and butter produced. During the first season 16 cows were used and during the second season 22 cows were used. The fly season was divided into periods of two weeks, and the herd was sprayed each morning during alternate periods. A comparison was made between the sprayed and unsprayed periods. The conclusion reached by the author was that the use of the fly repellent was fairly effective in preventing the annoyance from flies if applied every morning, but that the yield of milk and fat was not appreciably affected by its use. The only advantage observed was that the cows stood more quietly during milking. With regard to the shrinkage in milk production during hot weather, the author has the following to say: "The rapid shrinkage that occurs in the yield of a cow during the hottest summer months is a well-established fact, but is probably not so much on account of flies as to failure to graze sufficiently, if on pasture, on account of the heat."

THE INFLUENCE OF COLOR ON FLIES.

Several years ago Dr. Schroeder, of the Bureau of Animal Industry, called my attention to some pictures of Holstein cattle he had taken in connection with some tuberculosis work, in which the flies on the animals were confined almost exclusively to the black-colored spots. Beach and Clark (1904) state that some animals suffer more from hornflies than others and that dark-colored animals suffer more than light-colored ones. Marlatt (1910) states that the hornfly exhibits a certain preference for red or other dark-colored cattle, and that such animals are more thickly infested has been frequently noted. He states, however, that when the flies are abundant this preference is not so strongly marked.

Marre (1908) refers to a discovery which a farmer in the vicinity of St. Cyr made relative to the influence of color on flies. The farmer had 170 cows in a number of stables and noted that flies had a marked aversion for blue. The idea came to him to add blue to the whitewash with which he coated the walls of his buildings each year. After doing this the flies left his cattle stables.

The formula used for the wash is as follows:

Water	100 liters (105.6 quarts, or 26.4 gallons).
Lime (slaked)	5 kilos (11 pounds).
Ultramarine blue	500 grams (1.1 pounds).

Two applications, one in June and one in August, are recommended. The present writer is not aware whether this observation has been corroborated or not.

INTERNAL REMEDIES FOR REPELLING FLIES.

It would hardly seem likely that a drug could be administered to animals that would prevent flies from making their customary attacks. However, Ochmann (1911) has recommended potassium tellurate for this purpose. According to him this chemical does not affect the general health of animals. The hair, however, becomes temporarily rougher, paler, and drier. The expired air, the perspiration, and the feces take on an intensely offensive garlic odor which persists for a long time.

Two dogs received on two successive days each 0.25 gram of potassium tellurate. The results appeared on the day of the first administration and lasted three to four weeks. The olfactory sense of one dog suffered considerably. One of the dogs formerly troubled with ticks was no longer affected. The dogs were protected from flies.

An ass was given 0.25 gram of the chemical in the feed for three days. The action was negative. Another ass received on three successive days 0.25 gram. On the second day the odor appeared in the breath and disappeared one day after the last dose.

A mule received on three successive days 1.5 grams. The odor appeared on the day following the first administration and gradually disappeared in 10 days. There were no unfavorable results. Another mule was given on three successive days 0.5 gram. The odor appeared on the day following the second dose and disappeared one day after the last dose. A mule received on two successive days 2 grams. An intense odor appeared on the second day and disappeared after six days.

The author states that flies lighting on the animals were repelled.

Mayer (1911) conducted experiments for the purpose of verifying Ochmann's results, and reached quite different conclusions. Ten experiments were carried out, nine on horses and one on a cow. Each animal received in all 10 grams in single doses of from 1 to 5 grams. The best method of administering the drug was to dissolve the salt in drinking water. Subcutaneous administration leads to dry necrosis. The drug was taken unhesitatingly and caused no ill results except occasionally a staring coat in fine-haired animals. The garlic odor of methyltellurid appeared in the breath of the cow and was present for a long time. The odor appeared to a very slight degree in the breath of three of the horses, but disappeared very soon.

The author states that the administration of potassium tellurate in all cases failed to protect animals from flies.

It would therefore seem likely that this internal remedy is not efficacious. If it or any other internal remedy were found efficacious, it is doubtful whether it could be administered to dairy cows without imparting an odor to the milk. On the whole, therefore, the use of internal remedies seems to be an extremely unpromising means of repelling flies.

EXTERNAL REMEDIES FOR REPELLING FLIES.

There are almost innumerable homemade and proprietary external remedies for repelling flies. They contain various substances that are distasteful to the insects. Many of them contain strongly odoriferous ingredients that have a repelling influence on flies. The qualities to be sought in a satisfactory repellent are: Absence of toxic and other detrimental properties when applied externally to animals; a marked repellent action on flies; and a duration of this action for a reasonable length of time. A common defect of many otherwise rather good repellents is the very short period during which they are effective. Some repellents are undoubtedly toxic and must be used with care.

METHODS OF APPLYING REPELLENTS.

Repellents as a rule are in the form of liquids and may be applied by means of a dipping vat, a pail spray pump, an atomizer such as that commonly used in gardens and greenhouses for applying insecticides to plants, or by means of a rag or a paint brush. The method employed necessarily depends to a very large extent on the number of animals to be treated, the physical character and toxicity of the preparation, its cost, and the individual preference of the farmer or stockman. Some preparations, either because of their cost or their toxicity, or for some other reason, are not adapted for use in a dipping vat or for application by means of a spray pump. Others may be applied by any one of the methods mentioned.

Marlatt (1910) describes a special splash board for vats, devised by J. D. Mitchell. By means of this board the splash caused when the animal plunges into the vat is thrown back into the vat in the form of a spray and many of the flies are wetted and carried down with the dip. It is said that with vats equipped with such splash boards from 75 to 80 per cent of the hornflies are killed.

EFFICACY OF PROPRIETARY REPELLENTS.

Lindsey (1903), at the Massachusetts Agricultural Experiment Station, tried out 10 proprietary fly repellents. He found that four were quite satisfactory, four others were less satisfactory, and two were unsatisfactory. The chief defect of the second group seemed to be that they were not lasting. It is stated that these fly repellents are sold at retail from $1 to $1.50 a gallon.

POWDERS AS REMEDIES.

Smith (1889), of the New Jersey Agricultural Experiment Station, found by experiment that two powders were adapted for destroying hornflies and stable flies, namely, pyrethrum powder and tobacco powder. Pyrethrum acted promptly, but was objectionable from a practical standpoint because of its expense and because it lost its strength soon after application. Tobacco was found very much more satisfactory though the killing power was less. He recommended a proprietary powder having for its base tobacco dust and containing crude carbolic acid or creosote. The method of protecting cattle from the hornfly that he suggested was to apply carbolated fish oil to the belly, udder, and those parts of the animal where powder could not well be used, and to apply tobacco powder to the base of the horns, the back, and at the root of the tail. The effect of the oil is to repel and that of the tobacco to kill flies that attempt to feed.

OILS AS REPELLENTS.

Almost any kind of oil, whether it has a pungent or disagreeable odor or not, will repel flies to a certain extent. The mere physical condition of the hair and skin of an animal treated with oil seems to be repugnant to flies. Oils are used pure or in the form of an emulsion, or in combinations or mixtures. Crude petroleum, cottonseed oil, fish or train oil, and light coal-tar oil may be used pure.

Crude petroleum may be used in the form of an emulsion. The formula and method of preparing it so as to make 5 gallons of 80 per cent emulsion are as follows:

Hard soap	1 pound.
Soft water	1 gallon.
Beaumont crude petroleum	4 gallons.

In preparing the emulsion the soap should be shaved up and placed in a kettle or caldron containing the required amount of water. The water should be brought to a boil and stirred until the soap is entirely dissolved. Enough water should be added to make up for the loss by evaporation during the process. The soap solution and the required amount of oil are then placed in a convenient receptacle and mixed either by stirring or by means of a spray pump. If properly prepared the stock emulsion will keep indefinitely. When required for use the stock emulsion should be diluted, one part of the emulsion to three parts of water being used. The diluted emulsion does not remain uniformly mixed, so if allowed to stand it should be thoroughly mixed by stirring before using.

Jensen (1909) recommended the following mixture containing crude petroleum for dairy cows. He states that it remains on cattle for at least a week.

Common laundry soap	1 pound.
Water	4 gallons.
Crude petroleum	1 gallon.
Powdered naphthalin	4 ounces.

Cut the soap into thin shavings and dissolve in water by the aid of heat; dissolve the naphthalin in the crude oil, mix the two solutions, put them into an old dasher churn, and mix thoroughly for 15 minutes. The mixture should be applied once or twice a week with a brush. It must be stirred well before being used.

A mixture of cottonseed oil and pine tar in the proportion of two parts of the former to one part of the latter has been recommended to relieve cattle of flies.

Fish or train oil is generally rated as one of the best repellents. Its protective action is said to last from two to six days, depending on the temperature and humidity. A great many mixtures have been recommended in which fish oil occurs as an important ingredient. Moore (1903) recommended the following mixture for use on dairy cows:

Fish oil	100 parts.
Oil of tar	50 parts.
Crude carbolic acid	1 part.

The cost of the mixture was about 35 cents per gallon. The mixture was applied with a small hand spray pump. One application was effective for two days.

Bishopp (1913) gives the following formula for a mixture that is said to be very effective in keeping flies from live stock, when applied lightly:

Fish oil	1 gallon.
Oil of tar	2 ounces.
Oil of pennyroyal	2 ounces.
Kerosene	½ pint.

Parrott (1900), at the Kansas Agricultural College, found that repellents were not as effective in Kansas as they were said to be in other States. Fish oil was effective for less than two days.

The following formula is recommended by him as being as effective as fish oil, and at the same time cheaper and more lasting:

Pulverized resin	2 parts (by measure).
Soap shavings	1 part.
Water	½ part.
Fish oil	1 part.
Oil of tar	1 part.
Kerosene	1 part.
Water	3 parts.

Place the resin, soap shavings, the one-half part of water, and fish oil together in a receptacle and boil until the resin is dissolved. Then add the 3 parts of water, following with the oil of tar mixed with the kerosene. Stir the mixture well and allow it to boil for 15 minutes. When cool the mixture is ready for use and should be stirred frequently while being applied. Application should be made with a brush. One-eighth to half a pint is required for each animal. The cost of the mixture is given as 30 cents a gallon.

The present writer has not made or used the above repellent. Its formula and method of preparation seem too complex for wide use. It would appear that great caution should be exercised in boiling the mixture because of the inflammability of some of the ingredients.

The same author recommends the following formula for horses. It is said to be effective for three to four hours and even longer:

Fish oil	2 quarts.
Carbolic acid (crude)	1 pint.
Pennyroyal	1 ounce.
Oil of tar	8 ounces.
Kerosene	[1] 1½ quarts.

The cost is given at about 80 cents a gallon. The mixture must be applied with an atomizer and not with a brush.

Carlyle (1899), of the Wisconsin Experiment Station, states that fish oil to which is added a little oil of tar and a little sulphur will serve to protect cows from hornflies for four to five days if the weather is fine. He states that none of the remedies seem to be effective against the stable fly an hour after being applied.

Otis (1904) recommends a repellent worked out by the entomological department of the Kansas station. The formula is as follows:

Resin	1½ pounds.
Laundry soap	2 cakes.
Fish oil	½ pint.
Water enough to make	3 gallons.

Dissolve the resin in a solution of soap and water by heating. Add the fish oil and the rest of the water. Apply with a brush. If to be used as a spray, add one-half pint of kerosene. The cost is 7 to 8 cents a gallon.

Fish oil containing a small admixture of carbolic acid has been used with good success as a repellent.

Lindsey (1903), at the Massachusetts Agricultural Experiment Station, found light coal-tar oil quite satisfactory. This oil is described as the lighter of two oils derived from tar. It is a dark, thin oil with a strong creosote odor. It was applied as a spray.

[1] Or enough to make 1 gallon of mixture.

Kerosene mixed with cottonseed oil or in the form of an emulsion may be used for repelling flies. Spencer (1904), at the Virginia station, used an emulsion of kerosene in a special spraying apparatus for destroying the hornfly. The formula and method followed in preparing the emulsion are given below:

Yellow soap	½ pound.
Soft water	1 gallon.
Kerosene oil	2 gallons.

Shave the soap fine and dissolve in water at boiling temperature. Place the kerosene in a barrel, add the hot-soap solution, and by means of a spray pump agitate for 15 to 20 minutes, or until emulsification is complete. One gallon of water is added to prevent the solution becoming thick. This is a stock solution and should be diluted in the proportion of 1 to 5 of water. The diluted emulsion tends to separate, so only the amount needed should be diluted each time.

It is stated that at the Virginia Agricultural Experiment Station daily sprayings for a period of two weeks reduced the hornflies to a point of insignificance. The flies were killed in passing through the spray.

A milk emulsion of kerosene may be made as follows: To 1 part of milk add 2 parts of kerosene and mix by means of a force pump, or in some other way. The creamy emulsion that results is to be diluted with 8 or 10 times the bulk of water.

Mayer (1911) found that laurel oil applied to the skin of cattle and horses repelled the flies. The oil produced an inflammation of the skin in some of the tests. The oil applied to bedsores of horses repelled the flies and produced no change in the sores.

Laurel oil and linseed oil in the proportions of 1 to 10 repelled flies from a bedsore on the foreleg of a horse for five days. The entire right side of a horse was rubbed with the oil. No flies were seen on the right side and great numbers were present on the left side. The action lasted for 12 days. A light application of oil to a horse was effective for only two days. This mixture produced no inflammation of the skin.

The following mixture was also tested by Mayer: Laurel oil, 1 part; dilute alcohol, 4 parts; and olive oil, 5 parts. In place of dilute alcohol denatured alcohol with water may be used, and in place of olive oil linseed oil may be used. The mixture was tried on horses, but the results were not so good, as the mixture did not stick. The action lasted five days.

Rancid oil should not be used on account of its irritating action.

REPELLENTS FOR APPLICATION TO WOUNDS.

Jensen (1909) gives three formulas of repellents for application to wounds:

Formula No. 1:

Oil of tar	8 ounces.
Cottonseed oil to make	32 ounces.

Formula No. 2:

Powdered naphthalin	2 ounces.
Hydrous wool fat	14 ounces.

Mix into an ointment.

Formula No. 3:

Coal tar	12 ounces.
Carbon disulphid	4 ounces.

Mix; keep in a well-stoppered bottle and apply with a brush.

Mixtures Nos. 2 and 3 are said to adhere to moist surfaces, and No. 3 is said, in addition, to form a coating over raw surfaces and protect from the screw-worm fly.

The editor at the close of the article in which the above formulas are given adds the following formula:

Oil of turpentine	1 dram.
Phenol	1 dram.
Cottonseed oil to make	4 ounces.

Mix and apply freely to wounds.

It is stated that this remedy is highly effective and is used widely in the South. It is said to induce healthy granulation of wounds.

EXPERIMENTAL TESTS OF VARIOUS SUBSTANCES AND MIXTURES FOR REPELLING FLIES.

For the purpose of determining the efficacy of various substances and mixtures for repelling flies, a number of tests were made by the present author at the Bureau of Animal Industry Experiment Station during the summers of 1912 and 1913. The results of these tests are given below. In making various mixtures for the purpose of trial the plan adopted was to combine a pungent or odoriferous substance with an oil which served mainly as a vehicle.

CRUDE CARBOLIC ACID.[1]

The following tests were made with 10 per cent crude carbolic acid in cottonseed oil:

On July 22, 1912, a calf was sprayed with a mixture of 10 per cent crude carbolic acid in cottonseed oil. About 2 quarts of the mixture were applied. The calf was discovered down about 7 to 10

[1]A sample of the crude carbolic acid used in these tests was examined in the Biochemic Division of the Bureau of Animal Industry, and was found to contain 21.8 per cent phenols.

minutes later with symptoms of carbolic-acid poisoning. There was salivation, dyspnea, trembling, paralysis, inability to rise, rapid breathing, and rapid and irregular beating of the heart.

Another calf was sprayed on the same date with about 1½ quarts of the mixture. The calf showed distinct symptoms of carbolic-acid poisoning in 6 minutes. It showed a tendency to fall in 8 minutes, and fell in 14 minutes. The symptoms in the order in which they occurred were: Salivation, dyspnea, muscular tremors, loss of muscular control, and finally motor paralysis. The breathing was rapid and shallow.

It was necessary to destroy both of the animals.

July 15, 1913, applied the mixture to a calf by means of a brush. Used 2⅔ ounces of the mixture. The repellent action was very marked. July 16, about 18 hours later, the animal was worried as much by flies as were the controls. Oil was present only along the back. There was only a very faint odor of carbolic acid. The protection was practically nothing. There were no symptoms of poisoning.

The results obtained with crude carbolic acid may be summarized as follows: In the case of the first two calves treated it shows that carbolic acid in cottonseed oil is absorbed through the skin. It is well known that carbolic acid, when combined with oil, loses its caustic properties, but its toxic properties still remain, as evidenced by the above cases of poisoning. It seems certain that in the case of any such mixture, no matter how small the content of carbolic acid, a certain amount of the same must be absorbed. The amount absorbed will depend, other things being equal, on the amount of the mixture applied. In the third test that was made, the same strength (10 per cent) mixture was used, but it was applied with a brush and only to the amount of 2⅔ ounces. There were no symptoms of poisoning. It is therefore evident that a 10 per cent mixture of crude carbolic acid (21.8 per cent phenols) in cottonseed oil may be used with safety if the application is very light. It is undoubtedly true that a very much weaker mixture of carbolic acid if applied liberally would produce toxic symptoms.

The repellent action of this mixture, however, does not endure. Its action was very marked at first, but lasted less than 18 hours. It would be necessary therefore to apply this mixture every day. In order to ascertain whether daily applications of the mixture could be made without danger to the animal, a calf was treated with this mixture on October 2, 3, 4, 6, 7, 8, 9, 10, 11, and 13. The mixture was applied with a brush. There were no symptoms of poisoning or other untoward results.

PINE TAR.

TEN PER CENT PINE TAR IN COTTONSEED OIL.

July 29, 1912, sprayed a cow with 10 per cent of pine tar in cottonseed oil. Used 3½ quarts of the mixture.

July 30, the cow was looking droopy. The ears were hanging.

July 31, the hair was still oily. There was no odor of tar. The animal was bright and perfectly normal. No hornflies were observed. A few stable flies were present on the legs and body. The animal was not fighting the flies, whereas unsprayed animals were constantly switching their tails.

August 1, some oil was still present. Some stable flies were present, especially on the legs. Animal does not fight flies as much as do the untreated animals.

August 3, oil still present on the back, croup, and thighs. It is very sticky. There is little or no protective action.

TWENTY PER CENT PINE TAR IN COTTONSEED OIL.

July 15, 1913, treated a cow with 20 per cent pine tar in cottonseed oil. Used 5⅓ ounces of mixture. It was applied with a brush. The protection was marked but not quite so effective as either 10 per cent crude carbolic acid or 10 per cent oil of tar in cottonseed oil. July 16, about 18 hours later, the cow fought flies as much as did the controls. There was some oil present on the neck, back, and on the fore legs. There was no odor of tar. There was little or no protective action evident at this time.

A HALF-AND-HALF MIXTURE OF PINE TAR AND COTTONSEED OIL.

July 31, 1912, sprayed a calf with a half-and-half mixture of pine tar and cottonseed oil. Used about 2 quarts of fluid. The mixture was too thick to spray well in pump. The animal was sprayed very unevenly and some spots were not covered. Two types of nozzles were used, but a satisfactory spray was not developed.

August 1, there was plenty of oil present and also an odor of tar. Tar was visible here and there on the hair. No flies were observed.

August 3, some oil was still present. There was a slight odor of tar. A repellent action was still noticeable on the back, croup, and thighs.

July 31, a second calf was sprayed. Used about 2 quarts, which was not enough to cover the animal properly.

August 1, there was plenty of oil present, and there was a strong odor of tar. No flies were observed.

August 3, the oil and tar odor still present. A distinct repellent action on stable flies was still noticeable.

FIFTY PER CENT PINE TAR IN BEAUMONT OIL.

August 19, a cow was treated with 50 per cent pine tar in Beaumont oil. The mixture was applied with a brush.

August 20, the mixture had been rubbed off the sides and abdomen. The odor of tar was still present. The hair was rather untidy. Flies were present only on underside of abdomen.

August 21, the cow was stiff. The mixture was still present on the back. There was no repellent action.

SUMMARY OF RESULTS WITH PINE TAR.

It is noted from the first test made that a liberal application of 10 per cent pine tar in cottonseed oil caused the animal to look droopy. It is probable that this was due to a toxic action of the tar. The odor of the tar had disappeared on the second day following the treatment. The repellent action lasted for three days. Some oil was present five days after the treatment.

In the test in which 20 per cent of pine tar was used, the mixture was applied with a brush and only 5⅓ ounces were used. The repellent action was marked, but not so great as in the case of 10 per cent crude carbolic acid or 10 per cent oil of tar. The repellent action lasted less than 18 hours. The odor of tar had disappeared at that time.

In the third test in which a half-and-half mixture of pine tar and cottonseed oil was used, the mixture was applied liberally by means of a spray pump. The repellent action lasted more than three days in the case of both animals treated. The mixture is too thick to be used in a spray pump.

In the last test, in which a half-and-half mixture of pine tar and Beaumont oil was used, the repellent action lasted less than two days. This mixture had a detrimental effect in that it caused the animal to become stiff.

There seems to be no danger to animals in applying tar in cottonseed oil for the purpose of repelling flies. In the first test there were slight symptoms of poisoning, but the amount of 10 per cent mixture applied (3½ quarts) was much more than would ever be applied to an animal to protect it from flies.

It is evident from the second test that when a pine-tar-cottonseed-oil mixture of moderate strength is applied in quantities such as it is economical to use, the applications will have to be made every day in order to provide protection.

OIL OF TAR.[1]

TEN PER CENT OIL OF TAR IN COTTONSEED OIL.

July 22, 1912, sprayed a calf with 10 per cent oil of tar in cottonseed oil. Used about 2 quarts of the mixture.

July 23, the oil was still evident. No hornflies were observed. Stable flies were seen to light on the hair but left immediately. Some stable flies were seen on the legs of the animals.

July 25, the odor of the oil of tar had entirely disappeared. The hair was still oily but flies were seen to light on the oily spots.

July 29, there was no oil present.

July 15, 1913, applied 3⅜ ounces of the mixture to a calf by means of a brush. The repellent action was very marked.

July 16, about 18 hours later, the calf did not fight the flies quite so much as did the controls. There was no odor of tar. There was a very slight evidence of oil on the sides and back but no repellent action could be observed.

HALF-AND-HALF MIXTURE OF OIL OF TAR AND COTTONSEED OIL.

August 22, 1912, sprayed a calf with a half-and-half mixture of oil of tar and cottonseed oil. Used about 2 quarts of the mixture. The animal almost immediately began to show signs of sickness. The eyes were half closed. The skin about the eyes, on the face, and at the corners of the mouth was wrinkled. There was slight salivation. These symptoms were followed by a slight swaying in the hind quarters when the animal walked. Finally the gait became staggering and the animal fell from time to time and arose again only with the greatest difficulty.

August 26, when the next observation was made, the animal had entirely recovered. There was no repellent action noticeable.

TEN PER CENT OIL OF TAR IN BEAUMONT OIL.

July 22, 1912, sprayed a calf with 10 per cent oil of tar in Beaumont oil. Used about 2 quarts of the mixture.

July 23, oil was present on the hair. There were a very few stable flies on the legs. No hornflies were observed.

July 25, more oil was present on the hair than in the case of a calf sprayed on the same date with a mixture in which cottonseed oil served as the base.

July 29, oil was present on the back and rump. No hornflies were observed.

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[1] A sample of the oil of tar used in these experiments was examined in the Biochemic Division of the Bureau of Animal Industry and was found to contain phenols, volatile with steam, 14 per cent.

August 7, 1913, a calf was treated with 10 per cent oil of tar in Beaumont oil. The mixture was applied with a brush. The repellent action was marked.

August 8, no odor of tar was noticeable. The oil was rubbed off the abdomen, the sides, and outside of the thighs. Some stable flies were present on the legs. Only a very few hornflies were present.

FIFTY PER CENT OIL OF TAR IN BEAUMONT OIL.

August 19, 1913, a cow was treated with a mixture of 50 per cent oil of tar in Beaumont oil. The mixture was applied with a brush. There was a slight salivation, and the cow remained rather quiet following the treatment. It seems certain that there were symptoms of phenol poisoning.

August 20, the odor of the oil of tar was still present. Only a few stable flies were present on the legs. Other animals in the same pen were covered with flies. The mixture had disappeared from the sides and abdomen.

August 21, the cow was a little stiff. Oil was still present on the back. The cow was protected very little from the flies.

SUMMARY OF RESULTS WITH OIL OF TAR.

In the first test with 10 per cent oil of tar in cottonseed oil the mixture was applied with a spray pump. About 2 quarts of the liquid were applied. The repellent action lasted less than three days.

In the second test the mixture was applied by means of a brush, and 3⅜ ounces were used. The repellent action, which was very marked at first, had nearly disappeared at the end of 18 hours.

In the third test a half-and-half mixture of oil of tar and cottonseed oil was applied with a spray pump. About two quarts of the mixture were used. There were symptoms of poisoning. The next observation was made four days later, at which time there was no repellent action.

In the fourth test 10 per cent oil of tar in Beaumont oil was applied with a spray pump. About 2 quarts of the mixture were used. There were no symptoms of poisoning.

In the fifth test 10 per cent oil of tar in Beaumont oil was applied with a brush. On the following day the odor of tar had entirely disappeared and the repellent action had almost entirely ceased.

In the last test 50 per cent oil of tar in Beaumont oil was applied with a brush. The protection lasted about two days. There were mild symptoms of poisoning and the animal became slightly stiff.

The repellent action of 10 and 50 per cent of oil of tar in cottonseed oil or in Beaumont oil is very marked, but when applied in such quantities as it is economical to use the action lasts less than a day when cottonseed oil is used, and about two days when Beaumont oil is used. As shown by the third test, 50 per cent oil of tar is dangerous when applied in large quantities.

The last test shows that 50 per cent oil of tar in Beaumont oil when applied in small quantities with a brush is also dangerous. The increase of the content of oil of tar from 10 to 50 per cent does not seem to increase the duration of the repellent action materially, as indicated by tests 1 and 3, but the 50 per cent Beaumont oil mixture protected twice as long as the 10 per cent mixture.

For the purpose of determining whether daily applications of 10 per cent oil of tar in cottonseed oil would produce poisoning or other untoward results, a calf was treated with the mixture on October 2, 3, 4, 6, 7, 8, 9, 10, 11, 13, and 14. The mixture was applied with a paint brush. No symptoms of poisoning resulted, and the skin remained unaffected.

THE MOORE FORMULA.

October 4, 1912, a calf was sprayed with the following mixture:

Fish oil	100 parts.
Oil of tar	50 parts.
Crude carbolic acid	1 part.

About three quarts of the mixture were used. The animal appeared sick after being sprayed. It was restless and there was salivation.

October 7, the animal was very oily. There was present an odor of tar and fish oil. Flies were still repelled.

July 16, 1913, a bull calf was treated with the above mixture, which was applied with a brush, and 6 ounces were used. The repellent action was marked. There were no symptoms of poisoning.

It is noted from the first of the above tests that the application of the Moore mixture in large quantities is dangerous. Such a liberal application, however, would never be made in practice. The repellent action was still evident on the third day. In the second test a small quantity of the mixture was applied to a calf by means of a brush and no symptoms of poisoning resulted.

TEN PER CENT OIL OF CITRONELLA IN COTTONSEED OIL.

June 19, 1913, a calf was treated with 10 per cent oil of citronella in cottonseed oil, applied with an atomizer. A few hours later all protection had ceased.

July 2, 1913, the above calf was again sprayed. An hour or so later a repellent action was still noticeable. The calf was not troubled much with flies as compared with the untreated animals.

July 3, 1913, a cow was sprayed. Used 1½ ounces. There was a very marked repellent action, but an hour or so later this had become greatly reduced. There was a very slight odor of citronella at that time.

July 10, 1913, applied the mixture to a cow by means of a brush. Used about 6 ounces of oil. July 11, about 22 hours after application, oil was present on the neck and along the back. There was no odor of citronella. There was little or no protection as indicated by the presence of many hornflies on the underside of the abdomen, and the presence of many stable flies on the legs.

It is noted from the above tests that the mixture used is a powerful repellent, but that its effect does not last more than a few hours.

TEN PER CENT OIL OF SASSAFRAS IN COTTONSEED OIL.

June 19, 1913, a mixture of 10 per cent oil of sassafras in cottonseed oil was applied to a calf by means of an atomizer. There was a pronounced repellent action which, however, had disappeared at the end of a few hours.

July 2, 1913, the same calf was again treated. An hour or so later a repellent action was still present. The calf was troubled very little with flies as compared with the other animals. July 3, there was no odor or protective action noticeable.

July 3, 1913, treated a cow with the mixture. Used about 3 ounces. The repellent action was marked. An hour or so later the repellent action was greatly reduced and there was no odor of sassafras.

July 10, 1913, applied the mixture with a brush to the above cow. Used about 5½ ounces. July 11, about 22 hours later, a little oil was present on the neck, withers, and just behind the withers. Many hornflies were present on the front legs and on the underside of the abdomen.

The above tests show that the mixture has a marked repellent action, but that this only lasts for a few hours.

TEN PER CENT OIL OF CAMPHOR IN COTTONSEED OIL.

June 19, 1913, a mixture of 10 per cent oil of camphor in cottonseed oil was applied to a calf by means of an atomizer. A few hours afterward some protective action was still noticeable.

July 2, 1913, the same calf was again treated. An hour or so later the calf was still protected from flies.

July 3, 1913, no protection was noticeable in the case of the above calf. A cow was sprayed with the mixture. Used 2½ ounces. There was a marked protective action. An hour or so later the protective action was greatly reduced. There was no odor of camphor.

July 10, 1913, applied the mixture to the above cow with a brush. Used 5 ounces. July 11, about 22 hours after application, a little oil was present on the neck and along the back. There was no odor of camphor. Some hornflies were present and many stable flies were on the legs.

The immediate protection rendered by the above mixture is marked, but its action lasts only for a few hours.

HALF-AND-HALF MIXTURE OF KEROSENE AND COTTONSEED OIL.

August 7, 1913, a cow was treated with a half-and-half mixture of cottonseed oil and kerosene. The mixture was applied with a brush. The flies were repelled.

August 8, the oil was rubbed off the sides, abdomen, and the outside of the thighs. Very few flies were present.

KEROSENE EMULSION.

August 21, 1913, treated a cow with kerosene emulsion made according to the formula on page 11, diluted 1 to 8. The emulsion had only a very slight repellent action.

BEAUMONT OIL.

August 7, 1913, a calf was treated with Beaumont oil. The oil was applied with a brush. The repellent action was marked. August 8, the oil had been rubbed off the abdomen, the sides, and the outside of the thighs. Stable flies were present on the legs. There was plenty of oil present on the neck, shoulders, and back. There were no hornflies on the animal, although they had been numerous the day before.

FISH OIL.

July 22, 1912, a calf was sprayed with fish oil. About 2 quarts of the oil were used. July 23, the oil was present on the hair. Flies frequently lit on the animal but left almost immediately. A few stable flies were noted on the legs. No hornflies were observed.

July 25, considerable oil was still present. Some flies were seen to light on and crawl over the greasy hair. There was a very slight fishy odor.

July 29, oil was present on the back and rump. No hornflies were observed. Stable flies were observed on the legs.

August 6, rear portion of body very sticky and dirty. There was a loss of hair in spots on the back and sides.

July 15, 1913, applied fish oil with a brush. The protection was very marked. July 16, about 20 hours later, there was an abundance of oil present on the upper half of body, and a repellent action was noticeable in this region. There was still a very slight amount of oil on the legs, but it was not sufficient to keep the flies off.

In the first test with fish oil the oil was applied by means of a spray pump. Two liters were used. The repellent action lasted between one and three days. The liberal application of the oil caused the hair to become sticky and dirty in places. There was also a loss of hair. These unfavorable results were not noted in the second test, in which a light application of oil was made with a brush.

LAUREL OIL.

June 19, 1913, a calf was rubbed with laurel oil. The protection was very marked.

July 2, 1913, the oil was applied to a calf with a paint brush. There was a very marked repellent influence on both the hornflies and the stable flies. An hour or so later the repellent action was only very slightly reduced.

July 3, 1913, the same calf was treated. Used about 2 ounces. The mixture was applied with a paint brush. The repellent action was marked.

July 10, 1913, applied the oil with a brush to all parts of the body except the head. Used 5 ounces. July 11, about 22 hours later, there was an abundance of oil present on body and neck. There were no flies on the body and neck. Some stable flies were present on the legs.

July 15, 1913, a severe exfoliation was noted on the shoulders and neck. There was a slight exfoliation on the head. A similar exfoliation was noted on the withers shortly after the first treatment on June 19.

August 19, 1913, a calf was treated all over with laurel oil. Application was made by means of a brush.

August 20, there was an abundance of oil present. It was rubbed off the abdomen. The repellent action was marked, but the odor of the oil was not as strong as at first.

August 21, some oil was present on the back and sides. There was a repellent action still evident.

August 7, 1913, a cow was treated with 10 per cent laurel oil in cottonseed oil. The mixture was applied with a brush. The repellent action was marked.

August 8, oil was present on the neck, shoulders, and back. It was rubbed off the sides and abdomen. There was no odor of laurel oil. Stable flies were present on the legs. Hornflies were present on the abdomen where the oil had been rubbed off.

Laurel oil has a very marked repellent action on both hornflies and stable flies. No observations were made to determine the limit of the duration of the repellent action, but it undoubtedly as a rule continues for several days. On account of the fact that the oil has a tendency to produce an exfoliation of the skin it should be applied very lightly to the hair. As indicated by the last test, in a 10 per cent mixture of laurel oil and cottonseed oil the laurel oil disappears by evaporation in less than 24 hours.

PYRETHRUM POWDER.

July 25, 1912, a cow was dusted with pyrethrum powder along the neck and back. Used about 2½ ounces of powder. Flies were observed to light frequently on the treated portions of the body and remain for a time.

July 26, an attendant reported that there was plenty of powder still present and that it seemed to repel the flies.

August 9, 1913, pyrethrum powder was applied to the skin of a cow. The repellent action was very marked. August 10, only a very slight protective action was noted.

Pyrethrum powder when applied to the skin of cattle has a very marked repellent action, but this lasts only for about a day.

SUMMARY OF EXPERIMENTAL TESTS.

The experimental tests are summarized in the following table:

Summary of experimental tests.

Substance used.	Duration of odor.	Duration of repellent action.	Duration of presence of substance.	Method of application.	Effect on animals.
	Days.	*Days.*	*Days.*		
10 per cent crude carbolic acid in cottonseed oil.				Spray pump.	Phenol poisoning.
Do				do	Do.
Do	1+	1−	1+	Brush	None.
10 per cent pine tar in cottonseed oil	2−	3+	5−	Spray pump.	Caused depression.
20 per cent pine tar in cottonseed oil	1−	1−	1+	Brush	None.
50 per cent pine tar in cottonseed oil	3+	3+	3+	Spray pump.	Do.
Do	3+	3+	3+	do	Do.
50 per cent pine tar in Beaumont oil	2−	2−	2+	Brush	Caused stiffness.
10 per cent oil of tar in cottonseed oil	3−	3−	3+	Spray pump.	None.
Do	1−	1+	1+	Brush	Do.
50 per cent oil of tar in cottonseed oil		4−		Spray pump.	Phenol poisoning.
10 per cent oil of tar in Beaumont oil			7+	do	None.
Do	1−	1+	1+	Brush	Do.
50 per cent oil of tar in Beaumont oil	1+	2	2+	do	Slight symptoms of poisoning. On second day animal was stiff.
The Moore formula	3+	3+	3+	Sprayed	Phenol poisoning.
Do				Brush	None.
10 per cent oil of citronella in cottonseed oil.		1−		Atomizer	Do.
Do	1−	1−	1+	Brush	Do.
10 per cent oil of sassafras in cottonseed oil.		1−		Atomizer	Do.
Do	1−	1−		do	Do.
Do		1−	1+	Brush	Do.
10 per cent oil of camphor in cottonseed oil.		1−			Do.
Do	1−			Atomizer	Do.
Do	1−	1−	1+	Brush	Do.
50 per cent kerosene in cottonseed oil		1+		do	Do.
Beaumont oil	1+	1+	1+	do	Do.
Fish oil	3+	3−	7+	Spray pump.	Slight loss of hair.
Do				Brush	None.
Laurel oil	1+	1+	1+	do	Severe exfoliation.
Do	2+	2+	2+	do	None.
10 per cent laurel oil in cottonseed oil	1−	1+	1+	do	Do.
Pyrethrum powder		1+	1+		Do.
Do		1+	1+		Do.

GENERAL SUMMARY.

The biting flies that annoy domestic animals most in this country are the stable fly, *Stomoxys calcitrans*, and the hornfly, *Lyperosia irritans*. The bot flies are not biting flies, but are a menace to domestic animals because of the parasitic habits of their larvæ. This is also the case with the screw-worm fly, *Paralucilia macellaria*, which deposits its eggs in wounds, and a bluebottle fly, *Lucilia sericata*, occurring in the United Kingdom and Holland, and certain species of Calliphora occurring in Australia, the larvæ of which invade the wool and skin of sheep.

Repellents are more or less effective against all of these flies.

Opinions differ with regard to the injury by biting flies. The common opinion seems to be that these flies are responsible for great losses. However, a limited amount of experimental evidence relating to cattle seems to indicate that the losses, when they occur, are not great.

The repellent action of certain colors has been noted by various investigators. Light-colored animals suffer less from flies than dark-colored ones. One author (Marre, 1908) has recorded the observation of a farmer in France who found that a blue color applied to the inside of stables repelled flies. This observation seems to have remained uncorroborated.

Potassium tellurate has been recommended by Ochmann (1911) as an internal remedy for repelling flies. However, Mayer (1911) failed to obtain results with the remedy, and it seems safe to assume that internal remedies will never prove practicable in repelling flies.

Liquid repellents may be applied by means of a dipping vat, a pail spray pump, an atomizer, or by means of a rag or a paint brush. The method to be employed depends on the individual preference of the farmer and the nature and cost of the preparation used.

The powder remedies that have been used are pyrethrum powder and tobacco powder.

Various oils, emulsions of oils, and mixtures of oils are used in repelling flies. Crude petroleum, cottonseed oil, fish or train oil, and light coal-tar oil may be used pure. Jensen (1909) recommends for dairy cows an emulsion of crude petroleum containing an admixture of powdered naphthalin.

Fish oil is rated as one of the best repellents and has been used alone and in combination with various other substances. Other substances that have repellent qualities and that have been used in various mixtures are pine tar, oil of tar, crude carbolic acid, oil of pennyroyal, and kerosene.

Jensen's formula is said to protect cows for a week. The protective action of fish oil is stated to range from less than two days

(Parrott, 1900) to six days. Moore's formula is said to protect for two days. This mixture is safe when applied lightly with a brush, but not when applied liberally with a pail spray pump.

Laurel oil is a very effective repellent. Mayer (1911) found that the protection lasted from 2 to 12 days. The oil when used pure has an irritating effect unless it is applied lightly. According to Mayer the irritating effect may be overcome by combining it with linseed oil in the proportion of 1 to 10. The present author found that 10 per cent of laurel oil in cottonseed oil was active for less than a day.

A number of formulas for repellents for application to wounds have been recommended by various authors.

In experimental tests carried out by the present author the following results were obtained:

A 10 per cent mixture of crude carbolic acid (21.8 per cent phenols) in cottonseed oil has a very strong repellent action on flies, but this lasts less than a day, in consequence of which it is necessary to apply the mixture every day. The mixture should be applied lightly with a brush, since a heavy application with a spray pump is likely to cause phenol poisoning.

Mixtures consisting of 10, 20, and 50 per cent of pine tar in cottonseed oil have marked repellent qualities. They should be applied lightly and it is necessary to apply them every day. A liberal application of a 10 per cent mixture is deleterious to animals. This is also the case with a half-and-half mixture of pine tar and Beaumont oil when applied lightly with a brush.

A mixture of oil of tar (14 per cent phenols, volatile with steam) in cottonseed oil and in Beaumont oil has a very marked repellent action. A 10 per cent mixture of oil of tar in cottonseed oil is safe. A half-and-half mixture of oil of tar and cottonseed oil when applied liberally with a spray pump and 50 per cent oil of tar in Beaumont oil applied with a brush are not safe. Ten per cent oil of tar in Beaumont oil is safe. When applied lightly it is necessary to apply 10 per cent oil of tar in cottonseed oil or 10 per cent oil of tar in Beaumont oil every day.

Mixtures of 10 per cent of oil of citronella, oil of sassafras, or oil of camphor in cottonseed oil are powerful repellents, but they are active for less than a day.

A heavy application of fish oil causes the hair to become sticky and fall out. A light application did not produce these results.

Pyrethrum powder is an effective repellent, but its action lasts only for about a day.

LITERATURE CITED.

BEACH, C. L., and CLARK, A. B.

1904. Protecting cows from flies. Bul. 32, Storrs Agric. Exper. Station, Storrs, Conn., Dec., 14 p., fig. 15.

BISHOPP, F. C.

1913. The stable fly. Farmers' Bul. 540, U. S. Dept. Agric., Washington, July 14, 28 p., figs. 10.

CARLYLE, W. L.

1899. Protecting cows from flies. *In* 16th Ann. Rep. Agric. Exper. Station Univ. Wisconsin, Madison, p. 92–96.

1904. Protecting cows from flies. [Summary of 1899, pp. 92–96.] *In* 20th Ann. Rep. Agric. Exper. Station, Univ. Wisconsin, Madison, p. 105.

DELAMARE, M.

1908. Destruction des mouches et des moustiques par le formol. *In* Archives de méd. et de pharm. mil., v. 51, no. 4, April, p. 297–301.

ECKLES, C. H.

1905. Test of a fly repellent. *In* Bul. 68, Missouri Agric. Exper. Station, Columbia, July, p. 35–39.

FULLER, CLAUDE.

1913. Fly plagues. An unusual outbreak of *Stomoxys calcitrans* following floods. *In* Agric. Jour. Union South Africa, Pretoria, v. 5 (6), June, p. 922–924.

GARMAN, H.

1892. Some common pests of the farm and garden. Bul. 40, Kentucky Agric. Exper. Station, Lexington, Mar., 51 p., figs. 28, pls. 2.

HOPKINS, A. D.

1891. Department of entomology. *In* 3d Ann. Rep. West Virginia Agric. Exper. Station, Charleston, p. 145–180, pls. 12–13. The horn fly, p. 159.

JENSEN, H.

1909. [Fly repellents.] *In* Missouri Valley Vet. Bul., Topeka, Kans., v. 4 (5), Aug., p. 30; note by editor, p. 30–31.

KENT, F. L.

1903. Department of dairying. [Report dated June 30.] *In* 15th Ann. Rep. Oregon Agric. College and Exper. Station, [Corvallis], p. 29–33.

LINDSEY, J. B.

1903. Dairying and feeding experiments. *In* 15th Ann. Rep. Hatch Exper. Station, Massachusetts Agric. College, Boston, Jan., p. 57–68.

MARLATT, C. L.

1910. The horn fly (*Hæmatobia serrata* Rob.-Desv.). Circular 115, Bureau Entom., U. S. Dept. Agric., Washington, Apr. 15, 13 p., figs. 6. [MS. dated Nov. 17, 1909.]

MARRE, FRANCIS.

1908. Les mouches n'aiment pas la couleur bleue. *In* Jour. d'agric. prat., Paris, an. 72, n. s., t. 16, sem. 2, no. 33, 13 août, p. 215–216.

MAYER, A.

1911. Ueber die Wirkung des tellursauren Kaliums als Fliegenmittel. *In* Monatsh. f. prakt. Tierh., Stuttgart, v. 23 (2–3), 25. Nov., p. 49–50.

MOORE, E. L.

1903. Flies. *In* Bul. 81, South Dakota Agric. Exper. Station, Aberdeen, June, p. 41–42.

OCHMANN.

1911. Kalium telluricum. *In* Ztschr. f. Veterinärk., Berlin, v. 23 (4), Apr., p. 193–195.

OTIS, D. H.

1904. Experiments with dairy cows. Bul. 125, Kansas Agric. Exper. Station, Manhattan, May [issued September, 1904], p. 59–161, pls. 1–39 [i. e., figs. 1–39].

1905. Experiments with hand-fed calves. Bul. 126, Kansas Agric. Exper. Station, Manhattan (May, 1904), Mar., p. 163–198, figs. 1–14.

PARROTT, P. J.

1900. Horsefly remedies. [Letter to editor.] *In* Wallaces' Farmer, Des Moines, Iowa, v. 25 (15), Apr. 13, p. 415.

SMITH, J. B.

[1889a] The horn fly (*Hæmatobia serrata*). Bul. 62, N. Jersey Agric. Exper. Station, New Brunswick, Nov. 6, 40 p., figs. 11.

SPENCER, JOHN.

1904a. The horn fly (*Hæmatobia serrata*). *In* Bul. 153, Virginia Agric. Exper. Station, Blacksburg, v. 13 (4), Dec., p. 71–77, 5 figs.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 134

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
October 7, 1914.

(PROFESSIONAL PAPER.)

CITRUS FRUIT INSECTS IN MEDITERRANEAN COUNTRIES.[1]

By H. J. Quayle.

THE MEDITERRANEAN FRUIT-FLY.[2]

Ceratitis capitata Wied.

OCCURRENCE.

In the Mediterranean countries the Mediterranean fruit-fly (*Ceratitis capitata* Wied.) was first recorded from Spain in 1842, from Algeria in 1859, from southern Italy in 1870, from Sicily in 1882, from Tunis in 1885, from Malta in 1893, from Egypt in 1904, and from France in 1900.[3] This chronology, however, does not necessarily represent the spread of the insect, for it may have occurred in some of the countries long before any published record appears. In addition to the countries enumerated it is also said to occur in Asiatic Turkey. In the Mediterranean vicinity it is recorded from the Azores, Madeira, and Cape Verde Islands. The writer has taken this insect at Valencia

[1] This paper is of immediate value on account of the important information it contains bearing on the subject of the need of regulating the entry of citrus and other fruits imported from Mediterranean countries to prevent the entry of the Mediterranean fruit fly into the United States. The investigations embodied in this paper were made by Prof. Quayle during the summer of 1913 as a collaborator of the Federal Horticultural Board of this Department. Prof. Quayle is an expert on citrus insects and has previously made important studies in this field in California in connection with the State experiment station. Advantage was taken of the fact that he was proposing to use his sabbatical year to make a world-wide survey of citrus insects to commission him to make a much-needed preliminary survey of the citrus and other fruit insects in Mediterranean countries, more particularly in relation to the export fruit to the United States.

The fruit-fly conditions of the principal Mediterranean citrus districts was the important subject; the report, however, includes data on other fruit insects which ought to be considered in relation to any proposed regulation of the entry of fruits from countries covered.

As having an important bearing also on the possibility of the entrance of the fruit fly with Mediterranean fruit, the investigation includes a report on harvesting and marketing conditions of citrus fruit, more particularly as to methods of picking, sorting, curing, and shipping.

This paper indicates very clearly that there is little danger of fruit-fly introduction from the lemon, which is the main citrus importation from Mediterranean countries. That there is some danger from oranges and certain other fruits at particularly favorable seasons of the year has also been clearly brought out.—C. L. Marlatt, *Chairman Federal Horticultural Board.*

[2] Italian, *Mosca della arance;* Spanish, *Mosca.*

[3] For these and other facts, including a full bibliography of *Ceratitis capitata*, see Quaintance, A. L., U. S. Dept. Agr., Bur. Ent., Circ. no. 160, 25 p., 1 fig., Oct. 5, 1912.

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and Barcelona, Spain (also punctured oranges in the London markets from Murcia, Spain), at Marseille, France, throughout southern Italy and Sicily, and punctured oranges in the markets of Jerusalem, Palestine.

FOOD PLANTS AND INJURY.

In Spain, during July, 1913, the Mediterranean fruit-fly was found in peaches and oranges, but in very limited numbers. The extent of infestation in peaches, its favorite food, amounted to only a fraction of 1 per cent. It is true that most of the peaches had not yet matured, and there is no doubt that a heavier infestation occurred later in the season. Many of the pears, apples, and other fruits were examined, both in the market and in the field, but none was found infested at that

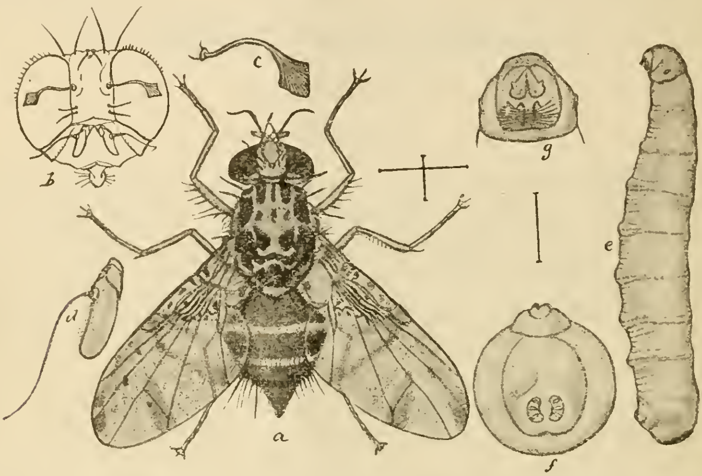


FIG. 1.—The Mediterranean fruit-fly (*Ceratitis capitata*): *a*, Adult fly; *b*, head of same from front; *c*, spatula-like hair from face of male; *d*, antenna; *e*, larva; *f*, anal segment of same; *g*, head of same. *a*, *e*, Enlarged; *b*, *g*, *f*, greatly enlarged; *c*, *d*, still more enlarged. (From Howard.)

time. Figs, which would probably be infested, were immature, as it was then in the period between the first and second crops.

During the month of March an extensive examination of oranges in the field and in packing houses was made, but at that season none was infested. It was learned that occasional complaints of infested oranges occur at the close of the shipping season during the last of June and the first of July, and again in a few of the earlier ripening fruits in October. When the section was again visited, in July, all of the crop was harvested, but scattering fruits on the trees and on the ground were common. These would be the ones likely to be infested were the fruit-fly present. After a week's examination in the groves around Valencia, only four oranges were found with the larvæ (fig. 1, *e*) of the fruit-fly. It is probable that the fly was unusually rare in 1913, because no complaint of infested fruit was recorded from any of the late shipments, and also because of the extreme scarcity of the fly as found by the writer in other fruits, as well as in oranges.

In Sicily *Ceratitis capitata* has been reared by the writer from the following fruits: Apple, azarole, fig, Indian fig, lemon, mandarin, nectarine, orange (sweet), orange (bitter), peach, pear, and plum. Of these fruits the peach is the most severely infested. This is particularly true of the late peaches in August and September. In many places much of the fruit as it approached maturity was attacked. As a consequence most of the fruit is picked rather green and not so many of the infested fruits find their way to the markets. In some sections, however, the fruit-fly was not so abundant in the field, and it was possible to get a good percentage of sound, mature fruit. Wormy fruit was supposed not to be sold in the markets of Palermo, and this was enforced by a few 50-lire fines. After the first few days following the hatching of the larvæ infested peaches are readily distinguished, and the writer was able to get all the infested fruit necessary for experimental purposes from the Palermo markets.

All of the peaches met with in Sicily were clings and of a very firm texture. The preponderance of such a variety may be due to the fact that such fruits do not break down so readily from the attacks of the fly. Figs are also more or less infested, but to no such extent as the peach, and the loss to the figs was very little. Most of the figs are picked for drying while they are still firm, and few in this condition contained larvæ. Plums and apples were rarely infested, while a few larvæ were found in pears. The pears of Sicily are likewise of solid, firm texture, there being no Bartlett or other representatives of our better varieties. Indian figs, a very common fruit in all parts of Sicily, were not infested until September, and then only a small percentage. It was not difficult to find azaroles containing larvæ, but the greater percentage of them was sound.

Aside from a few localities where considerable injury is done to the peach, the fruit-fly is not a very destructive pest in Mediterranean countries and fruit continues to be grown successfully in spite of its presence. In these countries, too, it should be noted, the growers have little knowledge of the insects infesting their fruit, with the exception of one or two species, and they do not, as a rule, practice any measures for artificial control. The writer knows of no case where the culture of any fruit in these countries has had to be abandoned because of the destructiveness of the Mediterranean fruit-fly. While this insect was on two or three occasions, during his sojourn in the Mediterranean vicinity, served to the writer through peaches at the table, codling-moth-infested apples and pears formed a regular part of the menu in comparison. These statements are made with no purpose of minimizing the importance of the pest.

INFESTATION OF ORANGES.

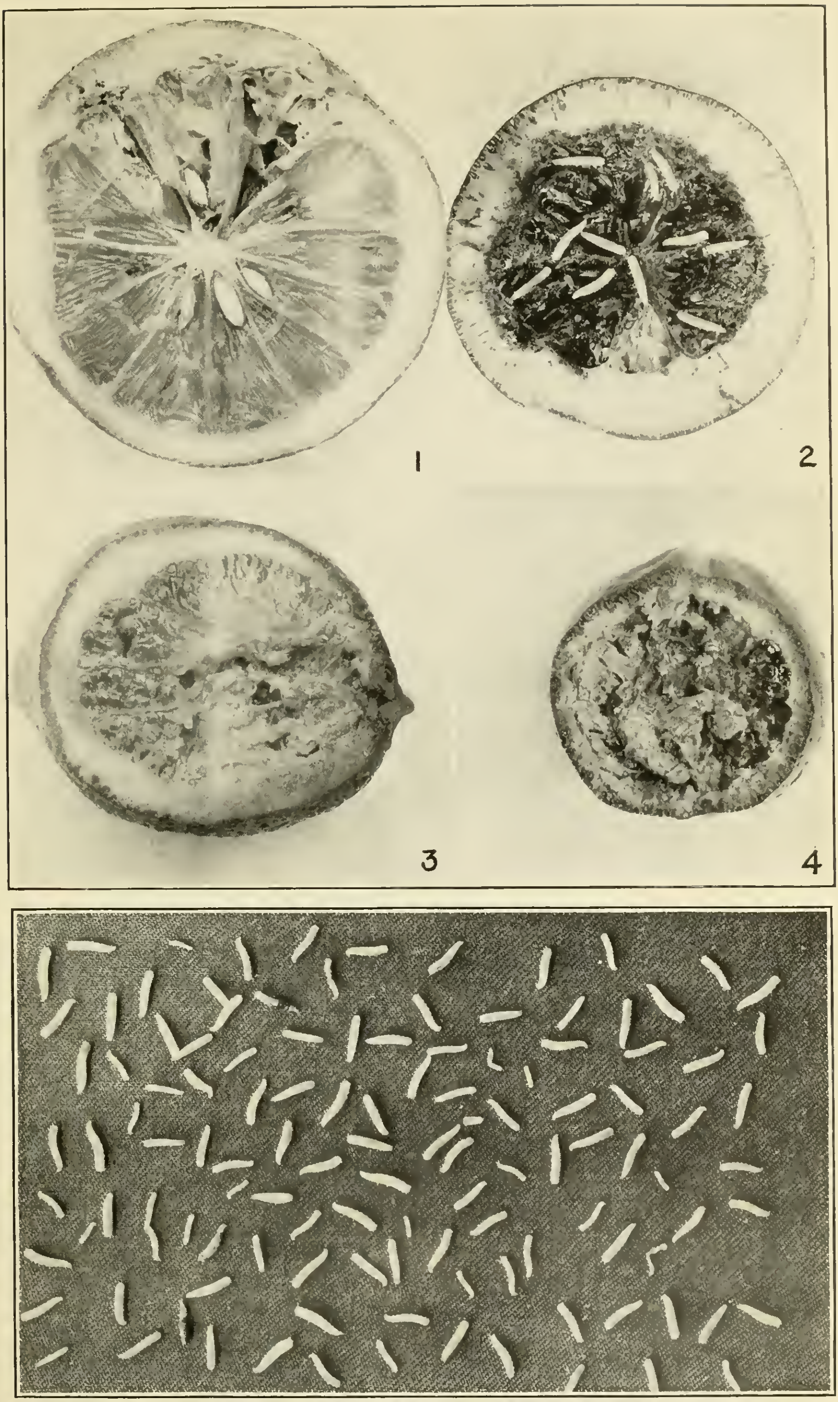
Oranges were not found infested with the fruit-fly during April and May. By the end of May oranges are almost entirely off the market in Sicily. Much orange fruit was examined during April and May, both on the Island of Sicily and on the mainland, but no infestation was found. In Calabria and at Messina oranges were seen with fruit-fly punctures from the previous season, but no larvæ were present. The eggs failed to hatch or the larvæ died immediately upon hatching without getting beyond the egg cavity. According to Dr. Martelli, entomologist at Messina, who has given considerable attention to the fruit-fly, oranges may usually be found infested by the 1st of June, but none was found with living larvæ anywhere, to the writer's knowledge, up to the second week in June of 1913.

When the writer returned to Sicily on the 1st of August such ripe oranges as were still on the trees or on the ground were heavily infested with the fruit-fly (Pl. I, fig. 2). Indeed, no oranges could be found that were either not infested or did not show punctures. For some reason unaccounted for, a few oranges among an almost complete infestation will show from two or three to a dozen punctures, yet will remain sound and contain no larvæ. One orange taken late in August contained the remarkable number of 118 larvæ (Pl. I, fig. 5). These were mostly full grown, and the orange was below medium size. The pulp alone did not furnish sufficient food for such a number, so many of them had retreated to the denser rind, and it was necessary to cut this into very small pieces to disclose the larvæ, which were concealed in small burrows. This orange, before it was cut, was firm and undecayed.

The usual number found in oranges varied from 6 or 7 to 15 or 20. In peaches there were about the same number, but occasionally as many as 30 or 35. In figs usually from 3 or 4 to 8 or 10 were found, while in azaroles and plums, which are smaller, from 2 or 3 to 5 or 6 would be the usual numbers.

Both the sweet and bitter oranges were infested. The bitter orange, therefore, at least as it occurs in Sicily, is not objectionable as food to the fly. The pomelo, or grapefruit, is very rare in Sicily, as elsewhere in Europe, so that a fair test of possible infestation was not presented. A few old grapefruit, however, occurring on three or four trees that adjoined orange trees on which all the fruit was infested, showed no larvæ or punctures. Mandarins are, of course, commonly infested. (Pl. I, fig. 4.) Occasional ones, apparently remaining over from the previous year, were collected as late as August, and these were in nearly all cases infested.

The first oranges of the crop of 1913 with fruit-fly punctures were seen about the middle of September. This fruit had begun to turn yellow over a small area on one side, and the punctures were in this



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DAMAGE TO CITRUS FRUITS BY THE MEDITERRANEAN FRUIT FLY.

Fig. 1.—Lemon infested with *Ceratitis capitata*. Fig. 2.—Orange infested with *C. capitata*. Fig. 3.—Lemon infested with *C. capitata*. Fig. 4.—Mandarin infested with *C. capitata*. Fig. 5.—118 larvae of *Ceratitis capitata* from a single orange. All from Sicily. (Original.)

yellow area. The adult flies (fig. 1, *a*) were commonly seen walking about on the fruit looking for a suitable place for oviposition. By the last of September the fly was seen in considerable numbers where the fruit was beginning to ripen. In Sicily up to the last of September it was but rarely that a tree would be found with any of the fruit showing yellow. An occasional orange would be seen at this time almost entirely yellow, but these were not mature, for they were still very sour. Punctures were common on such fruit, as well as on some others almost entirely green, and as many as a dozen punctures were often seen in a small yellow area. Possibly the punctures were partly accountable for the yellowing. The flies were seen more commonly on the trees during the morning and evening. In the rearing cages during the hot weather they remained on the ground or out of the direct sunlight during the middle of the day.

A large number of punctured oranges were examined during the last of September. Not a single one was actually found infested with the larvæ. Ninety per cent of the punctures examined either contained no eggs or larvæ, or contained eggs that had failed to hatch or larvæ that were dead. The remainder contained eggs but recently deposited, or young larvæ that had just hatched and were still within the egg cavity. The reason for the absence of eggs in many of the punctures is probably that the fly, after making the puncture, found conditions unsuitable for oviposition. The presence of shriveled eggs or dead larvæ in the egg cavity must be due to the immaturity of the fruit. In a large majority of cases the eggs had hatched; in fact, only a few unhatched eggs were found.

In immature oranges there is often a formation of gum about the puncture. Green oranges were known to have punctures, in some cases, by the presence of small globules of gum on the surface. When these oranges were taken from the tree and opened they were found to contain eggs, or larvæ that had just hatched. Very soon a yellow spot occurs about the point of puncture, and the gum upon hardening is easily removed, and probably soon falls off naturally. A hard, gummy, granular tissue also forms around the egg cavity, and it is often possible to remove this ball of brown tissue with the egg cavity intact. It was at first thought that the formation of this tissue, by furnishing an impenetrable wall around the egg cavity or by compressing the eggs and larvæ within, was the direct cause of the insect's mortality. But this hard tissue is not formed to any extent before the eggs hatch. In practically all cases where living young larvæ were found, which indicated recent oviposition, the surrounding tissue was not appreciably hardened, although the brown color began to show.

The egg cavity is situated in the spongy layer of the rind, just below the outer covering containing the oil cells. The surrounding wall of gum seems to be formed from the outer layer, but soon extends into the spongy tissue and entirely surrounds the egg cavity. The number of larvæ found in the punctures in September was always large—from 20 to 30 or 40. Larvæ were seen closely massed together in the egg cavity, but although appearing perfectly normal they were inactive. In such cases death had occurred recently, for later they became brown and shriveled. Occasionally one or two would be seen to move slightly. In some cases two or three larvæ had made their way out of the egg cavity and penetrated a short distance into the spongy tissue. In no case, however, was the pulp reached. Why the larvæ perished within the egg cavity or soft spongy tissue is not definitely accounted for. It appears to be because of lack of air or through the action of some substance in the rind.

A large majority of the punctures in green oranges were seen to be entirely sealed by gum. The tendency of citrus fruits, or, in fact, any fruit, to exude gum to repair wounds while they are immature, is well known. The condition of the larvæ in the egg cavity—simply dying massed together as they hatched, with no evidence of any attempt to migrate—may indicate suffocation. While many larvæ occur in a single cavity, and the space is well occupied, death can hardly be accounted for through compression by growth of tissue or gum formation, because some of them, at least, could work their way out of the cavity. In cases where living larvæ were found, from 30 to 40 were seen in a single cavity with plenty of opportunity for migration.

That fruit-fly larvæ require considerable air was shown in the case of those that were transferred into a juicy lemon, where the entrance was completely closed by the posterior tip of the bodies of a half dozen or more of the larvæ. Numerous instances of the death of full-grown larvæ have been noted to take place in the exuding juices of fruit in glass jars. In peaches and other fruits, also, there are holes in the outer epidermis, made at first through oviposition and later enlarged and serving for the entrance of air.

Fruit-fly larvæ appear to live largely in decayed tissue; that is, the decay induced by them seems to precede the progress of the larvæ. It is possible that in green fruit this decay is not so readily induced. And here, again, the organisms of decay may be kept entirely out of the fruit if the entrance to the surface is effectually closed.

On September 24, 1913, 25 living young larvæ that had just hatched were taken from an egg cavity of the greenest orange found infested and placed through a hole in the rind into the pulp of the same orange. In another orange, also very green, a hole was made connecting the egg cavity with the pulp without disturbing the young larvæ in the cavity. In both cases openings were left to the surface. When the fruit was examined on October 3, partly grown larvæ were found in both of the oranges mentioned. Only a small percentage, however, had lived, although the number was sufficient to indicate that the pulp of the orange was not too green or too acid to serve as food. These oranges were perfectly green, there being no yellow whatever on one and only a slight tinge over a small area on the other. The inability of the larvæ to reach the pulp seems, therefore, to be due to an injurious substance in the rind, to lack of air, to decay, or to all three combined.

From examination of oranges in Italy, Sicily, and Palestine, as they are maturing in the fall, there appears to be no possibility of infestation until the fruit reaches maturity, even though eggs of the fruit-fly may be deposited. The practical bearing of this fact is important in greatly limiting the season of infestation. And in the Mediterranean countries visited, cold weather appears by the time the fruit is mature and susceptible to infestation, so that the season is very short in the autumn, and most of the fruit is harvested before the return of warm weather in the spring.

APPEARANCE OF FRUIT-FLY PUNCTURES IN ORANGES.

Immediately after the adult fruit-fly has oviposited in the orange the puncture is not readily distinguishable, but it soon appears as a brown or grayish, oval-shaped area about 0.5 mm. long, with a crack or opening in the center. In green oranges the area immediately around this may be yellow. Later this area may become brown and depressed. After some time also the point of puncture is indicated by a distinct conical elevation. These elevations are conspicuous on the surface of the fruit and they may at once be diagnosed as indicating punctures of the Mediterranean fruit-fly. In older fruit these conical elevations may arise from circular depressions which are of a brownish or yellowish color. If the outer layer containing the oil cells be cut away, the egg cavity will be disclosed in the spongy tissue. After some time brown and hard granular tissue usually surrounds the egg cavity, so that the whole may be removed from the surrounding tissue as a gall. To make sure that punctures are present the egg cavity should be examined for the egg skins, shriveled eggs, or larvæ. If the orange is infested, small burrows may be traced through the spongy layer to the pulp, and the pulp itself will be decayed. Typical punctures are at once distinguished, but their character and form vary so greatly that sometimes other scars or abrasions on the fruit may be mistaken for them.[1]

INFESTATION OF LEMONS.

The only supposed instance recorded of the occurrence of *Ceratitis capitata* in lemons in Sicily is a note by Prof. Inzenga in the Annali di Agricoltura Siciliana, Volume XIV, 1884, page 101. In

[1] Since the foregoing was written the writer has examined fruit-fly conditions in the Hawaiian Islands, where they are strikingly different from those in Mediterranean countries. The most evident difference in appearance of the fruit in Hawaii is the much more copious exudation of gum.

this article Prof. Inzenga simply states that a "small worm" was observed by Profs. Alfonso and Bonafede to breed in the orange, lemon, Indian fig, and other varieties of fruit. Prof. De Stefani,[1] of the Universitate di Palermo, questions, and rightly so, the authenticity of the statement, adding as proof that in all the writings of Profs. Alfonso and Bonafede no statement occurs to the effect that *Ceratitis capitata* breeds in lemons. Prof. De Stefani further calls attention to the fact that no entomologist (excepting the questionable case above) has ever observed Ceratitis to breed in lemons in Italy; and concluded with the statement that "It is excluded absolutely that *Ceratitis capitata* lives in the lemons in Sicily." (E. da excludersi assolutamente che la *Ceratitis capitata* viva nei lemoni di Sicilia.)

Dr. G. Martelli, who has made careful studies on *Ceratitis capitata*, published an article entitled "La Mosca della arance non vive nei nostri limoni" (The orange fly does not breed in our lemons), in the Giornale di Agricoltura Meridionali, No. 9, Ann. V, 1913, Messina. In a paper read before the R. Scuola Superiore di Agricoltura at Portici in January, 1913, Dr. Martelli records experiments in attempting to transfer the eggs of *Ceratitis* into the lemons. These experiments all resulted negatively, and he concluded that the insect would not live in lemons.

During April and May an extensive examination in all the sections of Sicily was made in the field, as well as in numerous field and exporters' packing houses, with the result that no evidence of infested lemons was found. This was the season when the heaviest shipments were being made to the United States, and it was felt that a thorough examination should be made at that time. But at that season no fruit-fly larvæ appeared in any other fruit, and thus negative evidence under such circumstances would be of little value. Consequently it was proposed that the inspection be continued at a later and more favorable season, and this was at once agreed to by Mr. Marlatt, chairman of the Federal Horticultural Board. Accordingly the writer returned to the Island of Sicily, where he remained throughout August and September.

As already intimated, there was abundant evidence of the presence of *Ceratitis capitata* in other fruits at that time. Field inspection was therefore resumed in the lemon groves of Sicily during the first week in August, and during the second week there was found the first evidence of the breeding of *Ceratitis capitata* in lemons. (Pl. I, figs. 1, 3.) The infested lemons were large, overripe ones, with more or less decay, and were found on the ground. The total number found during the week was four, all taken in the same grove. Near by were many old ripe oranges severely infested with the fly. The week following 10 more infested lemons were found; most of these

[1] Intorno ad Alcuni Insetti degli Agrumi del Prof. Teodosio De Stefani, Palermo, p. 6, 1913.

were taken in this grove, but four were taken in three other places. Two out of the 10 taken during the week were on the tree, while the remainder were on the ground. It should be stated that the two taken from the tree were also partly decayed on one side. The decay in most of these lemons appeared not to be due entirely to the fruit-fly. No punctures were seen, and it is assumed that the eggs were deposited in the decayed side, or else the decay which set in later completely obliterated the punctures. One more lemon with fruit-fly larvæ was found during the fifth week, making a total of 15 infested lemons out of the thousands examined. None was found during the remaining three weeks of the inspection. None of the infested lemons would have been considered for shipment, and with three or four exceptions would not have been taken for the by-product factory. In some of the lemons, it is true, the larvæ were nearly grown, and the condition of the fruit can not be vouched for at the time of oviposition, but in others the larvæ were but partly grown, and thus the fruit had not been long infested.[1]

EXPERIMENTS WITH THE FRUIT-FLY.

Through the kindness of the Prince of Galati use was had of a neglected garden within the city of Palermo, and under a tree here was equipped an improvised laboratory. (Pl. X, fig. 5.) Three series of experiments were carried on. The first series was to determine if it is possible to transfer the larvæ of Ceratitis from other fruits into the lemon and bring them to maturity. The idea was generally held in Italy, even by the entomologists, that the lemon is too bitter or acid for the fruit-fly. The second series was to determine the possible extent of oviposition on lemons in confinement, and the third as a check on the second series and for life-history work, and to determine the extent of breeding in other fruits, as the apple, pear, peach, and orange, under the same conditions.

To summarize briefly, the first series of experiments resulted in establishing the fact that it is possible to transfer fruit-fly larvæ from a fine ripe peach to a ripe and also to a perfectly green lemon and bring them to maturity. The second series, so far as the experiments were conducted in small glass containers, resulted negatively. The third series resulted in securing oviposition and development in the peach, pear, and orange.

In the first set of experiments a small plug was cut out of the rind of the lemon, and a small cavity made in the pulp, just large enough to contain the larvæ. After the larvæ were transferred, the plug of rind was replaced, a small triangular piece first being cut out of one side of the plug for air. Aseptic methods were employed

[1] In Hawaii a perfectly sound lemon has been seen with a single specimen of *Ceratitis capitata*. In Hawaii, also ,Ceratitis punctures in lemons are very common, though actual infestation seems to be rare.

in these operations, although not with entire success, to prevent infection from molds, which gave considerable trouble. In 12 experiments 163 larvæ were transferred into lemons, and 108, or 66.2 per cent, changed to pupæ and emerged. The time spent in the lemons varied from 2 to 10 days, with an average maximum of 7.7 days.

The length of the larval period was determined as 10 to 11 days. On this basis the age of the larvæ transferred varied from 1 or 2 to 10 days. It will be noted that not all the larvæ developed, 33.8 per cent having died from one cause or another. The molds in the fruit were probably the chief factor in the mortality. The exuding juice drowned a good many that were emerging for pupation, others were dead in the fruit, and possibly some were injured in the transfer. Enough, however, emerged to show that the lemon is not an impossible food for the larvæ of *Ceratitis capitata.*

In each of 48 glass jars from 1 to 2 lemons were placed and from 6 to 22 flies liberated. These were fed with sweetened water, and lived from 3 to 26 days, the large majority, however, dying after 6 or 7 days. No infested lemons resulted from these experiments and no punctures were found. Under the same conditions peaches, pears, and oranges became infested, but with these some of the experiments also resulted negatively. Apples in three jars were not infested. In only a few cases were flies seen in copulation, and it appeared that they were too closely confined and under too unnatural conditions for free breeding.

In four large breeding boxes, where infested fruit was placed on the ground and the flies allowed to emerge, a total of 56 lemons in all stages of ripeness was placed. In 2 of these boxes the fruit was first punctured with a needle or scalpel, and in the other 2 the lemons were sound. Some of the lemons remained in these boxes for 6 weeks. Hundreds of flies emerged in each of the boxes. The lemons, when examined, were in various stages, many being decayed. No infested fruit was found, and no punctures of the fruit-fly were seen in any of the lemons.

While these experiments were not, of course, extensive and adequate enough to establish any fact on negative evidence alone, they do show that oviposition in the lemon in Italy is not at all common.

PUPATION.

Ordinarily fruit-fly larvæ go into the soil to the depth of about an inch, or otherwise seclude themselves for pupation; but this is not at all necessary, and pupation may occur anywhere in the open and direct light. The side of a packing box or any other container of fruit is thus suitable for the purpose, and the fruit-fly may be transported in this manner.

LIFE CYCLE.

No extended life-history studies were attempted or possible in the time available, but such records as were kept indicate that the life cycle of Ceratitis is completed in 22 or 23 days in Sicily in August. Out of this total, 2 or 3 days are required for the eggs to hatch, 10 or 11 days for the development of the larvæ, and 10 days for the pupal period. Since these records were made during the warmest weather they represent the minimum time for development.

OTHER INSECTS IN ORANGES AND LEMONS LIKELY TO BE MISTAKEN FOR THE MEDITERRANEAN FRUIT-FLY.

The commonest insect occurring in decayed or overripe oranges and lemons on the ground, and also occasionally on the tree, is a nitidulid beetle, *Carpophilus dimidiatus* Fab. Larvæ and adults of this beetle often occur in great numbers. Usually decay has already set in before the fruit is attacked, but if it remains on the ground for some time the beetles will bore through the rind and they themselves cause decay. The appearance of such fruit is very much like that infested by Ceratitis. The larva of Carpophilus is about the same length as that of the fruit-fly, but is easily distinguished because it is beetle-like and both ends are tipped with brown. Instead of breaking down, lemons often dry with extremely hard, firm rind, and they remain in this condition for months. Such lemons occurring on the ground are, however, frequently infested with this beetle. The beetle enters the fruit where it rests on the ground by drilling holes through the firm rind.

Another common "worm" in decayed oranges and lemons is the larva of a fly, *Lonchaea splendida* Loew. This larva is more slender and of a paler color than that of the fruit-fly, but small specimens are very likely to be mistaken for fruit-fly larvæ; hence they must be examined closely and identified by the spiracles to make sure of the species. The adult fly is smaller than Ceratitis and is of a metallic blue color.

Larvæ of Drosophila also frequently occur in decayed oranges and lemons, but, except in possible cases of very small specimens, they are easily distinguished from the more robust and yellowish white Ceratitis larvæ. Of all the "worms" infesting oranges and lemons, Ceratitis larvæ are the most sluggish and slow moving, so that with a little experience they may be distinguished by their movements.

THE BLACK SCALE.[1]

Saissetia oleae Bern.

DISTRIBUTION AND INJURY.

The black scale is generally distributed throughout the Mediterranean citrus sections. (Fig. 2.) It varies in numbers from an occasional scale to numerous specimens forming a complete incrustation on the twigs and branches, and in injury from an insect of no commercial importance to one doing much damage through the quantity of sooty-mold fungus found on the trees and fruit.

In the most important orange section of the Mediterranean countries, that of Valencia, Spain, the black scale is, according to our standards of judging, entitled to rank first among the citrus fruit pests. This statement is at least true for the years 1912 and 1913. In all of the scores of packing houses visited during the month of March, 1913,

FIG. 2.—Distribution of insect enemies of citrus fruits in Mediterranean countries. (Original.)

from a half dozen to 15 or 20 women were seen washing fruit to remove the sooty-mold fungus occurring as a result of black-scale infestation. In some cases the sooty mold was due to the mealy bug (*Pseudococcus citri*), but infection from this source would amount to only a small percentage of the total. During July, 1913, when the section was again visited, numerous young were seen on the leaves, which, barring a heavy mortality later, would furnish the same conditions for the season following. In numerous groves around Burriana, Spain, the sooty-mold fungus was seen to form a complete coating over all the upper surface of the leaves, branches, and fruit, and such a severe incrustation of scales occurred as actually to kill many of the smaller twigs, and in some cases even the larger branches.

The greatest injury from the black scale was seen in the "Plana," or level district opening to the sea north of Valencia, and centering around Burriana. The conditions here are much the same as in the

[1] Spanish, *Escania negra;* Italian, *Cocciniglia dell' olivo.*

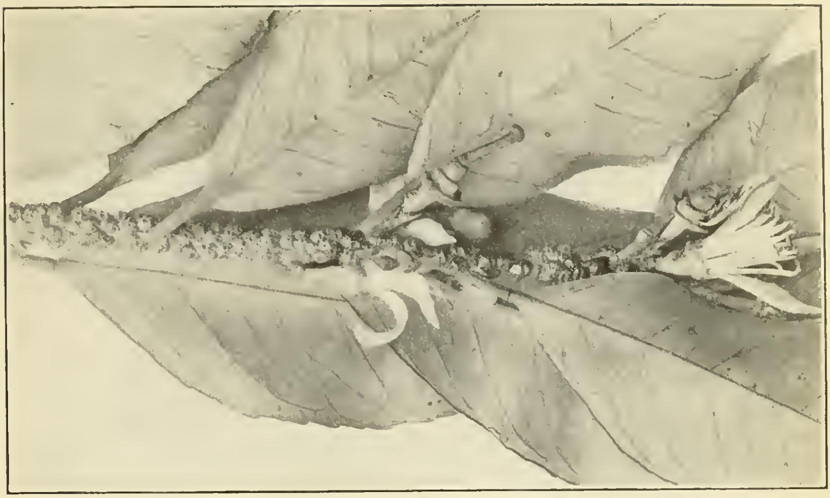

FIG. 1.—THE BLACK SCALE (SAISSETIA OLEAE) ON LEMON TWIG, SICILY. (ORIGINAL.)

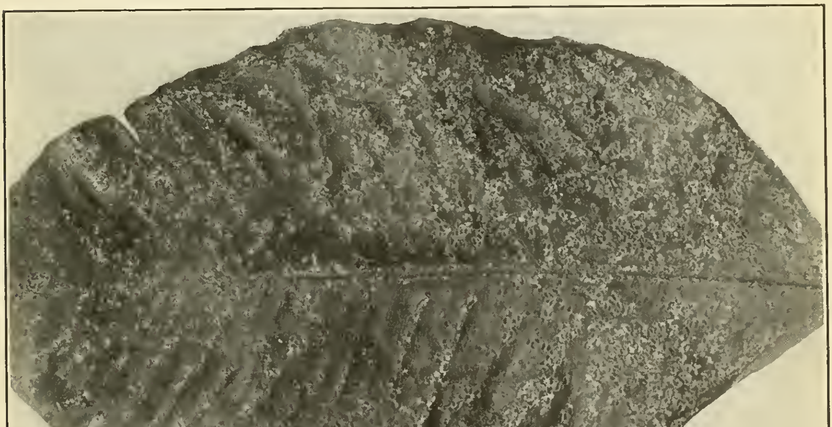

FIG. 2.—A COMMON CITRUS SCALE (PARLATORIA ZIZYPHUS) ON A LEMON LEAF, SICILY (ORIGINAL.)

SOME SCALE INSECT ENEMIES OF CITRUS FRUITS IN SICILY.

coast counties in southern California, where the same scale is most important as a pest. The "Ribera," or section south of Valencia, is hilly and rolling and is separated from the sea by hills and mountains. The direct sea influence is, therefore, not so pronounced, and the black scale is not so generally injurious. The influence of the sea consists in moderating the effect of the summer heat, which, if too intense, results in a wholesale mortality of the young scales, in which stage the scale is largely found during the summer months.

The black scale is also more or less abundant in localities farther south, as Murcia, Malaga, and Seville. But in these sections, which are still farther removed from the sea, the black scale is not so important a pest as is *Crysomphalus dictyospermi.*

The washing of oranges in Spain consists in rubbing each individual fruit, first in wet, and then in dry sawdust, the latter both to hasten the drying and to complete the cleaning. It is not a bad system so far as results are concerned, and, with the low price of labor (20 cents a day for women), the expense is no greater and probably much less than with the use of machinery as with us. The sawdust method, however, leaves more traces of the mold in the small depressions of the fruit than does our machine with brushes. When attention was called by the writer to the absence of any aseptic agent in the water used in dampening the sawdust—and it is used over and over again—the reply was evoked that there is no better disinfecting agent than ordinary sea water. But the writer was not sure that sea water was being used, and he was very certain it was not in many places. The amount of fruit receiving the sawdust treatment varied from 25 per cent to more than 90 per cent in most of the packing houses visited.

The washing of the fruit, according to Spanish standards, is regarded simply as one of the regular practices of the packing house, and is not an expense generally attributed to the black scale or any other insect. In fact, no one was seen in Spain who considered that the sooty-mold fungus [1] was in any way related to the black scale. It was for this reason that the statement appears at the beginning of this discussion that the black scale is considered by the writer to be the most important pest in the Valencia section, "according to our standards." According to Spanish standards it is no pest at all, chiefly because the insect and its important effect, the sooty-mold fungus, are not generally considered as in any way related.

But the injury by the black scale in the Valencia section is not due entirely to the presence of mold on the fruit. When such severe infestations occur as were frequently seen, the tree itself suffers. Small twigs are killed, and the coating of mold over the leaf, branch, and fruit not only interferes with the functions of the tree, but the fruit itself is deficient in sweetness and flavor.

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[1] Spanish, *Negrilla.*

In Sicily the black scale was seen in great abundance in several places, but these places usually consisted of but a small area, or even but a few trees. (Pl. II, fig. 1.) It is found in scattering numbers throughout the citrus area, but with the exception of a few cases of dirty fruit which have been seen, coming from limited areas, as noted above, the black scale is not a serious pest in this, the most important lemon section of the Mediterranean. It is the writer's opinion that, above all other factors, the absence of the scale in serious numbers in Sicily is due to the sirocco, which frequently prevails there during the summer and fall. This is a burning hot, dry wind from the African deserts. It is only necessary to experience one of these siroccos, which usually lasts about three days, to conclude what effect it would have on insects not well adapted to withstand heat and dryness. Opportunity was afforded for judging the effects of a sirocco on young black scale in Sicily, with the result that between 95 and 100 per cent were seen to be killed. The same effect of hot weather has been observed by Mr. C. L. Marlatt,[1] Mr. R. S. Woglum,[2] and the writer[3] in California.

SEASONAL HISTORY.

So far as could be observed the black scale has very much the same life and seasonal history in Mediterranean countries as it has in California. The majority of the young appear in June and July. These settle almost entirely upon the leaves or on the tender twigs. It is during this period that high temperatures are likely to cause a heavy mortality. Later in the fall the young that still survive migrate to their permanent abode on the twigs and branches, and pass the winter as partly grown insects. During this season growth is very slow, but with the resumption of warm weather in the spring it proceeds rapidly. By May and June oviposition occurs, and from 2,000 to 3,000 eggs are deposited by a single female during a period of from 30 to 60 days. While the majority thus mature in the spring and require 8 or 10 months for development, others, that have all the heat of summer, will mature in 4 or 5 months, and thus some scales will be found in all stages at all seasons.

NATURAL ENEMIES.

The most important natural enemy of the black scale in most sections where it occurs is *Scutellista cyanea* Motch. It was a surprise, however, to find that this parasite occurred in less numbers in

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[1] Marlatt, C. L. Insect control in California. U. S. Dept. Agr. Yearbook for 1896, p. 217-236, Pl. V, 1897. See p. 218.

[2] Woglum, R. S. Fumigation investigations in California. U. S. Dept. Agr., Bur. Ent., Bul. 79, 73 p., 28 figs., June 11, 1909. See p. 12.

[3] Quayle, H. J. The black scale. Cal. Univ. Coll. Agr. Expt. Sta. Bul. 223, p. 151-200, 24 figs., 8 pl., July, 1911. See p. 165.

many of the Mediterranean countries than it does in California. In those countries where no artificial control is practiced it was thought that all natural enemies would be more abundant. On the other hand, no place was seen where the numbers equaled those of the California citrus belt, with a possible exception in the case of *Ceroplastes rusci* L. on the fig, in a few places in Sicily. In Spain, where the black scale was so abundant on citrus trees, very few were attacked by Scutellista. Where counts were made the maximum did not exceed 20 per cent, while hundreds of scales were examined in many places with no evidence at all of parasitism. Scutellista, like most insects, has its periods of increase and decrease, and the year 1913 may have been at the end of a depression. But during years when it occurs in fewest numbers in southern California it is much more abundant than it was observed to be in Spain in 1913. In Sicily, also, Scutellista was not seen in large numbers anywhere on the black scale on citrus trees.

Aside from Scutellista the only other enemies of any importance noted were two coccinellids, *Chilocorus bipustulatus* L. and *Exochomus 4-pustulatus* L. These, however, are general feeders, and were seen to occur more abundantly on trees infested with *Chrysomphalus dictyospermi*, *Parlatoria zizyphus*, and *Lepidosaphes beckii* than on those infested by the black scale. *Rhizobius ventralis* Er., the most important coccinellid on the black scale in California, was not seen in Spain or Italy.

CHRYSOMPHALUS DICTYOSPERMI Morg.[1]

DISTRIBUTION AND INJURY.

Chrysomphalus dictyospermi is found in most of the citrus sections of Spain. It was commonly observed at Malaga, Seville, Murcia, and Valencia. In the Valencia section it was most injurious at Piaporto, Picaña, and Piug. At each of these places fumigation, introduced by Mr. R. S. Woglum, of this bureau, was seen in practice. Here the scale occasioned severe injury to the trees, mostly through the dropping of the leaves. While it was observed in scattering numbers around Burriana, nowhere was it seen to do any important injury. Why it does not occur there in greater numbers is not known. It was thought that parasites must be at work, but practically no evidence of parasites was seen, so far as examination was made during the month of March. That this scale was not recently introduced in the Burriana district appears to be indicated from the fact that it occurs there over such a large area. This scale was also seen occasionally around Alcira in the "Ribera."

[1] Spanish, *Piojo rojo;* Valenciana, *Poll roig;* in Murcia and provinces of Andalucia, *Cochinella rojo;* Italian, *Cocciniglia bianco-rosso;* Sicilian, *Bianca-russa.*

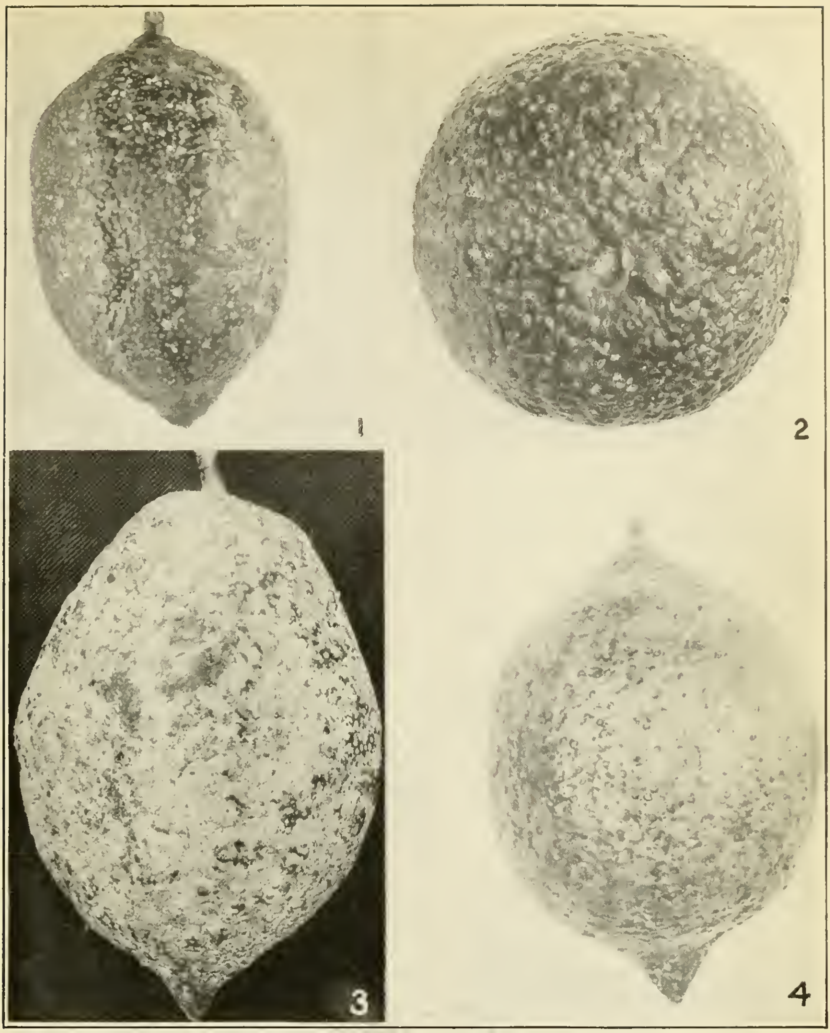
If this scale occurred widely over the Valencia section in such numbers as at Piaporto, Picaña, and Piug, it would, of course, outrank the black scale in destructiveness. At the points mentioned it is the most serious of all the scales because of its damage to the tree, as well as its effect on the market value of the fruit. It occurs also in injurious numbers farther south, as at Murcia, Malaga, and Seville. It is very commonly seen on the fruit in the markets in these sections, and the trees in many places show the effect of the scales. Even in the famous Patio de los Naranjos (Court of Oranges) of the mosque at Cordova and of the cathedral at Seville the trees are having a hard struggle to exist on account of the severe infestation by this scale. Taking the entire citrus area of Spain this scale may be the most important, but in the important commercial section of Valencia, where 90 per cent of the crop is produced, it is first only in a few small areas.

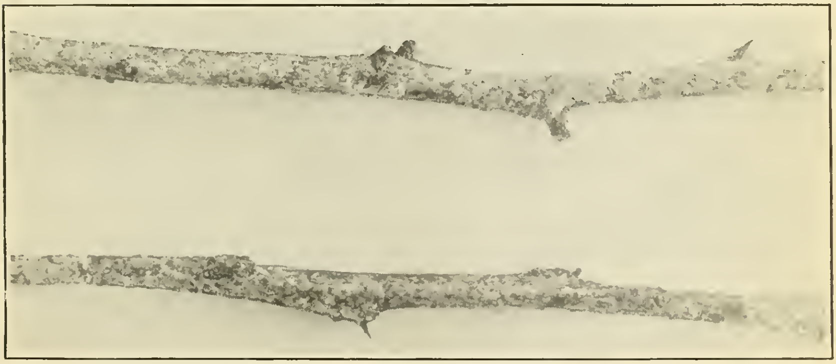
In the citrus belt along the French and Italian Riviera this species was seen at San Remo and Porto Maurizio; at the former place in destructive numbers on a few small trees. In Sicily it occurs at Catania, Messina, and Palermo. (Pl. III, fig. 4; Pl. IV, figs. 1 and 2.) At Messina it is found in several places around the city and does considerable injury. Its first recorded appearance on the island, four or five years ago, was at this place. At Catania it is more or less widely distributed, while at Palermo it is still limited to a few small areas, but it is destructive as far as its spread has occurred.

LIFE HISTORY AND HABITS.

This species, somewhat like the yellow scale (*Chrysomphalus aurantii* Mask., var. *citrinus* Coq.), attacks the leaves and fruit largely. These will be found heavily infested and often there will be but a few on the twigs and branches. This habit of avoiding the twigs and branches is not so complete as with the yellow scale, but is distinctly more pronounced than with the California red scale (*Chrysomphalus aurantii* Mask.). In severe infestations, of course, and where the leaves have fallen, *C. dictyospermi* will be found in considerable numbers on the twigs. Because the twigs and branches are not so severely infested the injury is neither so great nor so rapid as is the case with *C. aurantii.* But the dropping of the leaves greatly injures the tree temporarily and new leaves scarcely grow out until they in turn are attacked.

While the life history of this species has not been worked out in detail, it is probably very similar to that of *C. aurantii.* The latter species requires two and one-half to four months for its development. There would thus be between three and four, possibly four, full generations in a year.





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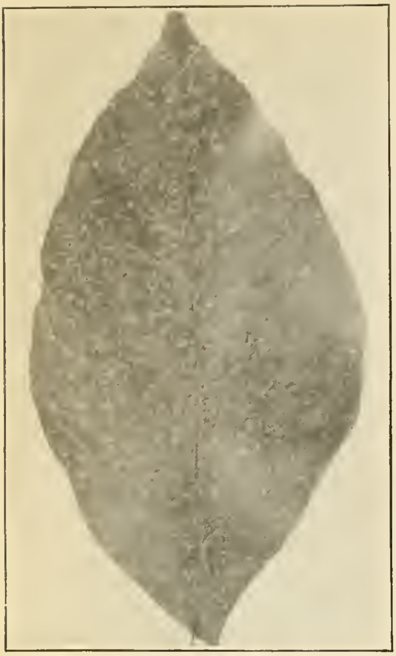
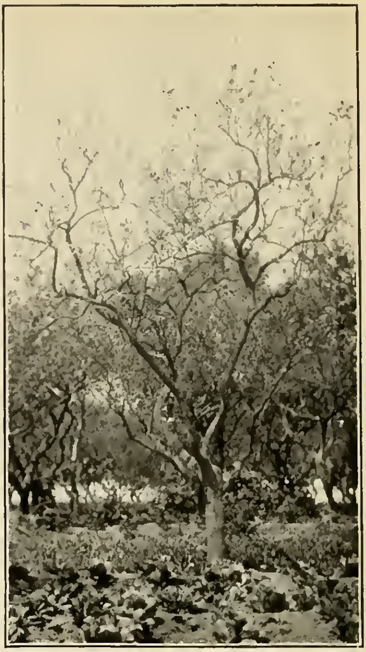
SOME SCALE INSECT ENEMIES TO CITRUS FRUITS IN SPAIN AND ITALY.

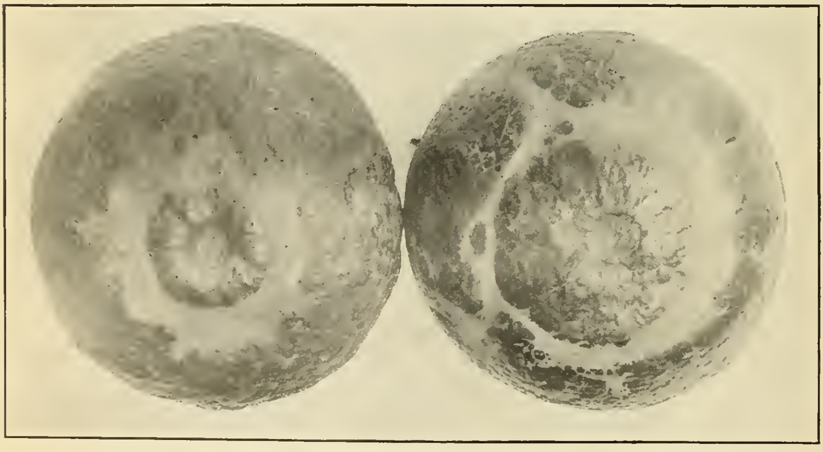
Fig. 1.—Lemon distorted by the oleander scale, *Aspidiotus hederae;* Italy. Fig. 2.—An orange infested with a common citrus scale, *Parlatoria zizyphus;* Spain. Fig. 3.—Lemon incrusted with *Aspidiotus hederae;* Sicily. Fig. 4.—Lemon infested with *Chrysomphalus dictyospermi;* Sicily. Fig. 5.—*Parlatoria zizyphus* on lemon twigs, Sicily. (Original.)



Chrysomphalus dictyospermi on Orange Leaf, Sicily. (Original.)



Lemon Tree Partially Killed by Chrysomphalus dictyospermi. (Original.)



Scars Resulting From Feeding of Thrips, Probably Heliothrips fasciatus. (Original.)

INSECT ENEMIES OF CITRUS FRUITS IN SICILY.

NATURAL ENEMIES.

The most abundant parasite of this scale is a species of Aphelinus.[1] Two or three species of Coccinellidæ have also been seen feeding on the scale. These are the same species as those already given for the black scale.

THE PURPLE SCALE.[2]

Lepidosaphes beckii Newm.

DISTRIBUTION AND INJURY.

The purple scale was seen in most of the citrus sections of Spain and Italy. It is found very generally in the Valencia orange section and in the Sicilian lemon section. Not infrequently the numbers are sufficient to do injury to the trees. This consists of the killing of a few branches, or a portion of one side of the tree. (Pl. V, fig. 1.) The scale is also more or less common on the fruit. It occurs in many places in Sicily in only scattering numbers, and in small areas, or, on a few trees, in large numbers. This is about the status of the scale in California and Florida and the Valencia section of Spain, but on the island of Sicily it is less injurious than in any of these three localities.

LIFE HISTORY.

The purple scale deposits from 40 to 80 eggs, which are well inclosed by the scale covering above and a lighter, cottony covering beneath. The eggs hatch in 15 to 20 days in summer. Most eggs and young will be found in the spring—May and June—and another large batch in August and September. At all other seasons eggs will be found, but usually in less numbers. The period of development from hatching to egg-laying ranges from one and one-half months in summer to three months in winter.

NATURAL ENEMIES.

The purple scale has been considered a pest of little economic importance in Mediterranean countries, and this has been accounted for through the efficient work of parasites. The writer takes exception to both of these counts. Just as severe injury has been seen from this scale in Spain as in California or Florida. And further, what natural enemies are keeping it in check? Hitherto, so far as known, no internal parasite has been reported from the purple scale in Sicily. Dr. Martelli was informed by the writer that he had seen evidence of *Aspidiotiphagus citrinus* attacking the purple scale, but the observation was questioned on the ground that the scale was *Lepidosaphes ulmi* and not *L. beckii*. Of course, the parasitized scales were not positively identified at the time. Later *Aspidiotiphagus citrinus*

[1] This species appears to be *A. diaspidis*, but its identity, according to Prof. Silvestri, of Portici, is somewhat questionable.

[2] Spanish, *Serpeta;* Italian, *Pidocchio a virgola;* Sicilian, *Pidocchiu.*

Craw was reared from scales on citrus trees, and those scales from which they emerged were positively identified, as was expected, as *L. beckii*. The record, therefore, stands. Dr. Leonardi, of Portici, a specialist on the Coccidæ, stated that he had seen some evidence of a parasite on the purple scale, but he had not as yet studied it and did not know the species. When the entomologists of Italy know so little about the parasite, and when it was only very rarely found by the writer, it certainly can not be counted as very effective in checking the scale. The only other enemies of this scale seen in Sicily and Spain were coccinellid beetles, and while these are more effective than *A. citrinus*, they have not been seen in large numbers, and are not accountable for keeping the scale in check.

Places have been seen in Sicily which were very free from the purple scale, but according to the growers the scale had been present there in considerable numbers several years ago, and disappeared. Because of the meager knowledge of scales and the confusion of names by most Sicilian growers, the foregoing may or may not be true. It is, however, altogether probable. (For a discussion of climatic influences, see under Meteorological data, pp. 34–35.)

THE LONG SCALE.[1]

Lepidosaphes gloverii Pack.

DISTRIBUTION AND INJURY.

The long scale, so far as observed by the writer, is limited to Spain. In that country it is particularly destructive in some sections. It is frequently associated with the purple scale, as in the Valencia section. In some cases it was more abundant than the purple. Trees most injured by this scale were seen near Burriana. (Pl. V, fig. 1.) The long scale also occurs in Florida, from which place it was first described. It has been reported from two counties in California, though it has never spread and is of no consequence as a pest there. It is distinguished from the purple scale in being much more slender, and the pygidial differences are also distinct.

PARLATORIA ZIZYPHUS Lucas.[2]

DISTRIBUTION AND INJURY.

Parlatoria zizyphus is the commonest of all the scales occurring on the lemon tree in Sicily. (Pl. II, fig. 2; Pl. III, fig. 5.) It is also found in most of the orange sections of Spain. (Pl. III, fig. 2.) In the Valencia section it was most abundant in the "Ribera" in the vicinity of Alcira. This scale ranges in abundance from a few scattering scales to a heavy incrustation on the leaves, twigs, and fruit. It

[1] Spanish, *Serpéta larga*.
[2] Italian common name, *Pidocchio nero:* Sicilian, *Pidocchiu niuru:* Spanish (Valenciana), *Poll négre*.

has been noted in several instances to cause a heavy dropping of the leaves, and it is one of the commonest scales occurring on the fruit in the markets. This may be partly because it adheres so firmly to the fruit and is not easily removed by rubbing. While it occurs abundantly in Sicily it is not extremely injurious to the tree, nor does it distort the fruit as does *Aspidiotus hederae*.

NATURAL ENEMIES.

This scale is especially free from parasites. On one occasion *Aspidiotiphagus citrinus* was obtained from material infested by *zizyphus*, but it can not be positively stated that there were not a few purple scales among the material, so the record remains doubtful.

THE OLEANDER SCALE.

Aspidiotus hederae Vall.[1]

DISTRIBUTION AND INJURY.

The cosmopolitan and omnivorous oleander scale is found throughout Spain and Italy and is an important pest on ripe lemons in the latter country during the spring and early summer. (Pl. III, figs. 1 and 2.) It was also observed on oranges in Spain, but is less injurious on oranges there than on lemons in Italy. In California the same scale occurs occasionally on old over-ripe oranges and lemons, but is of no commercial importance. In May and June it is really a pest of much economic importance in Italy. If such infestation occurred in California, it would certainly mean fumigation. As much as 90 per cent of the fruit in some of the by-product factories has been seen infested with this scale. Most of such fruit was brought there because of it.

The oleander scale very seriously distorts the growth of the lemon in Italy. (Pl. III, fig. 1.) Where the scale occurs there will be a depression, so that the fruit has a rough and uneven appearance and when numerous it becomes badly misshapen and distorted. The scale also delays the coloring of the lemon, and such fruit can be distinguished at a long distance by its blotches of yellow and green. While the inferior fruit caused by the scale is considerable in Italy, it is not a complete loss because it is acceptable for the by-product factory. On the Amalfi coast, where fruit of the finest texture is produced, it would seem that spraying, at a time when the young first appear, would in many cases be profitable.

NATURAL ENEMIES.

A species of Aphelinus is the commonest parasite on this scale in Italy. On host plants other than Citrus this parasite was sometimes seen in very large numbers. *Aspidiotiphagus citrinus* has also been taken from *A. hederae*.

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[1] Italian, *Bianca;* Sicilian, *Bianca o rugna.*

THE COTTONY CUSHION SCALE.

Icerya purchasi Mask.

DISTRIBUTION AND INJURY.

The cottony cushion scale was observed at Acireale, Messina, and Bagheria in Sicily. It was not seen elsewhere in Italy, except at Portici, and was not observed anywhere in Spain. It is of recent introduction in Sicily (five or six years ago) and is supposed to have come from North America or Portugal. A severe infestation occurred at the places mentioned in Sicily as observed in April. Several trees were killed and cut down at Bagheria. (Pl. V, fig. 2.) *Novius cardinalis* was seen at work at Messina and Acireale, but after persistent search none could be found at Bagheria despite the fact that the beetle had been liberated by Dr. Savastano in February. Dr. Savastano was informed of this fact, and another colony was promptly liberated. When the place was again visited in August it was gratifying to see that apparently the entire infestation was completely checked by the work of the beetle. The owner of the grove, who in May despaired of saving any of the trees, in August was elated and believed it little short of miraculous that he could be freed of the pest in such a short time. This infestation was so completely cleaned up that Novius had disappeared for lack of food, and no trace of the beetles could be found in August. These same conditions have been observed in California; the beetles, upon eating all of the scales by midsummer, would themselves disappear, reappearing, however, in the following spring. The few young scales that escaped the beetle the year previous would multiply to such an extent that a heavy infestation occurred by the following spring and would thus furnish food for the returning beetles wherever they came from. These circumstances were observed for four successive seasons in a particular grove in California, where the trees were finally cut back. It is hoped that these same circumstances will not prevail at Bagheria.

LIFE HISTORY.

From 500 to 800 eggs are deposited in the large fluted cottony mass which is secreted for this purpose. The eggs hatch in from 10 days to 3 weeks, depending upon the temperature. The young larvæ settle on the leaves and tender twigs largely, but later nearly all those on the leaves migrate to the twigs and branches, adults being found even on the tree trunk. The time required for development varies considerably under the same conditions and may range from three to four or five months. The great majority of eggs and young appear during May and June.

FIG. 1.—ORANGE TREES PARTIALLY KILLED BY THE PURPLE SCALE (LEPIDOSAPHES GLOVERI) AND THE LONG SCALE (LEPIDOSAPHES BECKII) AT BURRIANA, SPAIN. (ORIGINAL.)

FIG. 2.—LEMON TREES KILLED BY THE COTTONY CUSHION SCALE (ICERYA PURCHASI) AT BAGHERIA, SICILY. (ORIGINAL.)

SCALE INSECT ENEMIES OF CITRUS FRUITS IN THE MEDITERRANEAN.

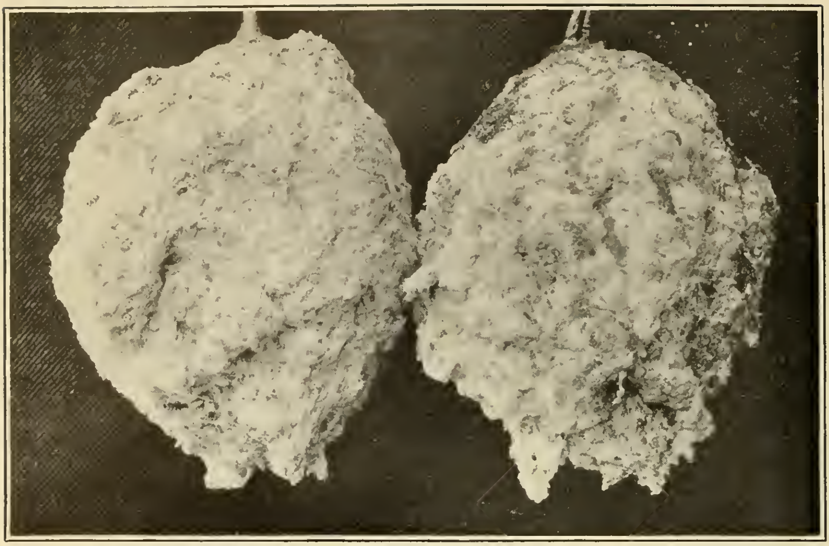

FIG. 1.—THE MEALY BUG (PSEUDOCOCCUS CITRI) ON ORANGES, SICILY. (ORIGINAL.)

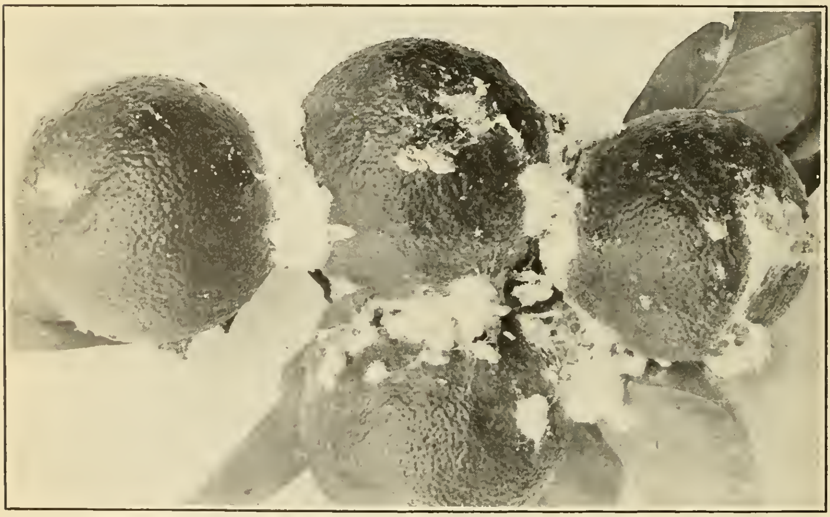

FIG. 2.—LEMONS WITH SEVERE INFESTATION OF MEALY BUG (P. CITRI), ACIREALE, SICILY. (ORIGINAL.)

DAMAGE TO CITRUS FRUITS BY THE MEALY BUG.

NATURAL ENEMIES.

The one important natural enemy of this scale in Italy, as elsewhere, is the Australian ladybird, *Novius cardinalis* Muls. This beetle, as already intimated, has been introduced into all the known colonies of the scale in Sicily. The beetle has also been distributed with success in Palestine.

Cryptochaetum icerya Will., a dipterous parasite, is the second most important enemy of the cottony cushion scale in some of the countries where it occurs, but it was not taken by the writer in Sicily. It is a small fly of a metallic green color, the larva of which lives within the scale.

THE CITRUS MEALY BUG.[1]

Pseudococcus citri Risso.

DISTRIBUTION AND INJURY.

The citrus mealy bug is found in greater or less numbers in nearly all parts of the citrus sections of Spain and Italy. It frequently occurs in serious numbers, and masses of the insects, with their cottony secretion and also much sooty-mold fungus, will be found on the leaves and fruit. In Sicily during the season of 1913 the writer unhesitatingly places the mealy bug at the head of all the citrus insect pests. *Chrysomphalus dictyospermi* is serious enough in several places, but the area involved is small as compared with that seriously infested with the mealy bug. The scale is also more amenable to treatment. The worst infestations of the mealy bug occurred along the east coast at Catania, Acireale, and Messina, and several intermediate points, though bad infestations were also seen at several points on the north coast. In many places the numbers were so great that the masses of cotton extended for an inch or two below the fruit. (Pl. VI, figs. 1 and 2.) Many of the lemons fell from the trees, others were stunted in growth, and a heavy dropping of the leaves occurred. The fallen fruit and leaves, with the insects and cotton still on them, gave the ground a distinctly whitish appearance.

Infestations of the mealy bug in Sicily in 1913 were just as severe and much more extensive than were those in the Ventura and San Diego sections in California a few years ago. Even outside of these extremely severe infestations, the insect was generally distributed and much more abundant throughout the entire citrus area in Sicily than was ever seen in California outside of the two sections mentioned.[2]

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[1] Spanish (Valenciana), *Cotonet;* Italian, *Cocciniglia farinosa degli agrumi;* Sicilian, *Cuttunedda.*

[2] The writer may be pardoned for making frequent comparisons between the Mediterranean citrus sections and that of California, but this is done for three reasons: First, people can best judge of conditions in foreign countries in terms of their own conditions; second, California is most like the Mediterranean citrus region; third, the writer is acquainted with citrus conditions in California.

It was stated by many people that the mealy bug was unusually abundant on the island in 1913.

LIFE HISTORY.

The mealy bug lays 300 or 400 eggs in the cottony mass that is secreted for the purpose, and these hatch in from 10 days to three weeks, according to the season. The development ranges from one month in summer to three in winter.

NATURAL ENEMIES.

The natural enemies of *P. citri* in Sicily are varied and numerous. The writer has found feeding on or attacking this insect one species of Hemiptera, two of Neuroptera, two of Coleoptera, two of Diptera, and six or seven of Hymenoptera. Of these, probably the most important is one of the species of Diptera. Two or three species of Hymenoptera were also very common, as well as one of the coccinellids.[1]

In spite of all these enemies the mealy bug was the worst citrus pest in Sicily in 1913. The increase and decrease of this insect there, however, may be very greatly influenced by the attacks of all these enemies.

PRAYS CITRI Millier.[2]

DISTRIBUTION AND INJURY.

Prays citri is the name of a small moth the larva of which often does serious injury to the blossoms of the orange and lemon. It is found in Sicily, in the Provinces of Calabria and Campania, and probably in other less important citrus sections of Italy. It was seen to be particularly abundant in the vicinity of Messina in August, 1913, and a large percentage of the blossoms and newly formed fruit was destroyed. It occurs from April to November, but is especially destructive to the blossoms of the forced *verdelli* crop, which occurs in midsummer. The injury is caused by the larvæ eating into all the flower organs—stamens, pistils, petals, and ovule.

LIFE HISTORY.

The eggs are deposited apparently upon the calices or peduncle of the flower, usually just prior to opening. The larvæ upon hatching bore through the inclosing parts to the organs within. Flowers thus attacked will have holes in the calyx, parts eaten out of the stamen, or burrows made into the pistil and ovule. Pupation usually occurs within the flower, but also in protected places on the leaves or forks of the twigs and branches.

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[1] These different species of parasitic and predaceous enemies of the mealy bug in Sicily may be treated in more detail in a later paper.

[2] Italian common name, *Tignola degli agrumi*.

RED SPIDERS.

One species of red spider was seen in all the citrus sections of Spain and Italy. With a few exceptions, however, the numbers were not sufficient to do any great injury. Over small areas, particularly along the roadside where there was considerable dust on the trees, many of the leaves had the characteristic light-colored mitelike areas. Not infrequently, too, the lemons would be scarred around the depression formed by the nipple at the calyx end, this situation being the most favorable feeding place on the fruit.

This species is identified by the Italian entomologists as *Tetranychus telarius*. What we have been calling *telarius* in this country has recently been made synonymous with *T. bimaculatus* Harv. The habits of *bimaculatus* in the citrus belt of California are very different from those of *telarius* in Spain and Italy. *Bimaculatus* has been observed to infest severely other food plants growing in the midst of citrus trees, both in California and Florida, without attacking the citrus trees at all. *Bimaculatus* on beans, violets, and a long list of other plants, feeds generally over the entire surface. *Telarius* in Spain and Italy feeds in restricted areas precisely as does *T. sexmaculatus* Riley on citrus trees. But red forms of *telarius* are common in Mediterranean countries, while in California all that have been observed of *sexmaculatus* are pale colored. The writer is not, however, necessarily assuming that *sexmaculatus* and *telarius* are synonyms, though their feeding habits are similar. He is, however, of the opinion that, judging from their difference in feeding habits, our *bimaculatus* and the European *telarius* are not synonymous if the Mediterranean citrus species is properly identified as *telarius*.

Another species which is flat and scalelike, probably a species of Tenuipalpus, was occasionally met with on citrus foliage in Sicily.

THRIPS.

A species of thrips, said to be *Heliothrips fasciatus* Perg., occasionally does some injury to the orange as shown by the marred fruit. (Pl. IV, fig. 3.) But thrips scars on the fruit in Spain and Italy are rare, so that the insect is of little economic importance. Around Jaffa, however, a species of thrips sometimes does considerable injury, and spraying has been necessary.

THE CONTROL OF CITRUS FRUIT INSECTS IN MEDITERRANEAN COUNTRIES.

With the exception of a little fumigation in Spain for the control of *Chrysomphalus dictyospermi*, and limited spraying in Sicily for the same insect, practically no remedial measures are employed for the control of citrus fruit insects in the countries bordering on the Mediterranean. This fact might be taken to mean that the pests there are of little economic importance because of their natural enemies, or for some other reason. But the lack of preventive measures in those countries as compared with California and Florida is largely a question of standards.

The black scale is as serious a pest in Spain as it is in California. A large share of the million dollars a year spent in California for the control of citrus pests is counted against this insect. The black scale is not, however, as serious a pest in Sicily as it is in California and Spain. The purple scale injures trees and mars fruit in Spain and Italy as it does in California and Florida. The long scale is more injurious in Spain than it is in Florida, so far as the writer's observations have extended in Florida. This scale is not reported from Italy. While it is recorded from one or two small sections in California, it is of no consequence as a pest. *Parlatoria zizyphus* not infrequently causes a heavy dropping of the leaves, and also attacks the fruit both in Spain and Italy. It is not a general pest in the groves of California or Florida. It is often taken, however, on lemons in the markets of the eastern States, having been imported from Italy. *Aspidiotus hederae* is a more serious pest on ripe lemons in Italy than it is anywhere in the United States. The mealy bug, *Pseudococcus citri*, ranks just as high, if not higher, as a pest in Spain and Sicily than it does in California. The citrus white-fly, the most serious of the Florida citrus pests, does not occur in the Mediterranean region.

Nothing in the way of artificial control is practiced against any of the foregoing insects in any of the Mediterranean countries. One or two cases were met with in Spain where the grower had tried some patent concoctions on a few trees. Pruning, however, may come in the category of control for insects in those countries more than it does with us, as the following dialogue may illustrate: "What do you do for the scales when they actually kill the twigs and branches as seen on the trees before us?" "We cut out the twigs and branches." Cutting out dead twigs and branches is, of course, a part of the pruning process, and not infrequently these dead parts are due to one of the foregoing insects. If the fruit is infested with the sooty-mold fungus, it is washed in sawdust, but the cause is not taken into consideration. If scales are present on the fruit, such fruit is placed in an inferior grade, or it is consigned to the by-product factory.

In the case of *Chrysomphalus dictyospermi*, however, a start in control work is really being made both in Spain and in Italy. This is no doubt due to the fact that this scale causes more complete injury to the trees—indeed, practically kills them. As before stated, fumigation was seen practiced in Spain last year at Piaporto, Picaña, and Piug in the Valencia section. Possibly it is practiced also in other places, but evidence was not seen elsewhere at the time of the writer's visit. Mr. R. S. Woglum, of this bureau, introduced fumigation in Spain in 1910, and it is being carried on in accordance with modern California methods. (Pl. X, fig. 4.) The cost as figured from a definite number of trees amounted to 1.10 pesetas, or about 20 cents per tree. In actual practice growers state that the cost averages from 25 to 30 cents a tree, which is about the same as that of California for trees of the same size. There are no large trees in the Valencia section and there are no seedlings.

Advocated by Dr. L. Savastano,[1] the well-known pathologist, director of the experiment station at Acireale, the use of lime-sulphur is becoming popular for the control of *C. dictyospermi* in Sicily. Fumigation is out of the question in most parts of Italy where citrus trees are planted solidly because of the nearness of the trees. Spraying, therefore, is the only artificial measure that may be employed. The lime-sulphur spray is intended to kill the young largely. It is applied in June and again in August or the first part of September. The strength used is 5 per cent of lime-sulphur of 1.25 gravity (29° Baumé). This is for summer use when high temperatures may cause burning if used stronger. During the winter it is used at a strength of 8 per cent and, if the infestation is severe and many of the leaves off, as high as 10 per cent. Lime-sulphur at the strength mentioned will probably kill most of the young that are hit, and if the application is repeated two or three times the numbers of the pest will be considerably lessened. Two or three sprayings are recommended at first to clean the trees, and then only one spraying annually thereafter. The same spray is recommended by Dr. Savastano with good results against *Aspidiotus hederae* and *Lepidosaphes beckii*.

The spray as used in the groves of Sicily is applied by means of a hand pump mounted on a wheelbarrow truck. This is about as large an outfit as may be used under the trees. No horses ever enter most of the Italian citrus groves, all the work of cultivation, etc., being done by hand labor. From the writer's observations a very great improvement resulted from the applications of lime-sulphur. Not all the insects were, of course, killed, but the numbers were greatly lessened, and a marked improvement in the trees resulted. This spray has the advantage, also, of checking many of the possible fungous troubles as well as stimulating the growth of the tree.

Aside from the control measures mentioned, Dr. G. Brigante[2] states that the worm, *Prays citri*, of the blossoms may, if necessary, be handled by a 1 per cent solution of lead arsenate. But poison sprays are in bad repute in Italy.[3] Prof. Ampola and Dr.

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[1] Savastano, L. Le conclusioni pratiche per la poltiglia solfocalcica (formo a della Stazione). R. Staz. Sper. di Agr. e fruitti coltura, Acireale, Sicily. Bol. no. 11, 11 p., April, 1913.

[2] La coltivazione degli agrumi in Provincia di Salerno, Dott. G. Brigante, Direttore Cattedra Ambulante di Agricoltura per la Provincia di Salerno, 1912.

[3] Insetti damnosi e composti arsenicali, Teodosio De Stefani, Gazetta Commerciale, Palermo, p. 5–10, 1912.

Tomasi, of the Station Chimico-Agraria Sperimentale di Roma, strongly recommended the prohibition of arsenicals for general agricultural purposes. They conclude that their use is injurious to all sorts of plants and animals, but the most potent of their reasons is that the farmers, instead of poisoning their insect foes, might destroy human life. In addition to these control measures practiced in Spain and Italy, a small amount of spraying has been done around Jaffa in Palestine for a species of thrips on the orange. From the little evidence of thrips work that was seen at Jaffa the species occurring there is not *Euthrips citri*, as was supposed.

MEDITERRANEAN CITRUS FRUIT INSECTS THAT DO NOT OCCUR IN THE UNITED STATES AND THE POSSIBILITY OF THEIR INTRODUCTION.

Of the citrus insects discussed in the foregoing pages, two do not occur in the United States, namely, *Ceratitis capitata* and *Prays citri*. Two others, *Chrysomphalus dictyospermi* and *Parlatoria zizyphus*, while occurring in the United States, do not appear to be established as important pests, as is the case in the Mediterranean region. Concerning the distribution of these two scales, Mr. C. L. Marlatt, under date of March 5, 1914, writes as follows:

> *Chrysomphalus dictyospermi* is frequently found on palms and quite a number of other plants which are probably imported, and has a wide distribution in greenhouses. Out of doors it does not seem to thrive very well on this continent, and I think we have very few outdoor records of it, and these naturally from southern points. It has been so often brought into this country that its failure to establish a foothold in citrus orchards apparently indicates unfavorable conditions for this insect, but it is, of course, possible that this may have resulted, after all, from lack of favorable opportunity. *Parlatoria zizyphus*, as you know, is brought to this country all the time on Italian lemons, and has been found in the open market wherever these lemons are sold, including well-established citrus districts such as those of Florida and Louisiana.

In case these two scales did become established in our citrus groves our present control methods, at least fumigation, would handle them successfully. This fact, however, should be no exccuse for not quarantining against them. On the other hand, the other two, *Ceratitis capitata* and *Prays citri*, would not only be serious pests but would not be controlled by any of our methods now in use for citrus trees. Ceratitis, moreover, is not limited as a pest to citrus fruits; indeed, citrus fruits are by no means its favorite food, but it attacks a long list of deciduous fruits. The scope of this paper has to do, however, chiefly with citrus fruits.

The first shipments of oranges are made from Spain as early as October, and a few of the mature fruits at this time may contain larvæ of Ceratitis. But with the approach of cold weather in November and December the fly disappears. The time when infested fruits might be received from Spain is at the beginning of the shipping season in October and November, and again during the final shipments, the last of June and first of July. The reason more infested oranges do not occur in Spain is not, as has been suggested, because the fruit is picked too green, but because practically all the fruit matures and is harvested at a season when the fly is not active or breeding. This applies to practically all semitropical countries where citrus fruits are grown commercially. Plenty of oranges were seen in Spain that were fully mature in March, but which were not harvested until May or June. The heavy shipments do not begin in Spain until November, and by May the season is virtually ended.

What has been said regarding oranges in Spain applies to all the Mediterranean citrus sections. Up to the middle of October in Palestine the oranges were still too green to be infested with Ceratitis. Even though the fly may be present and actually deposit eggs in the fruit, there is no danger of the larvæ developing if the fruit is immature. In spite of numerous punctures and eggs in the fruit which were seen in Sicily up to October 1 and in Palestine up to October 15, no larvæ succeeded in developing or getting beyond the egg cavity, but there perished.

The lemon is an unusual and rare host for Ceratitis, at least in the great lemon-producing section of Sicily. It was only very rarely, and, it must be admitted, more or less accidentally, and after much persistent searching, that lemons were found infested in Sicily. Out of numbers running into hundreds of thousands only 15 were found infested. And all of these infested lemons were so badly broken down by decay that they would not only be rejected for shipping, but, with three or four exceptions, would be rejected for the by-product factory. So far as one season's experience in Sicily warrants the conclusion, therefore, there is only the remotest possibility of the entrance of Ceratitis into this country through the importation of lemons from Italy.

In the case of most other fresh mature fruits, which are harvested between May and November, inclusive, and coming from the Mediterranean countries, the possibility of Ceratitis introduction can be removed only through a strict embargo against such fruits or a subjection to a rigid inspection.

THE OLIVE FLY.

Dacus oleae Rossi.

Since the olive is usually grown in the same countries as citrus trees, it may be pertinent in this place to mention the olive fly. This insect, *Dacus oleae*, is one of the most serious pests of the Mediterranean countries. In fact it is the opinion of the writer that it far outranks *Ceratitis capitata*. A heavy infestation of the olive fly has been seen in different places, but particularly in Sicily and southern

Italy. Most of the olives attacked fall to the ground before reaching maturity. In the case of the olive fly, mature fruit is not at all necessary for infestation. Because of the economical use made of all the inferior fruit in these countries—something we have yet to practice—infested olives are not a complete loss, for they are used for oil, most of which is used in the manufacture of soap. The striking difference in habits between the olive fly and the Mediterranean fruit-fly is that, with the former, pupation occurs within the fruit, instead of in the ground or otherwise out of the fruit as is the case with Ceratitis.

Infested olives may be distinguished by a circular area on the surface that is of a light gray color. Before entering the pupal stage the larva eats out a channel to the surface of the fruit, leaving only the thin epidermis. It is this, with the tissue eaten away below, that forms the characteristic gray area that indicates infestation. It is much the same as that made in the case of the pea and bean weevils. Having completed the burrow to the surface, the larva retreats a short distance and transforms to the pupa, enclosed in the characteristic puparium, that looks much like that of Ceratitis. Upon emerging the adult fly breaks through the epidermis, which has been left for protection, by means of its ptilinum.

Fortunately olives are not transported unless pickled, and thus the danger of introduction is not great. But a sharp lookout should be kept for any olives that might possibly be imported fresh from these countries, since the egg, larval, and pupal stages are all passed within the fruit.

THE MEDITERRANEAN CITRUS FRUIT INDUSTRY.[1]

SPAIN.

LOCATION.

The most important citrus section of Spain, where 90 per cent of the crop is produced, consists of a narrow strip, 10 or 15 miles wide and 150 miles long, extending from Denia in the Province of Alicante northward as far as Vinaroz in the Province of Castellon. This is the so-called "Valencia section," the city of Valencia being situated somewhere near the center of the strip. In this section are recognized two distinct districts, the "Ribera" and the "Plana." The "Ribera" lies to the south of Valencia and centers chiefly about the towns of Alcira and Carcagente. This district is more or less rolling and hilly and is separated from the sea, which is 15 or 20 miles distant, by hills and mountains. The "Plana" lies north of the City of Valencia and centers about the town of Burriana. This is a perfectly flat plain and borders directly on the sea. Around the

[1] In this account of the Mediterranean citrus industry only such phases are presented as are necessary to a better knowledge of the insects discussed in the earlier pages of this paper.

FIG. 1.—INTERIOR OF PACKING HOUSE AT ALCIRA, SPAIN. (ORIGINAL.)

FIG. 2.—THE RAILROAD PACKING HOUSE AT CARCAGENTE, SPAIN. (ORIGINAL.)

SORTING AND SHIPPING CITRUS FRUITS IN SPAIN.

FIG. 1.—HAULING ORANGES TO THE BOAT LANDING AT BURRIANA, SPAIN. (ORIGINAL.)

FIG. 2.—LOADING ORANGES IN SMALL BOATS TO BE TRANSPORTED TO STEAMER, BURRIANA, SPAIN. (ORIGINAL.)

ORANGES IN TRANSIT IN SPAIN.

city of Valencia itself in the "Heurte de Valencia" there are few oranges grown, excepting at Piaporto and Picaña and to the westward of these villages.

Going farther southward the next important orange section is at Murcia, and then at Malaga, with a few scattering groves between. In the Malaga section probably the most important center is at Alora, some distance back from the sea, and in a mountainous country. The next important section of Andalusian Spain is in the vicinity of Seville. Here, however, practically all of the crop is of the bitter variety and is shipped to Great Britain and made into marmalade.

METHODS OF HANDLING CROP.

The harvesting season in Spain extends from October to July, with the heaviest shipments occurring from November 15 to December 1. The oranges are picked in small baskets and from these are dumped into larger baskets along the roadside or edge of the grove, thence being carried, by means of carts, to the packing house. They are here spread on the floor to a depth of about 2 feet, the floor and sides for a couple of feet being first covered with a layer of rice straw. Women sit around the edge of these piles of fruit which, if infested with sooty-mold fungus, is rubbed first in wet and then in dry sawdust to remove the mold. Other women then sort out the fruit in three different sizes, entirely by sight, and also discard the culls. The fruit is then wrapped in paper by other women and packed in the boxes.

The three sizes of fruit are represented by the cases containing respectively 420, 714, and 1,064, and which weigh 165 pounds each, or about twice that of the American box. There is absolutely no machinery in a Spanish packing house, all the processes of handling, grading, washing, and box making being done by hand. The packing house itself is, therefore, simple, consisting of four walls and a roof, the earth forming the floor. (Pl. VII, fig. 1.) The appurtenances consist of the shipping cases, a good supply of shallow wicker baskets, and plenty of women to do the work. The time the fruit remains in the packing house depends largely on the departure of the steamer and varies from a day or two to more than a week.

After the fruit is packed in cases it is hauled, in carts, without springs, to the boat landing. Here the cases are unloaded along the shore and later placed in small boats and finally transferred to the steamer. At Burriana, the port of the "Plana" district, from which 2,000,000 cases are shipped annually, there is no pier, and the small boats are pulled up on the gravelly beach by oxen. (Pl. VIII, fig. 2.) The town, which is about 2 miles inland, and in which there are upwards of 100 packing houses, is not connected with the beach by any railroad, and all of the 2,000,000 cases are hauled in carts each year, over a very bad road. (Pl. VIII, fig. 1.)

The foregoing description applies to the fruit sent by sea. A very small amount of the crop that is sent by railroad is also packed in boxes and handled in the way described. But nearly all of the fruit shipped by railroad is simply conveyed in loose carload lots. From 10,000 to 15,000 tons are exported from the Valencia district in this manner, while 400,000 to 450,000 tons are shipped by sea. Where the fruit is to be shipped by railroad in loose carload lots, the packing house occurs alongside the railroad. These packing houses are even simpler than those already described, for they consist simply of a roof, the sides being left open. The earth is graded up to the height of the floor of the car to facilitate the transfer of the fruit. The floor of this open-air packing house is covered with rice straw, as are also the floor and sides of the car. The cars are usually of the pattern of our stock cars, with lattice work on the sides to allow for plenty of ventilation. (Pl. VII, fig. 2.)

The oranges are brought from the field directly to the railroad packing house, where they are piled on the floor. Women here give the fruit the sawdust treatment, if needed, and the culls are discarded. It is now ready for the car, where it is carried in baskets and filled to the depth of a couple of feet. Such fruit goes mostly into France, or to other parts of Spain.

PRODUCTION AND EXPORT.

From figures kindly furnished by Mr. Claude I. Dawson, American consul at Valencia, the total production of oranges for the season 1912–13 amounted to nearly 7,000,000 cases of 165 pounds each. This amounts to about 38,500 California carloads or 45,117 Florida carloads. Of this amount 5,573,627 cases were shipped by sea, as follows:

	Cases.
Great Britain	2,253,076
Germany	1,374,829
Holland	501,645
Norway and Sweden	84,374
Austria-Hungary	18,110
Denmark	17,103
France	6,033
Russia	1,000

The overland shipments to France approximated 1,200,000 cases, and the remainder of the crop was consumed in Spain.

According to the figures of the United States Bureau of Statistics there were shipped into the United States from Spain in 1912, 9,000 pounds of oranges and lemons (not separately listed), valued at $204. The only records the writer was able to obtain in Spain of orange shipments to the United States were of a few small shipments during the last two or three years from Seville. The use made of these shipments was not known, but was no doubt for the manufacture of marmalade, as is the case with all the bitter orange product of Seville. One hundred and fifty thousand cases are exported annually from Seville, mostly of the sour or bitter orange, and practically all are sent to Great Britain for the manufacture of marmalade.

ITALY.

LOCATION.

The important citrus fruit areas of Italy are on the Island of Sicily, in the Provinces of Calabria and Campania, and along the Riviera di Ponente and the Riviera Levante.

The most extensive section, particularly for lemons, is in Sicily. The area extends along practically the entire north and east coasts. There are, of course, breaks in this strip, as where the mountains extend abruptly to the sea, or where grapes largely occupy the territory, as at Milazzo, Carruba, and Riposta, or on the plain south of Catania, where various other crops are grown. The limits of this area are the Gulf of Castellammare on the north and Avola, below Syracuse, on the east coast. Even within these limits lemons do not occur solidly because of the irregularity of the land, lack of water, and unsuitable soil. Most of the lemons are grown in close proximity to the coast, but occasionally they extend inward for several miles, as at Monreale, Alcantara, and Floridia. Occasionally citrus trees will be found in the interior valleys, but here it is largely oranges, probably because of the greater likelihood of frost.

In the Province of Calabria there is a considerable area of citrus fruit along the coast from Reggio to Rosarno and farther northward and inland at Cantanzaro and Cosenza. The Campania section is situated principally along the coast from Salerno through Majori and Amalfi to Positano. Here the trees are grown on terraces (Pl. IX, fig. 1), formed on the very abrupt slopes extending upward from the sea. Unlike other sections, also, the trees are covered with trellis, on which, during the winter for protection against frost and wind, is placed straw and brush. The Riviera section consists of a narrow and much broken strip extending from Ventimiglia on the French border to Spezia.

METHODS OF HANDLING CROP.

Lemons in Sicily are harvested practically every month in the year, the heaviest shipments occurring in the spring and early summer, while the fewest shipments occur during the month of August. The number of pickings in any particular grove is from four to six. The lemons are broken from the tree by hand, leaving two or three inches of stems with the fruit. These are placed in small baskets, supported in the tree or carried on the arm, and when filled are carried to the men who clip off the extra stem, leaving the usual button. In the case of *verdellis*, green lemons, during the summer, these are sometimes broken from the tree by means of a forked bamboo rod. This rod is long enough to reach to all parts of the tree from the ground, and the fruit is simply allowed to fall as it is twisted off. When asked about the effects of bruising by such a method, it was stated that the fall does not hurt the green fruit. Such a method is rapid, since the lemons are quickly twisted off and allowed to fall, and are picked up, usually by small boys, but it is not practiced by the best growers.

The fruit with the small buttons is placed in baskets and carried thus to the field packing house (Pl. X, fig. 3). Here it is roughly graded, and the culls are separated for consignment to the by-product factory. It is placed in the regular shipping boxes (Pl. X, figs. 1, 2), but thrown in loosely, with paper around the inside of the box. Sometimes with the better grades, and in the case of long hauls, each lemon is wrapped separately. In these shipping boxes the fruit is carried in carts to the town or exporter's packing house, where it is regraded, sorted, and packed back in the same boxes, when it is carried in carts to the lighter, and thence to the steamer for final shipment. (Pl. IX, fig. 2.)

The time the fruit remains in the field packing house may vary from 1 to 3 or 4 days, or longer; in the exporters' packing houses, from a day or two to a week or two. The average time of transit from Palermo to New York is 12 or 15 days. The time between the picking and the landing of the fruit in New York may thus range from 18 days to 30 or 40 days.

A large percentage of the fruit that is harvested during the spring and early summer is what is called in California tree-ripe fruit, while that harvested in midsummer and fall is mostly green fruit, or *verdellis*. *Verdellis*, of course, occur with the yellow fruit, and they are packed separately and so consigned. The large proportion of *verdellis* which occur in midsummer are artifically produced. During the previous summer water was withheld from the trees for about six weeks, and then two or three irrigations were applied in quick succession. This procedure causes the trees to throw out an unusual amount of blossoms which mature into fruit the following summer. This fact of a very large preponderance of green fruit during the summer and fall has an important practical bearing in connection with the possible infestation of the Mediterranean fruit-fly. It is during the summer and fall that the fly is most actively breeding. Very little yellow fruit appears before November, but from that time until the following July it is nearly all yellow fruit. No place was seen in Sicily where lemons are subjected to forced curing, as they are in California.

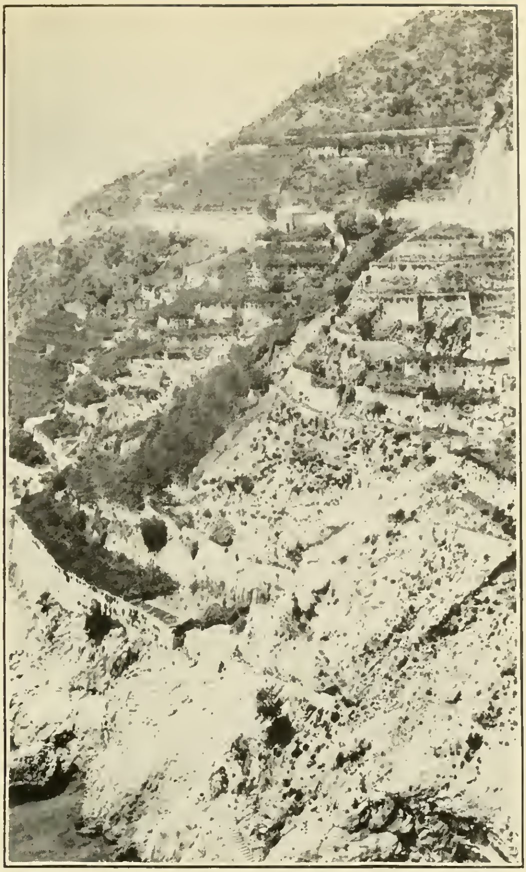

FIG. 1.—THE FAMOUS TERRACED LEMON GROVES ON THE AMALFI COAST OF ITALY. (ORIGINAL.)

FIG. 2.—LIGHTERS OF THE FELLUCA TYPE CARRYING LEMONS TO THE STEAMER, PALERMO.

LEMONS IN ITALY.

FIG. 1.—TRANSPORTING LEMONS IN THE HILLY SECTION OF SICILY, WHERE THE ROADS ARE POOR. (ORIGINAL.)

FIG. 2.—OPEN CARS (NO ROOFS) LOADED WITH BOXED LEMONS FOR TRANSPORTATION FROM THE SMALLER TOWNS TO THE SEAPORT, SICILY. (ORIGINAL.)

FIG. 3.—A "FIELD" PACKING HOUSE AND CART WITH BASKETS OF LEMONS FROM THE NEAR-BY GROVES, SICILY. (ORIGINAL.)

FIG. 4.—A FUMIGATING TENT, IN POSITION, SPAIN. MODELED AFTER THE OUTFITS ORIGINATING IN CALIFORNIA. (ORIGINAL.)

FIG. 5.—A LABORATORY AT PALERMO; THESE ARE THE PEPPER TREES. (ORIGINAL.)

TRANSPORTING LEMONS IN SICILY. FUMIGATION OF CITRUS TREES IN SPAIN.

PRODUCTION AND EXPORT.

The total acreage exclusively in citrus fruits in Italy in 1909, according to Powell,[1] was 108,400 acres, and 170,000 acres on which other crops were grown. A total of 85,252 acres were grown in Sicily, out of which 4,102 acres were in mixed cultivation; 13,890 acres entirely in citrus fruits were in the Province of Calabria and 9,385 acres in the Province of Campania.

The total production of lemons in Italy, including that converted into by-products and that used in home consumption, in 1911 was 1,192,701,829 pounds, or 47,785 of our carloads, basing this calculation on the size of the California box of lemons, which is estimated to weigh 80 pounds, and on the number of these boxes, namely, 312, loaded in the California cars. The exports of lemons alone were 570,306,431 pounds, or 22,841 of our carloads. The United States during the past 10 years has received about 35 per cent of the total exports. In 1910 the distribution among the principal countries was as follows:

	Per cent.
United States	31.5
Austria Hungary	19.8
United Kingdom	19.5
Germany	11.3
Russia	8

In 1911, 96 per cent of our Italian lemons came from Sicily, of which 86.4 per cent were from Palermo, 9.8 per cent from Messina, and 3.8 per cent from Naples, including the Amalfi Coast district. The Italian box contains about 73 pounds of fruit, which is chiefly in 300 and 360 per box sizes. About half of the total imports arrive here in May, June, and July; 85 to 90 per cent are received in New York, about 5 per cent in Boston, and smaller quantities in New Orleans, Philadelphia, Baltimore, and a few other places.

According to the United States Bureau of Statistics, the total imports of lemons from Italy in 1912 were 145,275,122 pounds, valued at $3,359,115; of oranges, 401,161 pounds, valued at $9,319.

FRANCE AND ALGERIA.

No extended observations were made in the citrus sections of France and Algeria. In France the area appears to be limited to a short and much broken strip along the Mediterranean Coast, the French Riviera, extending from Cannes to Menton on the Italian border. In northern Africa the most extensive production of oranges is in Algeria. But the output there is not large, for Algeria and France together do not produce nearly enough for home consumption in France, as evidenced by the large imports from Spain.

[1] The figures here given are from Powell, Harold C., and Wallschlaeger, F. O. The Italian lemon industry. *In* Citrus protective league of California, Bul. 10, 58 p., Jan., 1913.

PALESTINE AND EGYPT.

In the eastern Mediterranean countries the most important citrus-producing sections are in Palestine and Syria. The largest and most important district is in the neighborhood of Jaffa, the home of the well-known Jaffa orange; 1,600,000 boxes (same size as ours) were shipped from Jaffa alone last year. Most of these were sent to the Liverpool market, with smaller amounts, and of poorer grade, to Turkey, Egypt, and other near-by countries. In all the earlier plantings around Jaffa the trees are very close together—9 to 12 feet. In the later plantings, however, and particularly in the Jewish colonies, where all the best groves are located, they are from 14 to 18 feet apart. Irrigation is by the basin system, and the source is from wells, from which the water is pumped, in the Jewish colonies, by gasoline engines. On account of the sandy soil largely, water is applied every 8 or 10 days. The methods of packing and shipping are much the same as in Italy and Spain. Mr. A. Bril, a prominent grower and manager of the Jewish colonies around Jaffa, who visited the United States last year, has adopted California methods, and the fruit so handled and packed brought 25 cents a box more than other fruit.

Aside from Jaffa there is another small section around Acre, farther to the north and also along the Palestine coast. Still farther north in Syria there are citrus sections at Saida and Tripoli, there being a considerable lemon acreage in the latter place.

In Egypt citrus culture is limited to scattering groves, most of which are poorly cared for, and from which the production is limited to local consumption.

METEOROLOGICAL DATA FOR VALENCIA, SPAIN, AND PALERMO, ITALY.

Since meteorological conditions may have a very great influence on many insects, as has been specifically pointed out in the case of the black scale, the following data are given for the most important orange and lemon centers, respectively, of the Mediterranean countries.

It will be noted from the following tables that, excepting 1910, higher temperatures prevailed at Palermo than at Valencia. High temperatures at Palermo, moreover, are accompanied by extreme dryness, and usually much wind. This combination of heat and very great evaporation is sufficient to account for the scarcity of the black scale in Sicily, as compared with Valencia, Spain. The writer is also inclined to attribute the scarcity of the purple scale in Sicily to this same cause. In the United States the purple scale thrives best in Florida and the coast counties of southern California. While rather high temperatures prevail in Florida, there is also much humidity. The distribution of the purple scale at present in the United States is, therefore, limited to sections of more or less moisture. In this respect it is like the black scale, but the black scale does not thrive so well in high temperatures, even if accompanied by much moisture. The purple scale does not yet occur in the interior counties of southern California or in the great valleys of that State. Of course this may be due to the close quarantine that has prevailed in those sections in recent years against the purple scale. But judging entirely from its present distribution, the purple scale appears to be restricted to regions of more or less moisture, or at least to those in which the combination of high temperatures and low humidity does not prevail.

Temperatures at Valencia, Spain, and Palermo, Italy, January, 1910, to August, 1913, inclusive.[1]

	Valencia, Spain.			Palermo, Italy.		
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
1910.	°F.	°F.	°F.	°F.	°F.	°F.
January	72	37	50	69	35	50
February	79	33	54	71	35	50
March	70	35	52	69	35	52
April	83	32	58	87	39	58
May	84	40	62	79	44	61
June	95	49	70	86	52	68
July	102	52	74	91	55	72
August	99	57	74	91	58	74
September	84	53	62	90	53	69
October	81	43	65	94	50	68
November	79	37	58	87	37	58
December	72	34	53	77	38	55
1911.						
January	66	35	46	64	31	48
February	81	35	51	72	30	49
March	70	33	53	82	34	55
April	88	35	56	80	39	56
May	83	42	63	80	47	62
June	86	53	69	86	52	70
July	98	59	69	92	52	76
August	95	60	77	93	64	79
September	96	55	73	105	56	74
October	80	42	64	93	51	69
November	75	35	55	80	45	62
December	71	33	53	70	38	55
1912.						
January	71	35	51	70	35	52
February	77	33	55	71	37	55
March	84	37	58	73	40	57
April	75	37	57	79	41	57
May	94	43	65	93	45	64
June	86	50	68	87	54	70
July	97	59	74	106	59	77
August	100	48	74	92	57	75
September	96	52	68	83	51	66
October	86	45	63	79	50	64
November	79	33	55	74	42	54
December	70	36	50	68	40	52
1913.						
January	....	....	....	65	37	52
February	....	....	....	67	33	50
March	....	....	....	84	36	54
April	....	....	....	79	40	59
May	....	....	....	85	47	64
June	....	....	....	88	53	70
July	....	....	....	95	56	74
August	....	....	....	107	57	75

[1] In converting centigrade into Fahrenheit, fractions have been discarded.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

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DIV. INSECTS

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 156

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 27, 1915.

(PROFESSIONAL PAPER.)

DIV. INSECTS

WIREWORMS ATTACKING CEREAL AND FORAGE CROPS.

By J. A. Hyslop,
Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

Wireworms are the larvæ of several kinds of hard-shelled beetles belonging to the family Elateridæ. The beetles are known colloquially as "click-beetles," "skip-jacks," snapping beetles, etc.[1] These names are all derived from the beetles' unique habit of snapping the forepart of the body when placed upon their backs or held between the fingers. This habit is undoubtedly of use to the beetles in righting themselves when accidently overturned, and may also be a means of escape from their predatory natural enemies.

Wireworms are elongate, more or less cylindrical, having a very highly chitinized cuticle, and measuring, according to the species, from one-half inch to over 3 inches in length. They have three pairs of short legs near the anterior end of the body. The color is usually yellow or reddish-brown. The cotton and corn wireworm is an exception to this description.

The false wireworms (fig. 1, *a*) will also answer to the above description, but can easily be distinguished by their ability to move very rapidly and by the clavate last joint of the antennæ; the true wireworms, though able to move rapidly in the soil, are not very agile when placed on the surface of the ground, and their antennæ never have clavate terminal joints. The term "wireworm" is also, though erroneously, applied to these false wireworms, which are, however, the larvæ of another group of beetles, the darkling beetles (Tenebrionidæ). These beetles can not snap the forepart of the body. One species of darkling beetle (*Tenebrio molitor* L., fig. 1, *b*) is common throughout the United States, and its larva, the meal-

[1] The Cherokee Indians recognize the large-eyed elater (*Alaus* sp.) by the name "tulskuwa," which means "one that snaps with his head." This interesting note was made by Dr. J. W. Fewkes and communicated to the writer by Mr. F. M. Webster.

worm, is found in granaries and warehouses, where it feeds upon stored products. Another genus (Eleodes) is found only in the territory west of the Mississippi River, and attacks cereal crops in the field. The name "wireworm" is also incorrectly applied to several species of millipedes (*Julus* spp., fig. 1, *c*).

The true wireworms, from an economic standpoint, are among the five worst pests to Indian corn and among the twelve worst pests to wheat and oats. They are also important pests to many other crops. Since 1841, when Dr. Thaddeus Harris first published an account of these insects,[1] the literature of economic entomology has been replete with references to their depredations, and from the standpoint of the entomologist, as to the difficulty of combating them, they probably rank second only to the white grubs (*Lachnosterna* spp.).

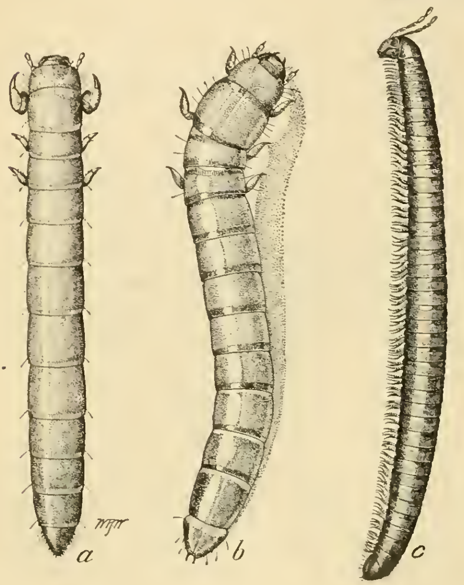

FIG. 1.—Larvæ likely to be mistaken for wireworms: *a*, False wireworm; *b*, mealworm; *c*, *Julus* sp. All enlarged. (Original.)

In view of the recently enacted Federal quarantine bill these insects assume an added interest, inasmuch as they can easily be introduced in the larval condition within fleshy roots, bulbs, and tubers. Mr. E. R. Sasscer, of the Federal Horticultural Board, recently intercepted an elaterid larva in the root of *Aralia cordata* from Japan: the larva was in good condition and is still alive in our laboratory (October, 1914). The writer has often seen the larvæ of *Agriotes mancus* Say within potato tubers that had been in a root cellar all winter.

These insects are destructive to cereal and forage crops in the larval stage only, although the adults of certain species (*Limonius discoideus* Lec., etc.) do considerable damage to the blossoms of fruit trees in the Pacific Northwest, and Fletcher reports[2] similar depredations of the adults of two other species (*Corymbites caricinus* Germ. and *C. tarsalis* Melsh.). The forms attacking cereal and

[1] Harris, T. W. Report on the Insects of Massachusetts Injurious to Vegetation, p. 46–50. Cambridge, 1841.

[2] Fletcher, James. Report of the Entomologist and Botanist, Central Experiment Farm, Canada, for 1892, p. 4. Ottawa, 1892.

forage crops confine their attention to the seed, roots, and underground stems and are exclusively subterranean, with the single exception recorded by Mr. E. O. G. Kelly, of this office, wherein he mentions finding a species (*Monocrepidius vespertinus* Fab.) damaging wheat at Wellington, Kans., by boring in the hollow of the wheat stems and not among the roots.

Their depredations are first to be noticed, with the exception of the cotton and corn wireworm, immediately after seeding, when they attack the seed, eating out the inside and leaving only the hull. When they are very numerous they often consume all the seed, making reseeding necessary, and in severe outbreaks a second reseeding is sometimes made before a stand is obtained. Aside from the extra labor and cost of the seed, this delays the planting of the crop, and if it be corn, in the Northern States the season is too short to mature so late-planted a crop and, except for the fodder, it is a failure. Where wireworms are present, even in very small numbers, corn will make a poor stand, which will necessitate the planting-in of missing hills. In some regions where these insects are quite numerous it is customary to sow three or four times the amount of seed that would normally be necessary in order to get a good stand.

KINDS OF WIREWORMS.

Several hundred species of Elateridæ occur in North America. They vary enormously in their habits, some forms living in dead and rotten wood (Alaus, Elater, Adelocera, etc.). Alaus has also been recorded as boring in solid wood, though the writer is inclined to discredit this observation, and other species live under moss (Sericosomus). A number of species abound in heavy moist soil filled with humus (Melanotus, Agriotes, etc.), while some prefer well-drained soils (Corymbites), and still others (Horistonotus) are most destructive on high sandy land which is very poor in humus. Many wireworms have been recorded as predaceous (Alaus, Hemirhipus, Adelocera, etc.). I am told by Mr. T. H. Jones, recently associated with the Rio Piedras Sugar Planters' Experiment Station, that the large luminous elaterid (*Pyrophorus luminosus* Illiger) of the West Indies is a decidedly beneficial insect, as it feeds on the Lachnosterna larvæ in the sugar-cane fields. Through the kindness of Mr. G. N. Wolcott and Mr. R. H. Van Zwalenburg I now have (October, 1914) a Pyrophorus larva from Cuba, one from Jamaica, and several from Mayaguez, P. R. All of these larvæ are living and apparently thriving on the larvæ of our native Lachnosternas. That this insect may some day be introduced into the southern United States as a natural enemy of Lachnosterna is not at all improbable. At least one instance has been noted[1] in which a wireworm [*Lacon* (*Agrypnus*) *murinus* L.] lived in the stomach of a child. Most of our common species lay their eggs on sod or very weedy land, but the wireworms (*Corymbites* spp.) of the dry-farming country of the Pacific Northwest are severe pests on land that has been seeded to wheat, by the summer fallow method, for the past 15 years, and, as this land was originally sage-brush prairie, it probably never was in sod.

Several distinct kinds of true wireworms are destructive to cereal and forage crops in the United States; and since, as has already been stated, the different kinds vary more or less in their life histories, there is consequently a variation in the method of control as recommended in the following pages of this bulletin. It is therefore quite necessary to determine the identity of the wireworm, and to meet this necessity the many species of importance as pests to cereal and forage crops are treated separately.

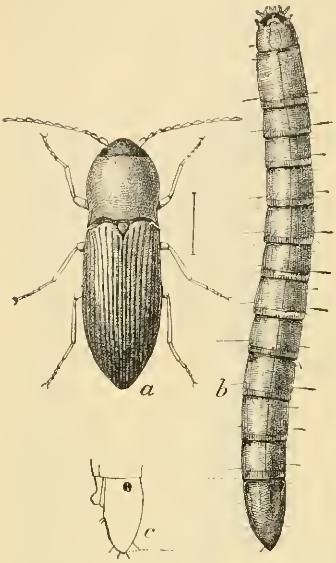

FIG. 2.—The wheat wireworm (*Agriotes mancus*): *a*, Adult beetle; *b*, larva; *c*, side view of last segment of larva. All enlarged. (From Chittenden.)

THE WHEAT WIREWORM.

(*Agriotes mancus* (Say), fig. 2.)

The adult of the wheat wireworm is a small brown beetle a little over one-fourth of an inch in length, quite robust, and moderately covered with very short, fine hair. The larva is pale yellow in color, very evenly cylindrical, and very highly polished. When full grown the larva measures about an inch in length and is about as thick as the lead in a lead pencil. These wireworms will be readily recognized by the singly pointed ninth abdominal segment and the two black spots on the upper side of this segment near its base.

This is one of the most common wireworms of the northeastern and middle western United States. A report of this species as a pest in the dry-farming regions of Washington State[2] is undoubtedly a

[1] Sandberg, G. El tilfälde af Coleopterlarvers tilhold i tarmkanalen hos et Menneske. In Entomologisk Tidskrift, v. 11, p. 77–80, 1890.

[2] Scobey, J. O'B. Wireworms. Washington Experiment Station. (State Agricultural College and School of Science.) Bulletin 4, p. 75–80, 3 figs., May, 1892.

misidentification, the insect probably being *Corymbites* sp. The wheat wireworm is normally a grass feeder, living on the roots of sod, and with the abundance of its natural food supply producing no appreciable disturbance in the meadows, but when the sod land is broken these wireworms concentrate in the drill rows or hills of corn, the usual crop to follow sod in the eastern United States, and often cause absolute failure of the crop by destroying the seed and eating off the roots of such plants as may germinate. This species is usually more destructive, therefore, on land recently broken from sod. Last year (1913) the writer investigated an outbreak in northern New York and located as many as 10 wireworms to the hill in cornfields, rendering the crop, so far as grain was concerned, an absolute failure. This year (1914) the same field was again planted in corn, and again the wireworms destroyed most of the crop.

The larvæ spend three years in the soil before transforming to beetles, so that the depredations of this pest may be looked for during the second season as well as the first following the breaking of sod.

LIFE HISTORY.

The beetles are in evidence early in the spring, and at this time can be swept from wheat and, in fact, from any vegetation around the fields, or they may be found under boards and rubbish. Mating occurs during April and May, and immediately egg-laying begins. The eggs are deposited in grasslands exclusively, so far as our observations go, the female burrowing into the ground or under rubbish to oviposit. The young larvæ feed during the ensuing summer, and, hibernating when about half grown, resume feeding the following spring. They continue to feed during the second summer and hibernate the second winter as full grown or mature larvæ. The third spring they resume feeding and continue it until early in July, when they leave the plants and form small earthen pupal cells in the soil.

In 1913 Agriotes started to pupate about July 15 in northern New York. The writer found many mature larvæ and pupæ in the fields at Bridgeport, N. Y., on the shore of Lake Oneida, on July 17, while investigating a severe outbreak of this pest on the farm of Mr. C. J. Fisher. Other larvæ collected at Bridgeport pupated as late as August 12. In 1914 several hundred larvæ were reared in the Hagerstown laboratory. All that became adult this year pupated between the middle and the end of July. The pupal stage varied in duration from 15 to 21 days.

Specimens collected by Mr. J. J. Davis, of this bureau, at Watertown, Wis., pupated on August 8. Mr. Pettit found the pupæ in the rearing cages on August 26 and adults emerged as late as the middle of September at Grimsby, Ontario, Canada.[1]

The pupal stage usually lasts from 15 to 19 days. One specimen collected at Watertown, Wis., by Mr. Davis pupated on August 8 and the adult emerged August 19. A specimen collected at Bridgeport, N. Y., pupated on August 12 and emerged September 1. Other specimens collected July 25 at the latter place became adult August 12.

The pupal chamber consists of an oval cell, the long axis of which is perpendicular, located at a uniform depth of about 5 inches below the surface of the soil. The dust mulch in the case under discussion was 4 inches deep and the pupal cells were about 1 inch deeper than cultivation in the moist, firm soil. The pupa stands erect in the cell with the head upward, the larval exuvium being at the bottom of the cell.

The adult evidently passes the remainder of the summer in the pupal cell, in which it also later hibernates. Matured adults were found in these cells in the fields at Bridgeport, N. Y., as late as September 15, and in our rearing cages adults passed the winter without feeding or drinking.

Three distinct generations of larvæ were collected in the field in the summer of 1913—full-grown larvæ about to pupate, half-grown larvæ, and larvæ about one-fourth inch long—actively feeding on the corn. We have now in the laboratory, subject to outdoor temperature, two distinct generations of larvæ collected in the summer of 1913. The first generation—that is, the largest larvæ collected—all transformed to adults during August. Mr. Pettit and several others have made similar observations, and there is no doubt that this species, at least in the northeastern United States, spends three years as a larva.

FOOD PLANTS.

Agriotes mancus was observed at Bridgeport, N. Y., feeding upon corn seed and roots, potato tubers, wheat roots, carrots, and the underground stems of string beans; a single specimen was also found within the stem of the common field mushroom (*Agaricus campestris*). Other writers have found it attacking the cucumber, turnip, and cabbage. Mr. Theo. Pergande, of this bureau, records[2] a larva of this species feeding on the larva of a lamellicorn beetle in one of his rearing cages. The writer is of the opinion, however, that normally this species is not predaceous.

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[1] Pettit, J. Description of the wheat wireworm (*Agriotes mancus* Say). *In* Canad. Ent., v. 4, No. 1, p. 3–6, fig. 1, January, 1872.

[2] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2795, Oct. 5, 1882.

REMEDIAL MEASURES.

We recommend plowing sod land immediately after the first hay cutting, usually early in July, when the land is intended for corn the following year. This land should be cultivated deeply throughout the remainder of the summer. Land that is in corn and badly infested should be deeply cultivated even at the risk of slightly "root-pruning" the corn. This cultivation should be continued as long as the corn can be cultivated, and as soon as the crop is removed the field should be very thoroughly cultivated before sowing to wheat. In regions where wheat is seeded down for hay any treatment of infested wheat fields is precluded. Where wheat is not followed by seeding, the field should be ploughed as soon as the wheat is harvested.

Thorough preparation of the corn seed bed and a liberal use of barnyard manure or other fertilizer will often give a fair stand of corn in spite of the wireworms, a vigorous plant often being able to produce roots enough to withstand the depredations of several wireworms.

Though we realize that usually this is not practicable, the interposing of a crop not severely attacked by wireworms, such as field peas and buckwheat, between sod and corn would materially reduce the number of wireworms in the soil when the corn was planted.

THE CORN AND COTTON WIREWORM.

(*Horistonotus uhlerii* Horn, fig. 3.)

The adults of the corn and cotton wireworm are small, slender, and dusky brown; the largest is a trifle over three-sixteenths of an inch in length and can easily be distinguished from other forms infesting cereal crops by the heart-shaped scutellum. The wireworms of this tribe (Cardiophorini) are very unlike any of the other wireworms. They are not hard and wiry, but soft, membranous, and elongate. The body, which is usually white, appears to be composed of 26 segments, every third segment being swollen. The last segment is simply pointed. The head, which is yellow, is long and slender, with a pair of very prominent dark-brown jaws. When full grown these wireworms measure about an inch in length and are but little thicker than pack thread.

Unlike most of the eastern wireworms, which are usually most destructive in damp, low-lying fields, these insects seem to be far more numerous on the higher parts of the fields in light sandy soil.

These wireworms are among the most troublesome species of the southern United States. Mr. W. A. Thomas records[1] one species of

[1] Thomas, W. A. Corn and Cotton Wireworm (*Horistonotus curiatus* Say). So. Car. Agr. Exp. Sta., Bul. 155, 10 p., figs. [i. e., pls.] 6, March, 1911. I have since been informed by Mr Conradi that this is a misidentification and that the species in question is *H. uhlerii*.

this genus (*Horistonotus curiatus* Say) as one of the worst pests in South Carolina.

Mr. Vernon King, of this office, is at present investigating a very serious outbreak of *Horistonotus uhlerii* in Missouri and has prepared the following preliminary account of this species:

Horistonotus uhlerii Horn is a serious pest to corn in southeastern Missouri, and to corn, cotton, and cowpeas in northeastern Arkansas, and has been reported from the Carolinas and Illinois.

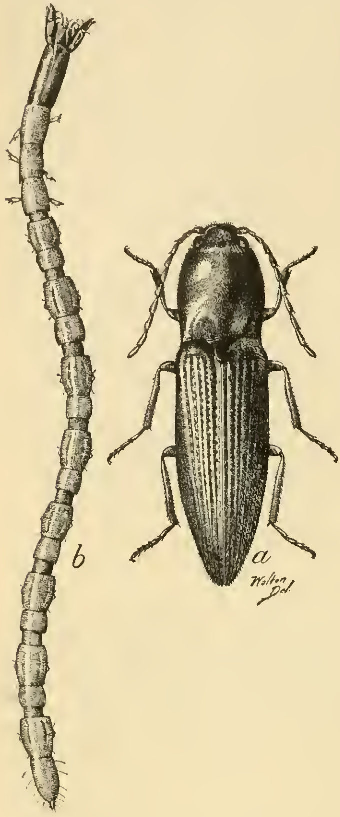

FIG. 3.—The corn and cotton wireworm (*Horistonotus uhlerii*): *a*, Adult beetle; *b*, larva. Enlarged. (Original.)

The larvæ may be found about the roots of their host plants in large numbers, nearly 50 having been taken from one hill of corn. Adults, pupæ, and larvæ can be seen in June, all beneath the surface of the soil, and later the adults will be found above the ground, resting on the plants. The eggs are probably laid about the end of June in the soil, on or about the roots of corn and cowpeas, for minute larvæ have been taken early in July. In May and June the larvæ are most plentiful, but as the season advances they become scarce, and finally disappear by the time winter sets in. By the third week in August the adults can no longer be found. Under laboratory conditions the larvæ pass the winter partly grown, and no doubt in nature they hibernate in the same form, but in what location is not yet known.

Although corn, cowpeas, and cotton are the main hosts of this insect, the larvæ feed on the roots of Johnson grass (*Sorghum halepense*) and have been reported as feeding on crab grass.

Infested corn plants become wilted and stunted, with leaves of a bluish shade, and brown at the tips, standing out from the stalk stiffly instead of bending over gracefully as in a healthy plant. Deprived of most of the roots through the work of the larvæ, the plant can be pulled up with little effort. Weak individuals soon succumb, leaving gaps in the rows, but the more vigorous plants put forth new roots in abnormal numbers. These are matted together and distorted, and although the plants survive, only nubbins are produced. Tall and apparently healthy plants may have larvæ among the roots without damaging the corn materially. The infestation, therefore, is not confined to the impoverished areas.

In cowpeas the fibrous roots suffer most, the thicker roots being perforated, so that the plants become yellow and dwarfed and fail to vine.

Cotton is injured in the early stages by the larvæ boring into the seed and injuring the very young plants, checking the growth so much that the plant dies or struggles along only to produce little or no cotton.

Rolling land infested by this insect presents a patchy appearance, the sandy knolls standing out distinct and bare, being overgrown later with weeds, particularly crab grass, briers, and morning-glory.

The infestation seems to be worst after a crop of cowpeas, but the exact significance of this crop in relation to wireworm injury has yet to be determined. Applications of barnyard manure and of wood ashes have had no effect in checking this pest. On account of the susceptibility of the larvæ and pupæ to exposure, plowing the soil in the heat of the sun would undoubtedly destroy many of the wireworms. The objection to this method, however, would be that the planter is occupied with other farm operations at that time, and also there would be difficulty in getting at these areas, which are often scattered, irregular, and isolated. From the data thus far gathered we can not say what effect fall plowing would have on this insect. Further investigation, however, will in all probability give a clue to remedial measures.

WIREWORMS OF THE GENUS CORYMBITES.

In the literature of American economic entomology there is no reference to beetles of the genus Corymbites as pests to cereal and forage crops. In the Pacific Northwest two species (*C. inflatus* Say and *C. noxious* Hyslop) are among the worst pests to cereal crops. The habits of the two species are quite distinct and will be treated separately. The occurrence of *Corymbites cylindriformis* Hbst. in enormous numbers in alfalfa and wheat fields about Hagerstown, Md., this spring (1914), and the finding of Corymbites larvæ in these fields at various times, might indicate that the genus is represented among the cereal and forage pests in this region also.

In Europe the habits of several species of this genus have been recorded by Schiodte and Perris. *C. pectinicornis* L., *C. castaneus* L., and *C. sjlandicus* Müll. are found living in woody meadows and *C. æneus* Fal. is found in fields.[1]

C. latus Fab. is recorded[2] as living "in the ground like other insect larvæ, feeding on roots * * *. They cause great damage to carnations in flower gardens." Following is a note by Mr. Pergande from the Bureau of Entomology files:[3] "Elaterid larva in apple tree, received from B. C. Hawkins, Horse Cove, Macon County, N. C. A larva of an elaterid found in a boring in trunk of apple with a dead larva of *Saperda bivittata*."

This note, though the correctness of the determination of the wireworm is not certain, is interesting, inasmuch as it seems to indicate that some species of Elateridæ now classified as Corymbites are

1 Schiodte, J. C. De metamorphosi eleutheratorum observationes, pt. 5, p. 520–522, pl. 8, fig. 9–10, pl. 10, fig. 4, 1871.

2 Perris, Édouard. Larves des Coléoptères, p. 179. Paris, 1877. "Cette larve vit dans la terree soit d'autres larves ou insectes, soit de racines. M. de Bonvouloir, en m'en envoyant des echantillons, me l'a signalée comme causant de grands degâts aux œillets de son parterre."

3 U. S. Dept. Agr., Div. Ent., Notes, v. 8, No. 6187, Apr. 3, 1894.

predaceous, while other forms also in this genus are known to be exclusively vegetable feeders.

During the spring of 1909 a reconnoissance was made to determine the extent and nature of the damage being done by these insects. Circular letters with blank forms inclosed were sent to the agents of the warehouse and elevator companies at most of the large grain-shipping points in the Pacific Northwest. These men are very intimately in touch with the farmers and usually know of any serious depredations that are likely to affect the production of grain. From their replies we found that corn was being seriously damaged at Spokane, Pullman, Kiona, Johnson, and Colville, in Washington, and Latah and Mineral in Idaho; oats were being almost completely destroyed at Ritzville, Downs, Espanola, Govan, and Vancouver, in Washington, and Moscow and Latah in Idaho; and that wheat was being damaged at Wilbur, Connell, and Govan in Washington. The fact that damage to wheat was not reported from more localities does not signify that wheat is less susceptible to the attacks of these insects. The buyers will not report any damage to wheat for fear of starting a scare among the farmers and thereby abnormally raising the price asked when the buying opens in the fall.

THE INFLATED WIREWORM.

(*Corymbites inflatus* Say.)

The inflated wireworm occurs throughout most of the northern United States, but is limited as a pest to cereal crops, so far as our observations now record, to the regions of eastern Washington and Oregon and western Idaho, known as the semiarid Transition Zone and characterized, when not under cultivation, by the presence of bunch grass (*Agropyron spicatum*) and June grass (*Poa sandbergii*) and by the absence of sagebrush. This region is only partly summer fallowed, crops often being grown on the same land for several consecutive years.

The beetle is robust, but little more than one-fourth of an inch in length, and of a slate-gray color, sometimes being almost black. The wireworm is about one-half inch long, depressed, with a pair of backwardly directed spurs on the ninth abdominal segment, and pale yellow.

In the spring of 1909 Mr. George I. Reeves, of this bureau, recorded finding the larvæ of the inflated wireworm damaging seed corn at Pullman, Wash. His observations were carried on principally in the cornfield of a Mr. Curtis, north of the town. On this farm he found from 4 to 10 larvæ to the hill when he first investigated the outbreak, on May 24, 1909. The wireworms were in various stages of development and were feeding on the seed, which had been planted on May 10 and 17, eating out the kernels and leaving only empty hulls. Usually the roots of such plants as had escaped were not damaged. The particular field under observation had been in oats in 1908 and in wheat in 1907. On June 1 Mr. Reeves again examined this field and then found the stand very poor, and the wireworms seemed to be more numerous than when he first examined it, as from 18 to 20 were to be found in nearly every hill. At this point the investigations were turned over to the writer.

On June 20 the entire field was harrowed and reseeded, the first seeding being absolutely destroyed by these wireworms. The second seeding started very well and looked as though it would succeed. Many wireworms were still present, however, and by July 8 the second seeding was about half destroyed and had to be planted in by hand. The season was then so well advanced that the crop was practically a failure.

LIFE HISTORY.

Early in May the beetles emerge from the pupal cells in which they pass the winter, a number of beetles having been caught at Pullman, Wash., by Mr. Reeves as early as May 5, 1908. They are about in enormous numbers during late May and early June. On May 28, 1910, the writer collected over a hundred of these beetles in a few minutes from some rosebushes in a fence row along the side of a last year's wheat field. The beetles continue abundant until early July, and by the middle of this month they have all disappeared but a few stragglers. During June the beetles mate and lay their eggs. The larvæ feed during this summer and pass their first winter about half grown. They resume feeding the following spring and continue to feed during the second summer, passing the second winter as nearly mature larvæ. The larval life is completed early the third spring, when they transform to pupæ during late June and early July. The last transformation takes place in late July and early August, and the adult beetles remain in the pupal cells from that time until early the fourth spring. Thus the wireworm, as such, is in the ground during the growing season of three years.

FOOD PLANTS.

The beetles of this species were observed in large numbers during May, 1910, at Pullman, Wash., on wild rosebushes, where they were apparently eating the petals of the unopened rosebuds, as many as 10 beetles having been counted on a single bud and the buds being badly riddled with holes. In a rearing cage the beetles were observed eating into kernels of wheat which were exposed on the surface of the ground. The beetles are also to be collected in large numbers in clover fields. The larvæ, so far as our records show, attack corn, wheat, and potatoes. They also undoubtedly attack oats and barley.

THE DRY-LAND WIREWORM.

(*Corymbites noxius* Hyslop,[1] fig. 4.)

The dry-land wireworm, so far as we at present know, is confined to the Upper Sonoran Zone of Washington State, though it will undoubtedly be found in the Upper Sonoran of Oregon. This zone is

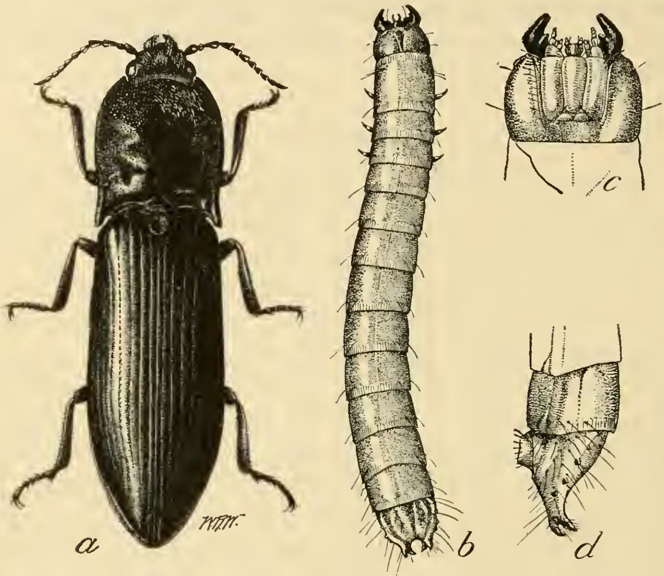

FIG. 4.—The dry-land wireworm (*Corymbites noxius*): *a*, Adult; *b*, larva; *c*, under surface of head of larva; *d*, side of last segment of larva. *a*, *b*, enlarged; *c*, *d*, more enlarged. (Original.)

characterized by the presence of sagebrush and occupies that part of Washington lying south of the Columbia River, east of the Cascade Mountains, and west of the semiarid Transition Zone, extending up the Snake River into Idaho and across the Columbia River into Oregon. This region is almost exclusively dry-farming country, summer fallowing being necessary to obtain enough moisture to mature wheat and other cereals.

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[1] Hyslop, J. A. Description of a new species of Corymbites from the Sonoran Zone of Washington State (Coleoptera, Elateridæ). *In* Proc. Biol. Soc. Wash., v. 27, p. 69–70, Mar. 20, 1914.

The beetle of this species is about one-half inch long, quite slender, and jet black in color. The wireworm is very similar to the inflated wireworm.

Early in April, 1910, our attention was called to a series of severe wireworm outbreaks in the region above outlined. On the 5th of the month the farm of a Mr. Dunnigan, at Connell, Wash., was visited. He was at that time reseeding 1,800 acres of wheat which had been killed out by these wireworms. From Connell we proceeded to Govan, Wash., and here we found the wireworms also doing considerable damage. In a fallow field that had been ruined by wireworms when in oats in 1909 we found them in enormous numbers. These wireworms when in the field are usually to be found between the dust mulch and the moister earth below. This species is more or less destructive throughout its range. During 1910 reports of severe outbreaks were received from eight wheat-receiving stations in the States of Washington and Idaho.

LIFE HISTORY.

This beetle is about during June and July, at which time it deposits its eggs in wheat fields, weedy fallow fields, and volunteer wheat on fallow land. The eggs are undoubtedly laid underground by the female burrowing into the soft earth, as many adults were collected in the fields at a depth of from 5 to 8 inches below the surface which were not in pupal cells. Mr. J. E. Graf, of the Bureau of Entomology, has found this to be the case with the sugar-beet wireworm.[2] The young larvæ are to be found in the soil during August and the remainder of the summer, but their depredations are not noticeable at this time, as, in the region where the species occurs, wheat is the only extensively grown crop. The young wireworms pass their first winter in the soil at a depth of from 12 to 20 inches below the surface. The following spring and summer they spend in the summer fallow and are not noticed. Their second winter they again hibernate as wireworms, and in the spring of their third year, the field being now planted to wheat, they turn their attention to the seed and young plants, and it is at this time that their depredations are so startlingly noticeable. They feed during late March, April, and May, and early in June burrow to from 4 to 8 inches below the surface, making small oval cells, in which the very fat larvæ lie in an inactive condition during June, July, and early August, when they pupate and the adults emerge from the pupal skins the middle of that month, but remain in the pupal cells the remainder of that summer and the ensuing winter, not emerging from the ground until the fourth spring from that in which the eggs were laid.

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[2] Graf, John E. A Preliminary Report on the Sugar-Beet Wireworm. U. S. Dept. Agr., Bur. Ent., Bul. 123, p. 18, Feb. 28, 1914.

In the spring of 1910 a large number of these larvæ were collected in the wheat fields at Govan and Wilbur, in Washington State, and confined in a root cage made by sinking a molasses barrel to the level of the earth surface in a field at Govan and closing the top with a short cylinder of sheet iron covered with wire gauze. The barrel was filled with earth and wheat planted therein. The larvæ could easily be separated into three distinct groups, according to size, which indicated a 3 years' life cycle. Later observations on the material in the rearing cage proved this to be actually the case.

Two lots of larvæ were confined in this cage—one on April 14 and the other on April 30, 1910, so that all must have hatched from eggs laid in 1909 or previous to that year. On June 21 the cage was examined and a number of the larvæ were found to be at from 4 to 8 inches below the surface, resting quietly in oval cells. They were very fat at this time. The cage was not examined again until November 4, and at this time 3 adults, evidently of the 1907 generation, were found at about the same depth as the larvæ observed in June. They were still in the pupal cells, as was evident from the last larval skins and the pupal skins found with them. The following spring (1911) the cage was examined on March 29. Several larvæ were found at this time. They were now moving actively about in the soil and almost immediately attacked some seed wheat sown in the cage on this date. An adult still in the pupal cell was also found at this time. The cage was next examined on July 4, at which time an adult was found on the surface of the ground. Several full-grown larvæ were also found on this date in their cells at the usual depth of from 4 to 8 inches below the surface. These were evidently the larvæ hatched from eggs laid in 1908. On August 17 the cage was examined and at about 5 inches below the surface a pupa and an adult were found. The latter had evidently just transformed, as it had not yet become quite black and was still very soft. The following day the cage was entirely emptied and at between 18 and 20 inches below the surface 10 larvæ and an adult were found in soil that was very hard, and very slightly moistened, in fact merely moist enough to prevent its being absolutely dry. The larvæ seemed to be full grown and had evidently just completed a molt, as they were quite soft. These were evidently of the 1909 generation.

REMEDIAL MEASURES.

As will be seen from the life histories of these two species, the generations about to become adult are inactive larvæ from June to August and very delicate pupæ during the early part of the latter month. These resting larvæ and pupæ are usually at a depth of from 4 to 8 inches below the surface, and any disturbance of the soil to that depth at this time would undoubtedly destroy them. At this time of the year the ground is very hot and the air exceedingly dry in this region, and even the resting larvæ and pupæ that were not actually crushed by the cultivation would soon succumb to drying when their cells were broken open. The writer had considerable trouble in bringing pupæ in from the field to his rearing cages and was forced to resort to tightly closed tin boxes which were fitted in the bottom with moistened blotters.

The usual farm practice in the region where the dry-land wireworm is troublesome may be roughly outlined as follows: Immediately after seeding the wheat in early spring the fallow land is plowed to a depth of from 4 to 7 inches. This is usually in April, but if horses and help can be spared from seeding, the summer fallow is plowed as early in the spring as the land can be worked. The next operation on the fallow land is disking it late in June or early in July to maintain the dust mulch and kill out the weeds and volunteer wheat. Many of the more progressive farmers now advocate, and a few practice, fall plowing of stubble and only disking the fallow land in the spring. The year following the summer fallowing the field is disk harrowed early in the spring if the land has run together during the winter and is caked; otherwise the land is harrowed with a drag or spike-tooth harrow. It is then seeded and dragged and receives no further treatment until harvest. The seeder is usually set to sow at a depth of about 3 inches, though if the moisture is high enough 1 inch is sufficient. Wheat hay is used extensively in this country and is cut while the wheat is in the dough, which is usually from July 4 to 15. The wheat crop is harvested from the 1st of August until the 1st of September.

We recommend altering this practice in order to destroy wireworms in the following manner:

(1) *Disk or drag harrow* the summer fallow as early as possible *in the spring*, in order to produce a dust mulch and thereby conserve the accumulated winter's moisture: (2) *continue disking* as often as is necessary to maintain the dust mulch and keep down the weeds; (3) *plow the summer fallow* in July or early in August, and immediately drag; (4) *plow the stubble* as soon as the crop is off.

As these worms are of three different ages in most infested fields. and as only about one-third of these will be in the pupal stage each year, it is evident that the first year of this practice will not show startling results. However, if the practice is continued for a couple of years it will undoubtedly reduce the number of these pests very considerably. Aside from its beneficial results in killing insects, this method of handling the land will materially reduce the weeds. The early disking merely softens up the soil and allows all the weed seed present to sprout, and the entire crop of weeds is subsequently destroyed by the summer plowing. By the present method of farming the weed seeds are turned down to such a depth that many can not germinate, but lie dormant and sprout whenever they happen to be brought to the surface by subsequent cultivation. One crop of weed seed is in this manner often a pest for several succeeding years.

A slight variation of these suggestions will readily adapt them to the more humid sections inhabited by the inflated wireworm.

THE CORN WIREWORMS.

Several species of beetles belonging to the genus Melanotus are recorded as pests to cereal and forage crops in the United States. The beetles usually range from medium-sized to large forms measuring from one-half to three-fourths inch in length. They vary in color from light reddish-brown to almost black. The beetles of this genus can always be distinguished with a low-power lens by the comb-like claws on the last tarsal segment.

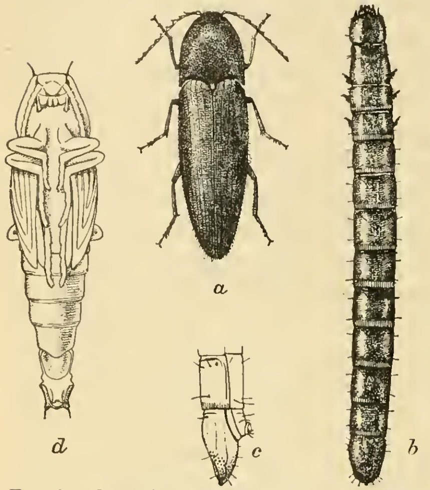

FIG. 5.—One of the corn wireworms (*Melanotus communis*): *a*, Adult; *b*, larva; *c*, last segments of same; *d*, pupa. All enlarged. (From Chittenden.)

The wireworms are reddish-brown in color, about 1¼ inches long, cylindrical in shape, and always with the last joint of the body ending in three inconspicuous lobes.

Many species of this genus inhabit decaying logs, and several writers record them as predaceous.[1] A note in the Bureau of Entomology files,[2] by Mr. Pergande, records a larva of this genus as feeding on the eggs of a locust, or grasshopper. A similar record,[3] dated September 19, 1884, is made by the same observer, wherein a Melanotus larva was found with locust eggs and reared to the adult condition by feeding on potato and dead beetle (lamellicorn) larvæ.

These wireworms are a pest to cereal and forage crops in the Middle Atlantic States, the New England States, and in the Mississippi Valley from Kansas northward. Forbes places *Melanotus communis*

[1] Perris, Édouard. Histoire des insectes du pin maritime. *In* Ann. Soc. Ent. France, ser. 3, T. 2, p. 139 (séances du 13. Avril, 1853).
[2] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2883, Oct. 9, 1882.
[3] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2884, Sept. 19, 1884.

Gyll. (fig. 5) and *M. fissilis* (Say) as among the important corn pests of Illinois. Webster found *M. communis* a very serious pest in Indiana and Ohio; Comstock and Slingerland consider *M. communis* one of the worst wireworms in New York State; and Swenk records serious depredations of *M. cribulosus* Lec., *M. communis*, and *M. fissilis* in Nebraska.

In 1907 Mr. E. O. G. Kelly found a species of Melanotus attacking corn in North Dakota. In 1910 Mr. W. W. Yothers, of this bureau, investigated a very severe outbreak of these wireworms at Corry, Pa. At the time he visited the fields as many as 7 to 15 larvæ were to be found in nearly every hill. This field had been broken from sod in 1908. In 1912 Mr. Kelly found the larvæ of *Melanotus communis* so numerous at Wellington, Kans., that they entirely destroyed his experimental corn plantings. He also found the larvæ of this species attacking kafir seed at Mulvane, Kans., in the spring of 1912. In places they had completely eaten out the seed for spaces of from 4 to 6 feet in the drill rows. In 1914 we received reports of damage by wireworms belonging to the genus Melanotus from seven localities in Indiana, seven in Wisconsin, six in Maryland, three in Michigan, three in Iowa, and one each in Alabama, Ohio, Virginia, Kentucky, North Dakota, Vermont, and West Virginia.

Several species occur on the west coast, and *M. communis* is reported as a pest to wheat in Garfield County, Wash.,[1] but the writer is inclined to believe that the pest in this case was either a false wireworm or a species of Corymbites.

Mr. Pergande records[2] this species as attacking lettuce roots, wheat, and potatoes.

LIFE HISTORY.

The adults of these wireworms are flying about in late April, May, and June, when they undoubtedly deposit their eggs in the grasslands. The larvæ spend two to five years in the soil. That any have so short a life-cycle period as two years is not at all certain. We have, however, in our outdoor insectary, larvæ received from Inman, Nebr., April 19, 1912, subject to very nearly natural conditions. These larvæ were well grown when received and were at least of the 1911 generation. At the date of this writing (October, 1914) they are larvæ. They have passed the summers of 1911, 1912, 1913, and 1914 in the soil, and if they pupate next summer (1915) the adults will, without doubt, remain in the pupal cells until the spring of 1916, making, in this case, five full years from egg to egg. These beetles pupate during July and early August.

[1] Scobey, J. O'B. Wireworms. Wash. Exp. Sta. (State Agr. Coll. and School of Sci.), Bull. 4, p. 75, May, 1892.

[2] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2884.

Mr. Webster found pupæ in the ground August 19, 1885, at La Fayette, Ind.

At the Hagerstown Laboratory over 100 larvæ of this genus are under observation. Those that emerged as adults this year pupated between the end of July and the middle of August. The pupal stage varied in duration from 12 to 22 days.

The adults do not leave the pupal cells, however, until the following spring. Mr. Webster found adults of *M. communis* in pupal cells on March 17, 1894, at Wooster, Ohio, and the writer found an adult in a wheat field at Hagerstown, Md., on November 22, 1912. This adult was in a cell with its pupal and last larval exuvia. The cell was 1 inch below the surface, in the drill row in which several consecutive plants had been killed.

REMEDIAL MEASURES.

The larvæ of the genus *Melanotus*, so far as our observations go, are confined to poorly drained and usually to heavy, sour soil. In making a survey of Birch Creek and Eel Creek bottoms in Clay County, Ind., we were informed by nearly all of the farmers that up to within the past four years wireworms caused very large annual losses to corn growers, while for the past three years this pest has been quite unknown to them. Coincident with the disappearance of the wireworms we find that the land was tile-drained on most of the farms. That the tile drainage of the land was actually responsible for the disappearance of the wireworms is more than we are prepared to say. However, the coincidence is very suggestive.

WIREWORMS OF MINOR IMPORTANCE.

The following species, though not serious pests to cereal and forage crops over extensive areas, are, during certain seasons, very destructive in restricted localities.

The wireworms belonging to the genus Limonius are among the most important of this group. In 1909 the writer received report of serious damage being done to corn and potatoes at Spokane, Wash. The outbreak was investigated and proved to be very severe, but at the time no larvæ were reared. This year (1914), through the kindness of Mr. William Tews, of Spokane, the writer received a large number of these wireworms with the report of another serious outbreak. From this material we succeeded in rearing adults which are Limonius (species undetermined). The confused wireworm (*Limonius confusus* Lec.) has made its appearance in Illinois[1] within the last few years, and although its principal damage was confined to potatoes, it was also destructive to corn. The beetle is

[1] Davis, J. J. Preliminary report on the more important insects of the truck gardens of Illinois. *In* Ill. Farmers' Inst. 16th Ann. Rpt., p. 216–263, 42 figs. Springfield, 1911. Wireworms. *Limonius confusus* Lec., p. 251, figs. 26–27.

about three-sixteenths of an inch long, reddish-brown in color, and moderately hairy. The wireworm is about three-fourths of an inch in length and is depressed, with a shallow emargination in the terminal segment; the color, as in the beetle, is reddish-brown.

The species is recorded as attacking corn, potatoes, tomatoes, onions, cabbage, radishes, turnips, horseradish, and spinach. It burrows into the underground parts of the plants, quite ruining them for market purposes, and in the case of corn, tomatoes, cabbage, and onions often kills the plant. This species does not seem to attack beans, peas, cucumbers, melons, rhubarb, lettuce, and peppers, and these crops might be of value in clearing a badly infested field prior to seeding it to grain.

The sugar-beet wireworm (*Limonius californicus* Mann.) is a very serious pest to alfalfa and corn over restricted areas in California.[1] Alfalfa is so badly infested in certain localities that it has to be plowed out and reseeded every three or four years. This species lays its eggs during late April. The eggs hatch during late May and the larvæ spend the remainder of that season and the whole of the two succeeding seasons in the ground. They pupate during July and August of their third summer, the adults remaining in the pupal cells until the spring of the fourth year. Alfalfa fields badly infested with this wireworm should be plowed out immediately after the first crop is harvested and harrowed several times before reseeding. Land intended for corn should be plowed in late July or August of the year preceding cropping. Land in corn should be deeply cultivated during August.

The abbreviated wireworm (*Cryptohypnus abbreviatus* (Say)) occurs over the entire northern part of the United States, being quite common in New England and New York, and is recorded from New Jersey by Smith.[2] In the upper Mississippi Valley this species is also a pest and specimens have been collected in Utah and Washington.

The beetles of this species are very small, being little over three-sixteenths inch in length and quite broad and flattened. The color is very dark brown to almost black and the forepart of the body is very shiny. An obscure yellowish spot ornaments each wing cover near the tip. The legs are also obscure reddish-yellow.

The wireworm is about one-half inch long, flattened, with a pair of backwardly directed prongs on the ninth abdominal segment, and is pale yellow in color.

Owing to the confusion of this wireworm with *Drasterius elegans* Fab., the literature relative to either of these insects is very unre-

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[1] Graf, John E. A Preliminary Report of the Sugar-Beet Wireworm. U. S. Dept. Agr., Bur. Ent., Bul. 123, 68 p., 9 figs., 23 pl., Feb. 28, 1914.

[2] Smith, J. B. Catalogue of the Insects Found in New Jersey, p. 159. Trenton, 1890.

liable. The best account of the species of which we are cognizant is that of Comstock and Slingerland.[1]

On March 13, 1912, Mr. J. J. Davis received a communication reporting a very bad outbreak of wireworms on corn at Watertown, Wis., in 1911. The fields attacked were low-lying peaty muck-lands that had been reclaimed by tile draining. The correspondent said that he "plowed up a strip of land early last spring and turned up these insects by the millions, so that some of the furrows looked real white." Larvæ were inclosed with this communication and proved to be of this beetle. In June, 1913, Mr. Davis visited this locality and collected a number of the larvæ and sent them to the writer alive. They were confined in rearing cages on June 6. August 5 a pupa was found, and on August 14 the adult emerged from the pupa. Another larva pupated on September 2 and the adult emerged on September 11. These two records limit the pupal stage to nine days.

For this species we recommend plowing sodland, intended for corn the succeeding year, *during late August*. Cultivate corn as late as possible, and plow small-grain stubble during August, if possible.

Another genus of importance in this group is Monocrepidius. The two species of this genus recorded as attacking cereal and forage crops in the United States are quite distinct. One (*Monocrepidius lividus* DeG.) is a large species over one-half inch in length, of a dull, even brown color. It is shaped very much like a Melanotus, but can easily be distinguished from that genus by the simple tarsal claws. The other species (*Monocrepidius vespertinus* Fab.) is a small elongate beetle, a little over one-fourth inch long. The body is prettily marked with yellow and dark brown. Both of these species are more or less southern in distribution, *M. lividus* DeG. being distributed over the entire southern part of the United States from Florida to Texas and northward to northern New Jersey, scattering specimens being collected as far north as Massachusetts, while *M. vespertinus* covers the same territory, but is more generally distributed northward.

A third species, *Monocrepidius bellus* Say, is a very small form, the beetle being hardly three-sixteenths of an inch long. This species is quite often taken in cornfields during the summer and under stones in pastures during the winter about Hagerstown, Md. Dr. F. H. Chittenden[2] records this species as having been reared from larvæ feeding on the roots of creeping bent (*Agrostis stolonifera*) on the department grounds at Washington.

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[1] Comstock, J. H., and Slingerland, M. V. Wireworms. Cornell Univ. Agr. Exp. Sta., Bul. 33, p. 270, Nov., 1891.

[2] U. S. Dept. Agr., Div. Ent., Notes, v. 10, No. 7472.

Monocrepidius auritus Hbst. is also quite common about Hagerstown, adults being often found hibernating with *Drasterius amabilis* Lec. under stones. Mr. C. M. Packard, of the Hagerstown laboratory, collected a pupa of this species in the insectary garden on August 11, 1913. The adult emerged from this pupa on August 16. This year (1914) Mr. J. J. Davis sent the writer a large number of larvæ of this species from Indiana. The last two species will probably eventually be found to attack crops.

The largest, and in the southwest the most important, species of this genus is *Monocrepidius lividus* DeG. In the bureau files is a note made by Mr. Pergande, dated June 6, 1881.[1] Larvæ were found in hills of recently seeded sorghum. No locality accompanies this note. On July 4 one of the larvæ transformed to a pupa, and on July 11 the adult issued, making the pupal period just a week.

Mr. Kelly collected an adult in a hay pile March 21, 1911, and also a larva of this species burrowing in a young corn plant at Wellington, Kans., on June 11, 1910. This larva pupated on September 8, but was not reared to an adult. He also collected an adult in an alfalfa field on May 10 of that year. Another larva, supposed to be this species, was collected June 12 and was kept alive in a rearing cage until November 25, indicating that the species hibernates in the larval state. The particular specimen, however, died during the winter.

During July, 1911, Mr. G. G. Ainslie found the adults of this species on the fresh silk on the corn ears down in the tip of the husk. He found them in the act of eating the corn silk and also the pollen.

The writer, while investigating an outbreak of the "curlew bug" (*Sphenophorus callosus* Oliv.) at Hartford, N. C., found several of these wireworms in a cornfield. These larvæ were collected on November 4, 1911, and by December of that year one of the larvæ had eaten all his comrades and had gone into hibernation in the rearing cage in the office at Washington. The data relative to the life history of this individual can not be relied upon as of value in determining the normal life history, as the office was subjected to great extremes of temperature that winter, often freezing at night and being over 80° F. by noon. However, this larva transformed to a pupa and emerged as an adult between May 21 and June 7, 1912. This beetle lived in the rearing cage without food until July 24 of that year. Mr. G. G. Ainslie collected a larva of this species on March 25, 1914, in sod land at Orlando, Fla.

Undoubtedly second in importance, and in parts of the South probably first, is the southern corn wireworm (*Monocrepidius vespertinus* (Fab.), fig. 6). Mr. Kelly has found the larvæ of this species

[1] U. S. Dept. Agr., Div. Ent., Notes, v. 2, No. 857, June 6, 1881.

doing considerable damage to wheat at Wellington, Kans. These larvæ attack the wheat in a very unique manner for wireworms. They do not seem to attack the roots, but bore into the cavity of the wheat stem and feed on its inner wall. In some fields as many as one-eighth of 1 per cent of the wheat stems were infested. A large number of these larvæ were placed in a rearing cage on May 6, 1910, and on June 24 four adults were found in the cage. Mr. Kelly found the adult beetles of this species numerous on corn plants in the field from July 3 to August 23. Early in March, 1910, an adult of this species was found in a clump of grass (*Andropogon scoparius*). In 1911 Mr. Kelly succeeded in rearing an adult from a pupa collected among the roots of corn. This adult emerged on July 19. Mr. T. H. Parks, at that time with this office, found the beetles very numerous on young corn at Winfield, Kans., and Oklahoma City, Okla., in June, 1910, and Mr. R. A. Vickery, also of this office, found the beetles very numerous on corn at Brownsville, Tex., in June. Mr. Pergande records[1] the injury to these beetles to cotton at Wetumpka, Ala., and Dr. J. B. Smith found the larvæ injuring beans at Da Costa, N. J.[2] Mr. W. R. McConnell, of this office, found the larvæ of these beetles very numerous in alfalfa fields at Carlsbad, N. Mex.

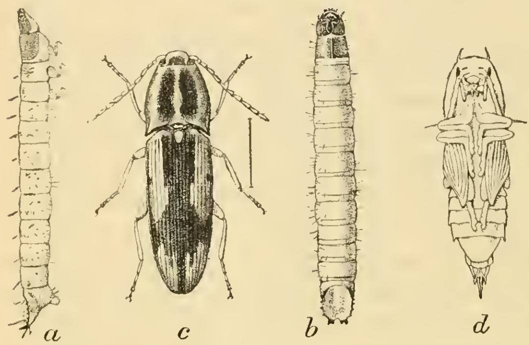

FIG. 6.—The southern corn wireworm (*Monocrepidius vespertinus*): *a*, Side view of larva; *b*, top view of larva; *c*, adult beetle; *d*, pupa. All enlarged. (After Chittenden.)

Owing to the superficial resemblance of the larva of Drasterius to those of Cryptohypnus, the notes in the files of the Bureau of Entomology relative to these two genera are very unreliable. Webster records[3] *Drasterius elegans* Fab. as a serious pest to corn and wheat in Indiana, and Forbes records finding larvæ attacking corn in Illinois.

Drasterius elegans is found throughout the northern half of the United States. *Drasterius amabilis* Lec. is common in the Middle Atlantic States and has also been collected in New England and the Mississippi Valley. All of the beetles in this genus are

[1] U. S. Dept. Agr., Div. Ent., Notes, v. 11, No. 8668, July 11, 1899.

[2] Smith, J. B. Annual Report of the New Jersey State Museum. Including a Report of the Insects of New Jersey, p. 285. Trenton, 1909.

[3] Webster, F. M. Report of observations upon insects affecting grains. *In* U. S. Dept. Agr., Div. Ent., Bul. (Old Ser.) 22, p. 52, 1890.

small, about one-fourth of an inch in length. They are yellow or reddish yellow in color, with more or less black marking. The wireworms are about one-half of an inch long when full grown. They are depressed forms with two prongs on the ninth abdominal segment and are yellowish colored, except the head and first joint, which are brownish.

In the general bureau note files, as well as those of the branch of Cereal and Forage Insect Investigations, are many notes referring to *Drasterius elegans* as predaceous, and also many other notes referring to this species as a pest to crops. None of these notes is at all conclusive, however, and in many cases it is very probable that the form attacking corn and wheat is really the abbreviated wireworm (*Cryptohypnus abbreviatus* (Say)), and it may be that the predaceous form is *Drasterius amabilis*, which the writer finds in many collections under the name *D. elegans*.

Mr. Theodore Pergande, of this bureau, received several larvæ of *Drasterius amabilis* from Manhattan, Kans., on May 3, 1877.[1] He says that these larvæ were found preying on the eggs of *Melanoplus spretus*. On June 20 some of them were killed and eaten by mites, so that nothing but the shell was left. June 25 the other larvæ were completely covered with small mites, so that they could scarcely move, and he believed that probably they would die, also.

These mites to which Mr. Pergande refers were evidently the hypopial stage of some tyroglyphid. In all probability the Drasterius larvæ ate one another, as this is a common occurrence when these larvæ are placed together in a rearing cage. He goes on to say:

> May 31, 1878, another larva of this species about half grown was placed with an Epicauta larva. It has eaten the Epicauta larva. June 18 pupated. July 9 issued.

This note gives a considerably longer pupal period than that observed by the writer at Hagerstown. In another note under the same number there is a record of the finding of a larva of this species within a potato stalk which was infested with *Trichobaris trinotata* Say, and it was probably feeding on these larvæ.

The writer found a very young *Drasterius amabilis* larva eating a pupa of *Meromyza americana* Fitch on July 9, 1912, at Hagerstown, Md. Mr. George Dimmock says that "this species (*D. amabilis*) devours locust eggs."[2]

Drasterius amabilis is very common in western Maryland, where the adults can be found under stones or rubbish from the middle of September until early in the spring.

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[1] U. S. Dept. Agr., Div. Ent., Mem. XII, Note 7621P, May 3–June 25, 1877.

[2] Standard Natural History, edited by J. S. Kingsley, v. 2, p. 361. Boston, 1884. "* * * a few of these larvæ are carnivorous, the larvæ of *Drasterius amabilis*, in the United States, being known to devour locusts' eggs."

A larva was collected at the roots of a corn plant, which, however, it did not seem to be damaging, at Hagerstown, Md., in June. This larva pupated on July 6, and the adult emerged July 15. The beetle remained alive without feeding until September 12 of that year. On April 30 a large number of beetles were placed in a small root cage in which corn had been planted. On May 6 all the adults were removed. On July 31 the cage was examined and three full-grown larvæ and one pupa were found. This cage was again examined September 8, and two adults, which, judging from the color and hardness of the integument, were at least a week old, were found.

Pupæ collected in the field emerged July 28, and two larvæ collected July 8 pupated August 10, and one of the beetles emerged August 21, the other August 23.

From the foregoing data it is evident that the life cycle is completed within one season, a very exceptional condition in this group of beetles. The beetles leave their hibernating quarters in early spring and deposit their eggs early in May. The wireworms feed during May and June, and sometimes even throughout July. They start to pupate in early July, continuing pupation throughout July and early August. The pupal stage lasts from 8 to 13 days. The adults emerge from the ground in late summer and in the fall seek hibernating quarters under stones, boards, and rubbish.

Forbes records[1] a species of wireworm (*Asaphes decoloratus* (Say)) as attacking clover in Illinois. This species is also recorded[2] as a pest in New York State.

Mr. Kelly is now investigating an outbreak of a wireworm (*Lacon rectangularis* (Say)) in Kansas. This species has not heretofore been recorded as a wheat pest, but in a recent letter to the writer Mr. Kelly says:

> In one wheat field at Argonis, Kans., in the spring of 1912, as many as 27 per cent of the plants had been bored into and ruined in some spots, with an average of about 18 per cent for the field. Later, however, the damage was much greater, and it was a question whether the grain was worth cutting.

The collared wireworm (*Cebrio bicolor* Fab., fig. 7) has not as yet been recorded as an actual pest to any crops, but as several notes wherein this species has been recorded as feeding on cultivated plants have come to the notice of the writer, and as one of these plants is a cereal, we believe it pertinent to make a short note of this species, that it may be readily recognized should it ever become a serious pest.

The beetles of this species are not now considered as belonging to the same family as the true wireworms, but they are so intimately

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[1] Forbes, S. A. Insect Injuries to the Seed and Root of Indian Corn. Ill. Agr. Exp. Sta., Bul. 44, p. 226, May, 1896.

[2] Comstock, J. H., and Slingerland, M. V. Wireworms. N. Y. Cornell Agr. Exp. Sta., Bul. 33, p. 258–262, Nov., 1891.

related to these insects and the larvæ are so very wireworm-like that they can be treated, from an economic standpoint, as wireworms. The beetle is about three-fourths of an inch long, rather slender, with very prominent scythe-like jaws; the color is brown. The wireworm is cylindrical. The first joint of the body is very large and extends forward under the head, so that the head is partly inserted within it; the last joint is long and thimble-shaped. The wireworm when full grown measures 1¾ inches in length and is nearly an eighth of an inch thick. The color is reddish brown.

The genus is recorded by Schiodte[1] as living in moist earth in Europe. In the bureau files is a note[2] by C. V. Riley which records the finding of a pupa at the roots of a grapevine in July, 1874. No locality accompanies the note, which is with other notes made at St. Louis, Mo. On July 11 an adult emerged. In the same files another note[3] records this wireworm as injuring peach and other deciduous tree roots near Fairmont, Cal. In April, 1911, Mr. G. G. Ainslie sent a larva of this species to the writer, stating that he found it feeding on oat plants near Jackson, Miss. He sent two other larvæ of this insect to the writer from Orlando, Fla., where they were found in black, sandy soil.

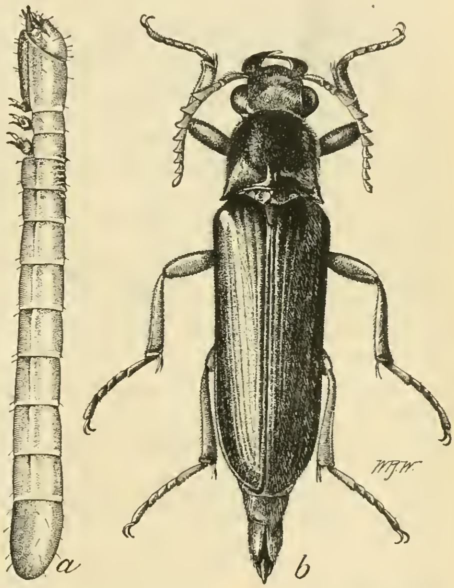

FIG. 7.—The collared wireworm (*Cebrio bicolor*): *a*, Larva; *b*, beetle. Enlarged. (Original.

Another interesting record of a wireworm (*Ludius hepaticus* Germ.) of decidedly minor importance is found in the bureau files.[4] Four larvæ of this species were found attacking cruciferous plants at Georgiana, Fla. Our only other record of this genus is one in which adults were actually reared from larvæ of *Ludius attenuatus* (Say) found in rotten wood; these larvæ were predaceous.

NATURAL ENEMIES.

Probably the most important factor in keeping wireworms in check are the birds. The following list of birds known, by examina-

[1] Schiödte, J. C. De metamorphosi eleutheratorum observationes, pt. 5, p. 530, 1871.
[2] U. S. Dept. Agr., Div. Ent., Mem. VII, No. 350X, July 11, 1874.
[3] U. S. Dept. Agr., Div. Ent., Notes, v. 5, No. 3681, June 24, 1885.
[4] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 3570, Feb. 23, 1882.

tion of the crops and stomachs, to feed on Elateridæ, either as larvæ or as adult beetles. is compiled from the records of the Biological Survey of the United States Department of Agriculture:

Franklin gull (*Larus franklini*).
Herring gull (*L. argentatus*).
American black tern (*Hydrochelidon n. surinamensis*).
Wilson snipe (*Gallinago delicata*).
Woodcock (*Philohela minor*).
Upland plover (*Bartramia longicauda*).
Killdeer (*Oxyechus vociferus*).
Bobwhite (*Colinus virginianus*).
California quail (*Lophortyx californica*).
Ruffed grouse (*Bonasa umbellus*).
Mourning dove (*Zenaidura macroura carolinensis*).
Red-shouldered hawk (*Buteo lineatus*).
Red-tailed hawk (*Buteo borealis*).
Broad-winged hawk (*Buteo platypterus*).
Yellow-billed cuckoo (*Coccyzus americanus*).
Black-billed cuckoo (*Coccyzus erythrophthalmus*).
Red-cockaded woodpecker (*Dryobates borealis*).
Downy woodpecker (*Dryobates pubescens*).
Hairy woodpecker (*Dryobates villosus*).
Arctic three-toed woodpecker (*Picoides arcticus*).
Yellow-bellied sapsucker (*Sphyrapicus varius*).
Pileated woodpecker (*Phlœotomus pileatus*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Red-bellied woodpecker (*Centurus carolinus*).
Flicker (*Colaptes auratus luteus*).
Whippoorwill (*Antrostomus vociferus*).
Nighthawk (*Chordeiles virginianus*).
Texan nighthawk (*Chordeiles a. texensis*).
Ash-throated flycatcher (*Myiarchus cinerascens*).
Crested flycatcher (*Myiarchus crinitus*).
Scissor-tailed flycatcher (*Muscivora forficata*).
Kingbird (*Tyrannus tyrannus*).
Arkansas kingbird (*Tyrannus verticalis*).
Cassin's kingbird (*Tyrannus vociferans*).
Phoebe (*Sayornis phoebe*).
Black phoebe (*Sayornis nigricans*).
Say's phoebe (*Sayornis saya*).
Wood pewee (*Myiochanes virens*).
Western wood pewee (*Myiochanes richardsonii*).
Olive-sided flycatcher (*Nuttallornis borealis*).
Western flycatcher (*Empidonax difficilis.*)
Least flycatcher (*Empidonax minimus*).
Traill's flycatcher (*Empidonax trailli*).
Yellow-bellied flycatcher (*Empidonax flaviventris*).
Acadian flycatcher (*Empidonax virescens*).
Horned lark (*Otocoris alpestris*).
Blue jay (*Cyanocitta cristata*).
Steller's jay (*Cyanocitta stelleri*).
California jay (*Aphelocoma californica*).
Crow (*Corvus brachyrhynchos*).
Bobolink (*Dolichonyx oryzivorus*).
Cowbird (*Molothrus ater*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Bicolored red-wing (*Agelaius gubernator californicus*).
Red-winged blackbird (*Agelaius phœniceus*).
Meadowlark (*Sturnella magna*).
Baltimore oriole (*Icterus galbula*).
Bullock's oriole (*Icterus bullocki*).
Orchard oriole (*Icterus spurius*).
Rusty blackbird (*Euphagus carolinus*).
Brewer's blackbird (*Euphagus cyanocephalus*).
Purple grackle (*Quiscalus q. quiscula*).
Great-tailed grackle (*Megaquiscalus major*).

English sparrow (*Passer domesticus*).
Vesper sparrow (*Poœcetes gramineus*).
Henslow's sparrow (*Passerherbulus henslowi*).
Sharp-tailed sparrow (*Passerherbulus caudacutus*).
Sandwich sparrow (*Passerculus sandwichensis*).
Ipswich sparrow (*Passerculus princeps*).
Grasshopper sparrow (*Ammodramus s. australis*).
Lark sparrow (*Chondestes grammacus*).
White-throated sparrow (*Zonotrichia albicollis*).
White-crowned sparrow (*Zonotrichia leucophrys*).
Field sparrow (*Spizella pusilla*).
Chipping sparrow (*Spizella passerina*).
Junco (*Junco hyemalis*).
Lincoln's sparrow (*Melospiza lincolni*).
Song sparrow (*Melospiza melodia*).
Fox sparrow (*Passerella iliaca*).
Chewink (*Pipilo erythrophthalmus*).
California towhee (*Pipilo f. crissalis*).
Spurred towhee (*Pipilo m. montanus*).
Cardinal (*Cardinalis cardinalis*).
Rose-breasted grosbeak (*Zamelodia ludoviciana*).
Black-headed grosbeak (*Zamelodia melanocephala*).
Blue grosbeak (*Guiraca cærulea*).
Indigo bunting (*Passerina cyanea*).
Lazuli bunting (*Passerina amœna*).
Painted bunting (*Passerina ciris*).
Dickcissel (*Spiza americana*).

In the desert regions of the Northwest a small lizard (*Phrynosoma douglasii douglasii*, fig. 8), locally called the "sand toad," eats the adult Elateridæ in large numbers. A pair of these small lizards kept in the insectary would eat *Corymbites inflatus* beetles as fast as these could be fed to them. That this is a large part of their natural food is evidenced by the contents of the stomachs of three of these lizards collected at Govan, Wash., on April 24, 1910. In the stomach of lizard No. 1, 60 per cent of the food was ants, 8 per cent click-beetles, and 30 per cent other beetles; in lizard No. 2, 90 per cent was click-beetles and 10 per cent ants; and in lizard No. 3, 75 per cent ants, 15 per cent click-beetles, and 10 per cent other beetles. Several other kinds of these lizards inhabit the more southern desert lands of the West and are usually called "horned toads" in these sections.

In rearing cages wireworms are often infested with small mites (Tyroglyphidæ). The writer received a shipment of Melanotus larvæ from Inman, Nebr., in April, 1912. This material when received was apparently free from any vermin. When examined again, on June 17 of that year, some of the larvæ were found to be badly infested with these mites in the hypopial stage. The mites were so close together on the last two segments of the wireworms' bodies that they gave the impression of an incrustation. On June 24 all the wireworms were infested with these mites. Mr. Pergande also found these mites on larvæ of *Melanotus communis* in his cages at Washington, D. C., in March, 1900.[1] Mr. Banks is of the opinion that these mites are not attacking the wireworms, but merely make use of insects as a ready means of dispersal. He is evidently correct in

[1] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2884, Oct. 9, 1882.

this opinion, as the larvæ in question from Inman, Nebr., are alive at the present writing (October, 1914).

A gamasid was found attached to the body of an adult of *Alaus oculatus* at St. Louis, Mo., by Mr. E. R. Fisher. This mite was under the wing covers.[1] Another mite (*Chelifer alaus*) is recorded[2] as a parasite of the adult *Alaus oculatus*.

The writer has published[3] a record of a fly (*Thereva egressa* Coq.) the larva of which actually attacks and feeds upon wireworms. The larva was found in a wheat field near Pullman, Wash., and when found had its head and first four anterior joints within the body of a wireworm and was eating out the insides. This larva was brought into the insectary and fed upon wireworms, of which it ate usually two a day. On June 10 it pupated, and on June 24 the adult fly emerged. Two other species of Therevidæ (*Psilocephala aldrichii* Coq. and *P. munda Coq.*) were reared by the writer from larvæ taken in the field, associated with wireworms, in the Pacific Northwest. These flies in their larval stages are probably predaceous on elaterid larvæ. Forbes mentions[4] rearing a parasitic fly from an elaterid larva. A Proctotrupes has been reared from an elaterid larva in England by Curtis.[5] In the same work Curtis refers to a similar record by Bierkander.

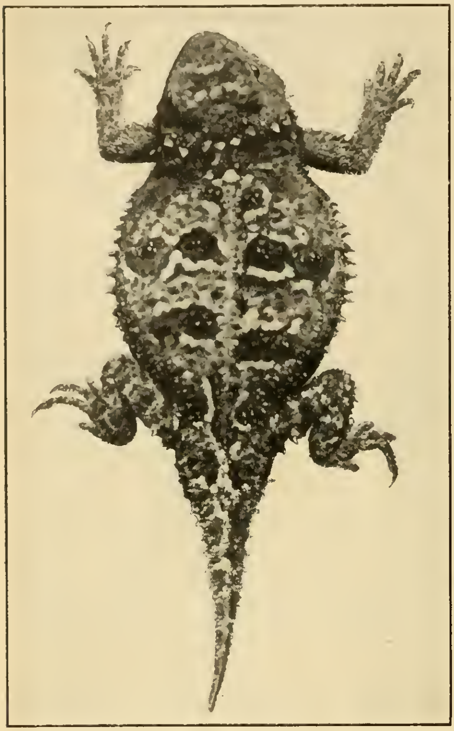

FIG. 8.—A horned toad (*Phrynosoma douglasii douglasii*), an enemy of the western wireworms. (Original.)

[1] U. S. Dept. Agr., Div. Ent., Note 165R, July 21, 1889.

[2] Leidy, J. Remarks on the seventeen-year locust, the Hessian fly, and a Chelifer. *In* Proc. Acad. Nat. Sci. Phila. [v. 29], 1877, p. 260–261, June 19, 1877.

[3] Hyslop, J. A. *Therera egressa*. *In* Proc. Ent. Soc. Wash., v. 12, No. 2, p. 98, June 15, 1910.

[4] Forbes, S. A. Insects Insects to the Seed and Root of Indian Corn. Univ. of Ill. Agr. Exp. Sta., Bul. 44, p. 228, May, 1896.

[5] Curtis, John. Farm Insects, p. 181. London, 1860.

Bierkander obtained through a correspondent a Filaria from a wireworm.[1] The author found a skin of a Melanotus larva firmly attached to the pupa case of a hymenopteron from which the parasite had emerged. The case was very similar to that of *Typhia* sp.

Several records have been made of elaterid larvæ being attacked by fungous diseases. An interesting note is made by Girard [2] in which he records Cordyceps attacking wireworms in Trinidad. A note in the files of this office [3] records a larva of *Agriotes* sp. received from Halifax, Nova Scotia, and placed in a rearing cage in the insectary at Washington, as being found later dead and filled with the mycelium of a fungus which Dr. Flora W. Patterson, of the Bureau of Plant Industry, determined as *Penicillium anisopliæ* Viull. This fungus is known as a parasitic disease of other insects and without doubt killed the larva in question. Comstock records [4] larvæ in his rearing cages being killed by *Metarrhizium anisopliæ.*

The writer found a larva of *Corymbites inflatus* in a rearing cage at the laboratory in Pullman, Wash., which had evidently been killed by a parasitic fungus. It was filled with white mycelium, which distended the body and even grew out between the segments. The specimen was sent in to Washington, but was received in too poor condition for determination.

Early in June, 1913, a large amount of the culture of the white-grub fungus (*Metarrhizium anisopliæ*) was sent to the writer by Mr. J. J. Davis. This material was introduced into a field at Nisbet. Pa. On revisiting the inoculated field on July 14 of that year, a larva of Melanotus was found dead and completely covered with a green fungus. This specimen was sent to Mr. Davis, who tentatively determined the fungus as *M. anisopliæ.* From this culture material the insectary room at the Hagerstown Laboratory became infected, and during the past summer, despite all precautions, at least one-half of the Elateridæ in our rearing cages were killed by this disease.

REMEDIAL MEASURES.

Remedial measures have been given with each of the more important wireworms treated in this paper. Here we wish to report on a number of measures that have been suggested from time to time as efficient in combating these insects. We have actually tried most of these measures, and to prevent repetition of these more or less costly experiments we publish here the results.

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[1] Gardner's Chronicle, London [v. 3], p. 433, June 24, 1843.

[2] Girard, A. Une nouvelle espèce d'Entomophyte. *Cordyceps hunti,* n. sp. (Champignon), parasite d'une larve d'Elateride. *In* Ann. Soc. Ent. France, Bul. des seances, 1895, p. CLXXXI–CLXXXII.

[3] U. S. Dept. Agr., Bur. Ent., Webster Note No. 4751.

[4] Comstock, J. H., and Slingerland, M. V. Wireworms. N. Y. Cornell Univ. Agr. Exp. Sta., Bul. 33, p. 211, November, 1891.

Remedial measures may be classified under three headings: (1) Seed treatment to prevent insects eating the seed; (2) introduction of poisonous or noxious substances into the soil; and (3) cultural methods.

TREATMENT OF SEED.

Under the first head many substances have been used and reported as more or less efficient, among which might be mentioned Paris green and coal tar, gas tar, coal oil, tar, Paris green, and arsenate of lead. In 1884 Webster used kerosene as a treatment of seed corn to protect seed from wireworms. Although his experiment did not apparently impair the vitality of the seed, a farmer who attempted to apply the recommendation claimed that the vitality of the seed was destroyed thereby. In 1888 Forbes treated corn seed with Paris green, and though wireworms fed on corn so thoroughly coated as to be quite green they seemed to experience no ill effects. He also experimented with alcoholic solutions of arsenic and water solutions of strychnine and potassium cyanid.

In the spring of 1911 wireworms were very numerous on the wheat land at Wilbur, Wash., and the writer carried on a series of very extensive experiments to determine the value of some of these substances and also added a few which, to his knowledge, had not been tried before.

Three sacks of wheat (6 bushels) were treated on March 24 with arsenate of lead. Six pounds of insecticide were used for the batch. The arsenate was thinned to the consistency of thick whitewash, with water, and thoroughly mixed into the seed in a large box. The seed, when dry, was very white and well coated. On the same date two sacks (4 bushels) were treated with coal tar. The tar was applied with a paddle, the paddle being first dipped into the tar and then stirred around in the wheat until the seed was well coated. The seed was then mixed with sand and allowed to dry. One sack of wheat was treated with strychnine, 2 ounces of this poison being used to 2 bushels of wheat. The strychnine was dissolved in 2 quarts of hot water and 1 pound of sugar was added as an adhesive. The seed was then soaked in this liquid and allowed to dry. On March 31 all of these treated batches of seed were sown. The sowings were made in plats which were about half a mile long. They were made in an 11-foot wheat seeder, and were arranged as follows:

2 seeder widths of seed treated with strychnine.
2 seeder widths without treatment, as a check.
2 seeder widths of seed treated with coal tar.
4 seeder widths check.
5 seeder widths of seed treated with lead arsenate.
5 seeder widths check.
3 seeder widths of seed treated with coal tar.
9 seeder widths check.
4 seeder widths of seed treated with arsenate of lead.

These plats were carefully staked and examined from time to time, but at no time could any appreciable difference be noted as to their appearance. Wireworms were as numerous in all the treated plats as in the checks. Wheat was very generally attacked and no dead wireworms were found.

A number of wireworms were confined in a large tin cage with wheat treated with strychnine as their only food. After two months these larvæ were still alive and apparently unaffected by the poison, though they ate the poisoned grain.

While these experiments were going on at Wilbur a more intensive series was being carried on at Spokane. Here, instead of wheat, sweet corn was used. These experiments were carried on in a field recently cleared of timber. The soil was quite heavy and very moist. Wireworms were very numerous and apparently quite generally distributed.

On April 5, seed corn was treated in the following manner:

Lot 1. Coal tar was applied very heavily and Paris green dusted onto it until it was quite green.

Lot 2 was treated by soaking for a few minutes in copper sulphate and then drying rapidly in the sun. Several potatoes also were soaked, cut into small pieces, in a saturated solution of strychnine.

This field was all in corn in 1909 and was badly infested with wireworms. In 1910 it was half in wheat on fall plowing and half in potatoes on spring plowing, and was also badly infested this year with wireworms. A plat of each treatment with a check row between each plat was planted on each half of the field. Seventy hills of corn were in each plat. All the plantings were made on April 24. The coal-tar treatment prevented about 90 per cent of the seed so treated from germinating, so this precludes the use, at least as applied to this experiment, of this seed treatment. On May 2 the hills were dug out and the wireworms in each hill counted. Wherever wireworms were present they were attacking the seed. The results of this count appear in Table I:

TABLE I.—*Results of experiments against wireworms with treated seed.*

Row.	Treatment.	Number of hills examined.	Number of wireworms found.	Number of wireworms per hill (average).	Total average number of wireworms per hill for each treatment.
1	Copper sulphate	10	40	4	
11	......do	24	138	5.75	4.87
5	Coal tar and Paris green	24			
7	......do	24			
2	Check	3			
4	......do	24	35	1.458	
6	......do	24	40	1.667	
8	......do	13	22	1.692	
10	......do	24	93	3.875	1.758

From the last experiment we conclude that the use of coal tar and Paris green is not a remedial measure to be recommended. However, Dr. H. T. Fernald has published[1] an account of a series of experiments that seem to reach quite the opposite conclusion, and it is very probable that gas tar will not prevent germination as did the coal tar of our experiments.

The copper-sulphate plat was more severely infested than the check plats, so this treatment is quite useless as an insecticide for wireworms. The potato bait poisoned with strychnine was a failure because the potatoes were allowed to dry up before being placed in the ground.

Mr. G. I. Reeves carried on an experiment at Pullman, Wash., using a commercial tobacco extract applied to the seed corn as a repellent. This experiment was carried on in a root cage. On May 27, 1909, he treated 15 kernels of seed corn by soaking for 24 hours in a solution of commercial tobacco extract, 1 part to 16 parts of water. The seed was dried before planting and was sown with alternate untreated seeds as a check. Wireworms were introduced at the time of seeding and also on June 2. The experiment was discontinued on June 10, and all the seed carefully examined. Of the treated seeds, eight were eaten into by wireworms, while nine of the untreated seeds were destroyed. It is very evident from this experiment that tobacco solution as a repellent is quite useless, at least for wireworms.

Soaking the seed in formalin has been suggested as a means of repelling wireworms. This measure is quite useless. In the regions of the Pacific Northwest where the author was studying severe wireworm outbreaks nearly all the seed wheat had been treated with formalin as a means of preventing the development of smut fungus.

Mr. O. A. Johannsen and Miss Edith M. Patch have published[2] the results of a series of experiments carried on in Maine. They treated seed corn with tar and Paris green, and with arsenate of lead, and found both of these treatments inefficient.

SOIL TREATMENT.

The second group of remedial measures—soil treatment—has received considerable attention. Experiments with soil fumigants are now being carried on by the writer, but as the methods have not as yet been placed on a practical basis this matter will not be treated herein.

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[1] Fernald, H. T. A new treatment for wireworms. *In* Jour. Econ. Ent., v. 2, No. 4, p. 279–280, August, 1909.

[2] Johannsen, O. A., and Patch, Edith M. Insect Notes for 1911. Maine Agr. Exp. Sta., Bul. 195, p. 229–248, December, 1911.

Webster carried on experiments at Cedarville, Ohio, in 1894 to determine the effectiveness of kainit as an insecticide. The fertilizer was applied at the rate of 500 pounds to the acre without any effect whatever. He also carried on a series of experiments at La Fayette, Ind., in 1889, to test the efficiency of an often-recommended substance—table salt. Pots were used in these experiments, and table salt applied to the surface and washed in with water. Three dosages were used at the rate of about 500 pounds, 1,000 pounds, and 25,000 pounds per acre, respectively, and in no case were wireworms killed by the application.

The Maine experiment station has tried a patented preparation composed largely of slaked lime, a "soil fungicide," and tobacco dust, applied to the hills in cornfields infested with wireworms, and has found all of these treatments quite useless. Experiments[1] with chlorid of lime, gas lime, chlorate of potash, bisulphid of carbon, crude petroleum, kerosene, and emulsions of crude petroleum and kerosene, applied to the soil, have demonstrated that none of these substances is of practical value in destroying wireworms. However, the use of petroleum products as soil sterilizers is suggestive, and will be further investigated.

Mr. J. J. Davis[2] has found that a soil fumigant highly recommended by some English entomologists is quite useless in combating *Limonius confusus.*

CULTURAL METHODS.

The third group of remedial measures—cultural methods—is the only one which so far has been actually proved to be of practical value.

Flooding land where irrigation is practiced would be of little avail unless long continued, as we have records of severe outbreaks of wireworms on land in Indiana that is annually overflowed by the rivers. Fall plowing is of but little use in combating these insects. The cornfields so severely attacked by the wheat wireworm at Bridgeport last year had been plowed in the spring. The garden patch, however, was fall plowed, and potatoes on this patch were absolutely destroyed by wireworms. Another piece of fall-plowed land on another part of the farm planted to corn was practically free from worms, which illustrates how easily faulty conclusions can be arrived at, with insufficient data. Mr. O. A. Johannsen and Miss Edith Patch record observations made at Monmouth, Me., in 1911, wherein a field was plowed after the ground

[1] Comstock, J. H., and Slingerland, M. V. Wireworms. N. Y. Cornell Univ. Agr. Exp. Sta., Bul. 33, November, 1891.

[2] Davis, J. J. Insect notes from Illinois for 1909. *In* Jour. Econ. Ent., v. 3, No. 2, p. 182, April, 1910.

had been stiffened by frost in the fall, and which was so badly infested the following spring that the crops were absolutely destroyed.

The fatality to the beetles caused by the destruction of the pupal cell in the fall has been apparently somewhat overdrawn. In our cages at the field station at Hagerstown, Md., we had, in March, 1914, many adults of *Agriotes mancus* alive in cages wherein they were subjected to outdoor weather conditions. These adults were removed from their pupal cells during September, 1913.

Two other remedial measures have been suggested from time to time, the first of which is trapping the larvæ in potato and other vegetable baits and hand killing; the second is killing the adults with poisoned bait of several kinds—clover, sweetened liquids, bran mash, potatoes and other vegetables, and rape cake. Miss Ormerod found a true rape-seed cake quite useless, but reports[1] "Kurrachee cake," made from mustard seed, as killing the larvæ which fed upon it. These methods have been found very inefficient, and even were they successful in killing the insects they would be impractical so far as the extensive cereal and forage crops are concerned.

[1] Proc. Ent. Soc. London, 1882, p. xix.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 160

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 22, 1915.

(PROFESSIONAL PAPER.)

CACTUS SOLUTION AS AN ADHESIVE IN ARSENICAL SPRAYS FOR INSECTS.[1]

By M. M. High,
Entomological Assistant, Truck Crop and Stored Product Insect Investigations.

INTRODUCTION.

In the application of arsenical sprays against insects with biting mouth parts the object in view is, of course, to protect the plant or plants from insect ravages by poisoning the foliage, so that the insects will, in feeding, take into their system enough of the poison to produce death. Some arsenicals, because they possess a higher percentage of free arsenic, act more quickly in this direction than others, but these are, as a rule, injurious to most plant foliage, unless mixed with some agent that will counteract the free arsenic and produce a more uniform distribution on the plants sprayed. Arsenicals containing a high percentage of arsenious oxid generally possess only slight adhesive powers and after a heavy dew or light rain are washed from the foliage.

Certain crops demand very prompt protection from the ravages of biting insects; otherwise severe losses are almost certain to be incurred, and to insure the preservation of the crop concerned it is highly important that a poison with some lasting qualities, as well as one quick in action, be applied. Thus it follows that an arsenical must adhere to the foliage if the most favorable results are to be realized.

In 1913 and 1914 some experiments were conducted for the purpose of discovering a good adhesive which could be obtained easily and at little expense to the grower. This adhesive has been found in a cactus that flourishes in the Southwest. The variety which was most extensively used in the following experiments, and

[1] This bulletin describes the use of cactus solution as an adhesive in the application of arsenical sprays against the belted cucumber beetle. It is applicable to regions where prickly pear is easily obtainable and for the treatment of insects of related habits, such as the striped and twelve-spotted cucumber beetles, etc.

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one of the most abundant of the many species to be found in the lower Rio Grande Valley, is *Opuntia lindheimeri* Engelm., commonly known as the "prickly pear." This plant produces a fruit that is available about one month in each year and one of which the natives are especially fond. Further, the plants themselves furnish food to many domestic animals and, it is claimed, prevent many cattle from dying during severe droughts because of their highly watery composition. Many ranchmen protect their cacti during a wet season and save them against the time of drought. A gasoline torch, manufactured especially for the purpose, is used to burn off the spines, and as soon as this burner is put into operation cattle, recognizing the peculiar noise, come at once to obtain the food thus rendered available.

The prickly pear, besides being high in fluid content, is very mucilaginous and is invariably used by Mexicans in the manufacture of whitewash, to promote adhesiveness. The cactus is sliced the evening previous to the application and placed in the water or in the lime mixture, where it remains for several hours. The whitewash is then ready for use. The utilization of cactus in whitewash thus suggested to the writer its availability as a factor in promoting adhesion in poisonous sprays.

EXPERIMENTAL WORK WITH CACTUS.

EXPERIMENTS WITH ZINC ARSENITE.

On March 23, 1913, 20 pounds of cactus were sliced lengthwise and immersed overnight in 50 gallons of water. The next morning 2 pounds of zinc arsenite in paste form were added, and after a thorough mixing spraying was commenced on sugar beets which were being injured by the belted cucumber beetle (*Diabrotica balteata* Lec.).[1]

A previous experiment demonstrated that cactus yields a higher percentage of mucilaginous matter if sliced at right angles to the spines, and, moreover, the time required for preparation is materially shortened by this method. It is best, however, to cut the larger pads both ways, since, owing to the cellular structure of the pads, this method insures a more copious and rapid flow of the juices. The result obtained from the use of the spray, at the rate of 20 pounds of prepared cactus to 50 gallons of water, was gratifying; the spray not only adhered to the foliage better, but spread more uniformly over the surface of the leaves. The quantity of cactus required to

[1] Accounts of this species, by Dr. F. H. Chittenden and Mr. H. O. Marsh, have been published in Bulletin No. 82, Part VI, Bureau of Entomology, U. S. Departemnt of Agriculture, pages 69–71 and 76–82, December 8, 1910. These include illustrations of the stages, notes on life history, lists of food plants, and technical descriptions of the different stages.

make 20 pounds is comparatively small. The results of this spraying operation were favorable, as the number of beetles present four days later did not exceed 30 per cent of the original number, and a majority of these had just arrived from near-by breeding quarters.

In the next experiment 10 pounds of cactus were used in combination with 3 pounds of zinc arsenite and 50 gallons of water. As before, the cactus was sliced and placed in water the evening previous to spraying, and the following morning the solid particles were thrown out before the poison was added. This spraying operation, with but 10 pounds of cactus, gave good results, but the spreading quality of the material was not as good as in the first experiment, in which 20 pounds of cactus were employed.

In the next experiment, on April 3, 15 pounds of cactus were used with 3 pounds of zinc arsenite and 50 gallons of water. In this case the poison appeared to adhere and spread as well as when 20 pounds of the cactus were used. It thus appeared that 15 pounds of the cactus with spines[1] would be about the proper proportion to use with 50 gallons of water in future work.

The following table shows the mortality of *Diabrotica balteata* placed on an encaged sugar-beet plant sprayed with zinc arsenite at the rate of 3 pounds to 50 gallons of water plus 15 pounds of prepared cactus:

TABLE I.—*Experiment No. 10.—Cactus as an adhesive in combination with arsenite of zinc, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 17	5	4	1	4	1
Mar. 18	5	3	2	3	2
Mar. 19	5	3	2	3	2
Mar. 21	5	1	4	1	4
Mar. 22	5	0	5	0	5

The beetles were placed on the sprayed plant at 6.30 p. m., March 15, but during several cool days which followed they were quite inactive and probably fed but little. Cactus was tested in the insectary as an adhesive before experiments were conducted in the field, to insure the absence of any inopportune chemical reaction that might injure the plants. This experiment demonstrated that in approximately six days after spraying 99 per cent of the beetles succumbed to the poison. Simultaneously with the foregoing experiment another

[1] Cactus with spines is preferable to the spineless varieties; in fact, the spiny variety appears to be nearly one-third richer in gluten. The Dairy Division of the Bureau of Animal Industry has been conducting some cactus-feeding experiments for dairy cows the past two years, and has made several analyses of both the spined and spineless varieties of cactus.

pot experiment was made, discarding cactus and using the same amount of arsenite of zinc. The following results were obtained:

TABLE II.—*Experiment No. 11.—Arsenite of zinc without cactus as an adhesive, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 17	7	6	1	6	1
Mar. 18	7	4	3	4	3
Mar. 19	7	4	3	2	5
Mar. 21	7	3	4	3	4
Mar. 22	7	3	4	1	6

It will be noticed here that at the end of the sixth day the mortality was much under that of experiment No. 10. The plants in both experiments were sprayed thoroughly, but the latter spray did not spread as well as the former. In the next experiment cactus was again used at the rate of 20 pounds to 50 gallons of water. The same amount of zinc arsenite was used in this experiment, or 3 pounds to 50 gallons of water. Table III shows the number of deaths on each date.

TABLE III.—*Experiment No. 12.—Cactus as an adhesive in combination with arsenite of zinc, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 17	14	8	6	6	8
Mar. 18	14	3	11	2	12
Mar. 19	14	3	11	1	13
Mar. 21	14	0	14	0	14
Mar. 22	....	0	....	0	....

The beetles were placed on the poisoned sugar beet at 6 p. m., March 15, and in 36 hours nearly all of them were dead.

EXPERIMENT WITH PARIS GREEN AND LIME.

In the next pot experiment Paris green was used in place of zinc arsenite and at the rate of one-half pound to 50 gallons of water plus 2 pounds of lime. The plant was sprayed on March 17, and as soon as the poison was dry on the sugar beet the beetles were liberated inside the cage. Table IV sums up the results.

TABLE IV.—*Experiment No. 13.—Cactus as an adhesive with Paris green and lime, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 18	10	10	0	6	4
Mar. 19	10	2	8	2	8
Mar. 21	10	0	10	0	10
Mar. 22	10	0	10	0	10

The cucumber beetle appeared, as will be seen from the foregoing table, to succumb more readily to the Paris-green spray than to any one of the former sprays of zinc arsenite. In the field experiments there was not much difference, though the zinc arsenite gave more favorable results in that it lasted longer. The dews in the lower Rio Grande Valley are usually heavy ones, which would naturally reduce the effectiveness of the Paris-green application. But, as already shown, in the pot experiment the results appeared much more quickly than with the other sprays.

UNSATISFACTORY RESULTS WITH LEAD ARSENATE.

Since the experiments with cactus as an adhesive and a spreader for zinc arsenite and for Paris green and lime had resulted so favorably, not only in increasing the adhesiveness of the spray, but also in the destruction of the beetle, it was decided to try it in combination with lead arsenate. The cactus was placed in a barrel of water about 12 hours before the arsenate of lead was added. A few minutes after adding the lead arsenate the formation of a precipitate was observed. In an hour's time a cottony scum had formed on the surface and appeared fairly well distributed throughout the mixture. In the meantime spraying had been going on, but with little success, as this semiliquid matter clogged the nozzles. In about two hours' time the precipitation was more complete and the solution was discarded, since its consistency rendered it useless for spraying purposes. Alkalinity of the water was at first suspected, and rain water was substituted, but with the same results, so that no further attempt was made to use the cactus with lead arsenate. The lead arsenate employed was air-dried, having been formerly paste which had dried out in an open keg; but no doubt even with fresh arsenate of lead the same precipitation would have taken place, as the air-dried arsenical had been used successfully without the cactus and had remained in solution, although it did not adhere well.

In experiment No. 14 (Table V) arsenate of lead was employed at the rate of 3 pounds to 50 gallons of water. As the potted plant was quite small, there was not sufficient foliage to support a great number of beetles, and on April 4, at 6 p. m., six belted cucumber beetles were placed on the plant.

TABLE V.—*Experiment No. 14.—Cactus as an adhesive with arsenate of lead. Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 6	6	5	1	4	2
Apr. 7	6	5	1	4	2
Apr. 8	6	4	2	3	3
Apr. 9	6	2	4	2	4
Apr. 11	6	0	6	0	6

The time required to kill all of the beetles placed on the sprayed plant was approximately six days, provided all specimens began feeding immediately after being placed on the poisoned plant.

In the next experiment $2\frac{1}{2}$ pounds of arsenate of lead were used to 50 gallons of water. The host plant was spinach that had been growing in the pot for some time. The spraying was done during the morning of April 14, and at 4 p. m. on the same date, after the poison had dried, 10 belted cucumber beetles were placed inside the cage and on the plant where possible. Table VI shows the mortality:

TABLE VI.—*Experiment No. 15.—Cactus as an adhesive with arsenate of lead, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 16	10	9	1	7	2
Apr. 17	10	8	2	5	3
Apr. 24	10	2	8	0	8

The spray here used was not so effective as in experiment No. 14, the mortality being only 80 per cent at the end of nine days. The plant died from some cause about the 24th of April, and probably very little feeding was done during the last few days the plant lived after being sprayed.

FURTHER EXPERIMENTS.

The results obtained in the foregoing experiments had been so favorable that further experiments on a larger scale were commenced. Several thousand pounds of the prickly pear were used in the work, and as the regular "pear burner," or torch, was employed to singe the spines from the pads, they could now be handled with some comfort. The work has been conducted in a small way and on a large scale with about the same degree of success. It requires only a short time to burn the spines from enough cactus to make a sufficient amount of adhesive material for several thousand gallons of spray mixture.

The list of insecticides that have been employed in combination with cactus as an adhesive includes Paris green, lead chromate, zinc arsenite (in both paste and powder forms), lead arsenate, ferrous arsenate, and iron arsenite. The preceding pages give an account of experiments with zinc arsenite in the paste form, Paris green, and lead arsenate in the paste form, while the experiments that follow will include zinc arsenite in the powder form, lead arsenate in paste form, ferrous arsenate, and iron arsenite, the last two used in the powder. The powdered zinc arsenite gave excellent results in every instance when used in combination with cactus water, and the mortality was in some cases higher than when three times the weight in paste form was used. Very favorable results were obtained with ferrous arsenate in most cases, while the results with iron arsenite were not quite so good. The following tables give results of the experiments conducted in the insectary with each of the arsenicals here mentioned.

On March 1, 1914, a cabbage plant was sprayed with ferrous arsenate at the rate of 1 pound to 40 gallons of water, and as soon as the poison had dried on the leaves, or at 6 o'clock p. m. the same date, four *Diabrotica balteata* were encaged on the plant.

TABLE VII.—*Experiment No. 16.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 2	4	4	0	1	3
Mar. 3	4	4	0	0	4
Mar. 4	4	4	0	3	1
Mar. 5	4	4	0	3	1
Mar. 6	4	4	0	3	1
Mar. 7	4	4	0	2	2
Mar. 8	4	4	0	3	1
Mar. 9	4	4	0	2	2
Mar. 10	4	1	1	1	1

It will be seen from the foregoing table that the mortality was much too low to pay for applying the poison. It was observed that the feeding was light for four or five days after confinement. The solution did not adhere and distribute itself well enough to make a good spray.

About the same time that spraying was done on experiment No. 16 a second solution was made up, using the same amount of ferrous arsenate or 1 pound to 40 gallons of water. Eighty per cent of the water used was taken from a tank where two days previous $1\frac{1}{3}$ pounds of cactus to the gallon of water had been placed. This made an exceedingly glutinous solution which caused the liquid to spread uniformly as well as to adhere. On March 2 seven *Diabrotica balteata* were placed on the plant.

TABLE VIII.—*Experiment No. 17.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 3	7	6	1	3	4
Mar. 4	7	6	1	6	1
Mar. 5	7	6	1	6	1
Mar. 6	7	6	1	4	3
Mar. 7	7	6	1	5	2
Mar. 8	7	6	1	4	3
Mar. 9	7	6	1	3	4
Mar. 13	7	5	2	1	6
Mar. 14	7	5	2	4	3

The death rate in this experiment was very low, which is accounted for to a certain degree by a decrease in the voracious appetite of the beetles, which were encaged on a cabbage plant. Feeding appeared to be more from the underside of the leaves, and usually the epidermis was left intact.

In the next experiment with potted plants spinach was substituted for cabbage, since it seemed preferable to the beetles, particularly as the cabbage plants had been growing for some time in the pots and had become more or less stunted and tough. In this experiment ferrous arsenate was used at the rate of 1 pound to 40 gallons of water, in which 40 pounds of cactus had been placed 72 hours previous. Table IX shows results and mortality. The plant was sprayed April 2, and on April 4 five beetles were liberated on the plant and covered with a lantern globe.

TABLE IX.—*Experiment No. 18.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 4	5	5	0	4	1
Apr. 5	5	5	0	1	4
Apr. 6	5	5	0	0	5
Apr. 7	5	4	1	0	5
Apr. 8	5	3	2	0	5
Apr. 9	5	2	3	0	5

The results here were much better than in experiments Nos. 16 and 17, and the beetles appeared to succumb more readily, since they fed more rapidly.

On April 6 a spray was made up of ferrous arsenate, using 1 pound to 12 gallons of water in which 10 pounds of sliced cactus had been placed 48 hours previous to spraying, insuring thorough glutinous consistency in the spray mixture. Some spinach plants in pots were sprayed previous to spraying plats in the field. On April 13, or one week from date of spraying, six beetles were encaged on a plant and observed for 10 days. Table X shows the number of beetles that succumbed.

TABLE X.—*Experiment No. 18.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	6	6	0	3	3
Apr. 14	6	4	2	4	2
Apr. 15	6	4	2	4	2
Apr. 16	6	4	3	3	3
Apr. 18	6	4	2	1	5
Apr. 20	6	3	3	2	4
Apr. 21	6	3	3	1	5
Apr. 23	6	3	3	0	6

This plant began to wilt and appear blighted on April 18, little feeding being done from that date, even though the poison had been on the plant for nearly two weeks. It is thought that a higher mortality would have occurred had the plant remained green and living.

An arsenate of lead spray was made, using the paste form at the rate of 4 pounds to 60 gallons of water. In this solution no cactus was used. On April 11 five beetles were placed on an encaged cabbage plant in the insectary that had been sprayed five days before. Table XI gives the final results.

TABLE XI.—*Experiment No. 20.—Arsenate of lead without cactus, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	5	5	0	4	1
Apr. 14	4	3	1	1	3
Apr. 16	4	3	1	1	3
Apr. 18	4	2	2	1	1

This spray did not adhere to the cabbage foliage as well as when cactus was used, and the beetles fed very slowly after the first two days of confinement. Better results were obtained in the field, as the beetles began feeding just after spraying, and where a partial uniform coating was secured the poison was effective. If the poison could be made to combine or mix with cactus water the results would undoubtedly be much better.

April 2 a solution was made up of iron arsenite, using 1 pound to 40 gallons of water. Some difficulty was experienced in bringing the poison into suspension, as it settled quite rapidly to the bottom of the barrel. April 4 another solution was prepared, using the same amount of poison to a given quantity of water, with the previous addition of cactus at the rate of 1¼ pounds to each gallon of water, in which salicylic acid had been used as a preservative to prevent fermentation of the cactus juice. As a check some potted cabbage plants were sprayed. On April 11 ten belted cucumber beetles were encaged on one of the cabbage plants that was sprayed April 4. Table XII gives the results.

TABLE XII.—*Experiment No. 21.—Cactus as an adhesive with iron arsenite. Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	10	9	1	7	3
Apr. 14	8	7	1	7	1
Apr. 15	8	7	1	7	1
Apr. 16	2	1	1	1	1
Apr. 18	2	1	1	0	2

It is apparent that although the application had been made for more than a week, a sufficient amount of the arsenical remained to have some effect on the feeding of the beetles. A later experiment with iron arsenite showed the mortality of the beetles when they feed on the plant immediately after spraying has been done.

While spraying a plat of sugar beets at the South Texas Gardens on April 15 the writer also sprayed some plants in the insectary, using zinc arsenite in the powdered form. The cactus was used at the rate of 1.8 pounds to the gallon of water and the zinc arsenite at the rate of 1 pound to 64 gallons. The plants were sprayed on the morning of the 15th, and on April 16 eleven beetles were liberated inside the cage surrounding the plants.

TABLE XIII.—*Experiment No. 22.—Cactus as an adhesive with zinc arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 16	11	11	0	8	3
Apr. 17	11	10	1	9	2
Apr. 18	11	10	1	9	2
Apr. 20	11	4	7	4	7
Apr. 21	11	4	7	3	8
Apr. 23	11	1	10	0	11

This spray adhered and spread exceedingly well, although much less cactus could have been used with equal results. However, no precipitation was observed when the cactus was used at this strength.

In experiment No. 23 a potted sugar beet was sprayed April 11 with zinc arsenite (powdered) at the rate of 1 pound to 35 gallons of water, using three-fourths of a pound of cactus to each gallon of water, the cactus having been placed in the water four days before. Fermentation was prevented by the use of copper sulphate. On April 15 ten belted cucumber beetles were encaged on the plant.

TABLE XIV.—*Experiment No. 23.—Cactus as an adhesive with zinc arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 16	10	10	0	5	5
Apr. 17	10	10	0	5	5
Apr. 20	8	2	6	2	6
Apr. 21	8	1	7	1	7
Apr. 23	8	0	8	0	8

It will be observed that in this experiment less than half the quantity of cactus was used than was added in experiment No. 22, but the zinc arsenite was increased to nearly twice the amount used in the preceding experiment, and there was only a 10 per cent difference in the mortality. The plants used were both sugar beets. The result of this experiment shows that by the use of cactus the lasting qualities of the poison on the plants may be greatly increased.

The spraying in experiment No. 24 was done at the same time as in experiment No. 22, 1 pound of zinc arsenite being used to 64 gallons of water but only one-third of a pound of cactus to each gallon, the glutinous matter having been extracted by soaking the cactus for four days in water. Salicylic acid was added as a preservative. The sugar beet was sprayed on April 15, and on April 16 five beetles were placed on the plant. April 17 one beetle was found dead and four still feeding. April 18 three had died from the effect of the poison and two were yet feeding. On April 20 all were dead. During the four days the beetles were encaged they appeared to feed very rapidly, as they had been confined for several days without food. This proves that 1 pound of powdered zinc arsenite with cactus to make it adhere is more effective than 2 pounds in the paste form and just as effective as 3 pounds in the paste form.

The plant in experiment No. 25 was sprayed with 1 pound of zinc arsenite to 35 gallons of water and at the same time as No. 23, on April 11, with the same quantity of cactus, but the beetles were not placed on the plant for six days after spraying. On April 17 three beetles were encaged, and by the 22d all were dead.

On April 5, after spraying a field plat of cabbage with ferrous arsenate, several plants were treated in the insectary. The strength used was 1 pound to 12 gallons of water. One pound of cactus was used to each gallon of water, the cactus water having been made 26 days when used. It was prepared on March 16 and sodium benzoate added as a preservative. On April 11 six beetles were placed on a cabbage plant covered by a lantern globe. Table XV gives the number of beetles that succumbed in a given period.

TABLE XV.—*Experiment No. 26.—Cactus as an adhesive with ferrous arsenate. Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	6	6	0	4	2
Apr. 14	6	6	0	5	1
Apr. 15	6	6	0	5	1
Apr. 16	6	6	0	1	5
Apr. 17	6	3	3	2	4
Apr. 18	5	1	4	1	4
Apr. 20	5	1	4	1	4
Apr. 21	5	0	5	0	5

The beetles from some cause fed very sparingly the whole time they were encaged. Whether the poison was distasteful or the plant had become tough, could not be ascertained.

On April 4 a small plat of cabbage was sprayed with iron arsenite at the rate of 1 pound to 40 gallons of water. Two pounds of cactus were added to each gallon and the decoction was prepared on March 14 and 15. It was preserved with salicylic acid at the rate of ¼ pound to 50 gallons. It was quite difficult to bring the arsenite of iron into suspension. Thorough agitation was required to prevent it settling to the bottom of the tank. With a hand sprayer it is impossible to secure uniformity in the spray. Table XVI gives results with 10 beetles on one cabbage plant sprayed on April 4, the beetles being liberated on the plant April 11.

TABLE XVI.—*Experiment No. 27.—Cactus as an adhesive with iron arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	10	10	0	10	0
Apr. 14	10	9	1	8	2
Apr. 16	10	9	1	6	4
Apr. 17	10	9	1	6	4
Apr. 18	10	8	2	7	3
Apr. 20	10	8	2	4	6
Apr. 21	9	6	3	6	3
Apr. 23	9	5	4	5	4

Feeding was very heavy on this plant, which had been growing for some time in the pot and had been seriously attacked by aphides on two occasions. Iron arsenite has some value as an insecticide, but not as much as ferrous arsenate, even when properly made up, and unless an effort is made to apply it in uniform coating on the foliage it has little value as an insect destroyer.

CACTUS COMPARED WITH WHALE-OIL SOAP AS AN ADHESIVE.

On February 20, 1914, while conducting spraying experiments against the belted cucumber beetle and cabbage looper (*Autographa brassicæ* Riley) on cabbage on the farm of Mr. George Federhoff, near Brownsville, Tex., it was decided to make a comparison of whale-oil soap and cactus as adhesives, without considering the cost of the two products. One acre of cabbage was sprayed with 1 pound of zinc arsenite (in powdered form) to 60 gallons of water, with the addition of 35 pounds of cactus. The cactus was sliced and put in the water on February 19, and had given up its glutinous matter to the solution by the time spraying was begun the following day. This mixture spread and adhered exceedingly well. The next acre was sprayed with the same amount of poison, but whale-oil soap was substituted for cactus. This was done both for a comparison of adhesive qualities and to observe the effect of the soap on the cabbage aphis (*Aphis brassicæ* L.), as in several spots in this acre the aphis was making its appearance. The soap was used at the rate of 3 pounds to 60 gallons of water. Very careful notes were made on the sticking qualities of the soap, and it was found that when compared at close range with the cactus spray the soap equalled the cactus in spreading power, although lacking in adherence. This information was obtained by observing sprayed plants with and without a lens. It was soon seen that the cactus spray adhered and dried on the foliage better than the soap spray. This favored the cactus, since the heavy dews in the Rio Grande Valley will wash poison having but slight adhesive qualities from the foliage in a short time.

COPPER SULPHATE AS A PRESERVATIVE FOR THE CACTUS.

On April 6, 1914, 50 pounds of cactus were cut into small pieces and placed in a barrel with 24 gallons of water, and on April 7, 1 pound of copper sulphate was dissolved in 4 gallons of water and added to the barrel which was numbered lot 6.

The solid portion of the cactus or prickly pear was removed before adding the copper sulphate. This made 28 gallons in solution. No chemical action was observed. The solution kept perfectly for about four weeks, when it had to be discarded to make room for other experiments. The temperature during this time averaged about 70° F.

COPPER SULPHATE USED WITH ZINC ARSENITE.

After using the copper sulphate as a preservative for the juice extracted from the prickly pear, the possibility of a chemical reaction upon the addition of the arsenical to the solution was tested. Upon the addition of powdered zinc arsenite at the rate of 1 pound to 60 gallons of water a slight chemical reaction was noticed, evidently the copper changing places with the zinc to a small degree. A slight precipitate was formed, but not enough to cause any trouble when a good pressure was maintained in the tank of the sprayer. The precipitate was not increased after the mixture was allowed to stand for three hours. No difference was observed in the effectiveness of the arsenical, either with or without the addition of the copper sulphate.

COPPER SULPHATE USED WITH LEAD ARSENATE.

The use of lead arsenate in combination with prickly pear without the addition of some other chemical has never been a success. A precipitate is always formed which makes it impossible to use the mixture to advantage as a spray. The same proportion of cactus and copper sulphate utilized in the zinc arsenite spray was here employed. On April 13, 1914, 1 pound of lead arsenate in the paste form was placed in 20 gallons of cactus water which contained copper sulphate in the amount of 1 pound to 28 gallons of water. It was at once noticed that the copper sulphate retarded the precipitation of the lead arsenate, so much so that the solution could be used as a spray with some success, at a normal pressure with a hand pump. This was encouraging, as it had been impossible to use lead arsenate alone in combination with cactus as an adhesive. The writer would recommend, however, that the foregoing combination be used on a large scale only when a strong pressure can be maintained throughout the operation, or the results will be unsatisfactory.

The mortality in the experiments was practically the same as when the arsenical was used alone. Had more experiments been made in the field, in all probability a higher mortality would have been observed in the end.

COPPER SULPHATE AND FERROUS ARSENATE.

The use of copper sulphate as a preservative for the cactus, combined with ferrous arsenate to form a spray, did not appear to produce any chemical changes, no noticeable precipitate being found that would prevent the use of the solution as a spray. It had been expected that more of an action would take place when the ferrous arsenate was added to the cactus water containing copper sulphate. The ferrous arsenate was not altered in insecticidal value when mixed with sulphate of copper.

EXPERIMENTS WITH OTHER PRESERVATIVES.

SALICYLIC ACID.

On March 13, 1914, 45 pounds of cactus were sliced and placed in 32 gallons of water, and in another lot 30 pounds were added to 24 gallons of water. The following day the solid portion of the cactus was removed from the two lots and the water poured from both into another receptacle. This made 56 gallons of the liquid to be preserved. One-fourth of a pound of salicylic acid was dissolved and added to the cactus water, and the mixture was allowed to stand exposed to the air. On April 1 the mixture was found to be in perfect condition. A bluish-white scum was noticed to have formed on the surface shortly after the acid was dissolved in the water. To dissolve salicylic acid a certain amount of alcohol is necessary. At first the acid was dissolved in a 10 per cent solution of alcohol, but it was later found that cactus water served equally well for this purpose after fermentation was well under way, although action was somewhat delayed.

SODIUM BENZOATE.

Sodium benzoate was used in a limited way as a preservative for the cactus solution. On March 14 one-fourth of a pound was dissolved in a small quantity of alcohol and added to a barrel containing 40 gallons of water in which 50 pounds of cactus had been placed March 13, after removing the solid portion of the pear. The mixture was stirred vigorously for five minutes and later covered. On April 2 an examination was made and the liquid used as a spray with zinc arsenite. Only slight fermentation had taken place, and no difficulty was encountered in applying the spray.

The first disadvantage in using sodium benzoate for such a purpose is its cost. It is somewhat more expensive than other chemicals of this class, and the element of cost is a primary consideration. Another feature is that it is not easily dissolved, and unless it is thoroughly dissolved its powers as a preservative are considerably lessened.

On April 2 sodium benzoate was again used in the proportion of 1 pound to 200 pounds of cactus in 100 gallons of water. This was quite a concentrated mixture, but it kept in perfect condition for two weeks, at the end of which time it was used up. The average temperature a part of the time was 80° F.

THE COMMON PRICKLY PEAR CACTI AND THEIR CHEMICAL COMPOSITION.

The common cactus or prickly pear of southern Texas is a variety known as "nopal" or "nopal azul" (*Platopuntia lindheimeri* Engelm.). This is the variety with flat, rounded leaves and growing about 4 or 5 feet high, and it is found well distributed over southern Texas. It is a native species which varies considerably in coloration of spines as well as in its general habit of growth. The fruit is purplish throughout, more so than the more spiny variety, *Platopuntia engelmannii* Salm., which is very similar in habit of growth, but usually occurs farther west than the region occupied by this species. The large spineless cactus frequently cultivated, but ordinarily not occurring abundantly in the cactus plains of southern Texas, is a species which has been called *Platopuntia tuna* Will. It grows much taller than the common "nopal" and is known in California as "mission pear" and in Texas as "Nopal de castilla." It frequently grows 10 to 15 feet in height, with the trunk 12 inches in diameter, and the joints in shape are more elliptical than rounded. The fruit is considerably larger than that of the common "nopal" and greenish throughout.

The chemical analyses of these plants, taken from Bulletin No. 60 of the New Mexico Agricultural Experiment Station,[1] are as follows:

TABLE XVII.—*Chemical analysis of Platopuntia lindheimeri.*

	Green.			Air dry.		
Sample No.	7515	7516	7567	7515	7516	7567
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Spines	0.10	....	0.42	0.72	....	2.60
Water	87.36	79.88	84.82	5.65	5.20	6.55
Ash	2.82	4.98	2.27	21.05	23.45	13.95
Crude protein	.60	.45	.96	4.49	2.12	5.92
Crude fat	.26	.20	.30	1.95	.95	1.82
Nitrogen free extract	7.54	9.55	9.84	56.26	44.98	60.61
Crude fiber	1.42	4.94	1.81	10.50	23.30	11.15
Organic matter	9.82	15.14	12.91	73.30	71.35	79.50

ANALYSIS OF THE ASH.

[Sample No. 7515.]

Carbon .... per cent..	0.14
Sand .... do....	.29
Per cent in pure ash:	
Soluble silica (SiO)	.43
Iron (Fe)	.20
Aluminum (Al)	.00
Manganese (Mg)	.49
Potassium (K)	14.22
Sodium (Na)	.35
Phosphoric acid radicle (PO_4)	1.11
Sulphuric acid radicle (SO_4)	1.15
Chlorine	2.15
Carbonic acid radicle (CO_3)	49.12

TABLE XVIII.—*Chemical analysis of Platopuntia engelmannii.*

	Green.				Air dry.			
Sample No	65621	6575	7810	78411	65621	6575	7810	78411
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Spines	....	0.32	0.04	....	....	3.33	0.33	....
Water	89.09	91.07	89.41	85.41	6.20	7.33	6.83	3.97
Ash	.91	2.00	1.60	.77	7.80	20.80	14.05	5.07
Crude protein	.48	.32	.35	.46	4.16	3.29	3.07	3.06
Crude fat	.33	.12	.23	.33	2.85	1.20	2.00	2.20
Nitrogen free extract	7.31	4.95	7.21	10.03	62.84	51.43	63.48	72.58
Crude fiber	1.88	1.54	1.20	3.00	16.15	15.95	10.57	13.12
Organic matter	10.00	6.93	8.99	13.82	86.00	71.87	79.12	90.96

TABLE XIX.—*Chemical analysis of Platopuntia tuna.*

	Green.		Air dry.	
Sample No	7519	7577	7519	7577
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Spines	0.36	....	1.82	....
Water	81.86	92.25	5.18	8.12
Ash	4.29	1.75	21.65	20.80
Crude protein	1.32	.63	6.68	7.53
Crude fat	.28	.16	1.40	1.85
Nitrogen free extract	8.88	4.02	44.56	47.60
Crude fiber	4.07	1.19	20.53	14.10
Organic matter	14.55	6.00	73.17	71.08

[1] Griffiths, David, and Hare, R. F. Prickly pear and other cacti as food for stock, II. N. Mex. Agr. Expt. Sta. Bul. 60, 134 p., 7 pl., November, 1906.

SUPERIORITY OF CACTUS FROM DRY LAND.

It has been found that cactus growing near resacas and in low wet places yields less glutinous matter to the gross pound than it does when growing on high dry soil. Thus time is saved in making up a spraying solution if the cacti are collected from the higher regions, and not in or near standing water.

On April 13, 1914, 75 pounds of cactus were placed in 40 gallons of water. Twenty-four hours later the cactus was removed and allowed to drain for about one-half hour. It weighed 85.5 pounds, or 10½ pounds more than when placed in the water. Another lot of 110 pounds was increased in weight to 124 pounds by leaving it in water 24 hours. However, when the cactus is sliced and allowed to remain in water until fermentation is well under way, there will be a slight decrease in weight. This will not happen where a preservative is used.

ADVANTAGES IN THE USE OF CACTUS AS AN ADHESIVE.

By the use of cactus as an adhesive not only do the arsenicals give better and more lasting results, but considerable expense may be saved in another way. In the Southwest, where all insecticide material must be shipped in from a great distance, the expense of transporting this material is often more than the cost of the insecticide itself, so that material of a poor quality is often used instead. For some years arsenicals in the paste form have been extensively used by fruit and truck growers on account of their better adherence and lasting qualities, but where a good adhesive is used the writer much prefers arsenicals in the powder form. In conducting experiments in the insectary and in the field at no time have the powdered arsenicals proved less effective, and at times the mortality would be considerably above that shown in another experiment conducted at the same time with arsenicals in the paste form. Better results have been obtained in using 1 pound of zinc arsenite in powder form with cactus than by the use of 3 pounds in the paste form to the same amount of water. Thus equal results may be obtained, with a reduction of 66 per cent in express and freight charges paid in securing arsenicals from a distance.

QUANTITY OF CACTUS TO USE.

The amount of cactus that may be used with good results varies with the environment under which the plants have been growing. If the plants have been growing in or near water it will be necessary to increase the quantity of cactus used to each gallon of water. In general, the correct proportion will range from ⅓ pound to 1 pound to every gallon of water used in making up the spraying mixture. These proportions have given the most favorable results in all experiments conducted so far. When amounts in excess of 1 pound to each gallon of water are used the adhesive powers do not appear to be increased to any great extent, and on the other hand difficulty is experienced in applying the spray, particularly where very fine nozzles are employed.

ZINC ARSENITE AS AN INSECTICIDE.

Zinc arsenite has been used both in the paste and powder forms with much success for the belted cucumber beetle, as well as for some other insects of this class. It has proved to be one of the most effective sprays for use in humid climates, as it appears to last longer. No other arsenical has given better results, and in the majority of cases the mortality has been higher than with any other arsenical spray. The powder when used with cactus to make it adhere is to be preferred for general use over any arsenical now on the market. This spray in the writer's opinion surpasses in lasting qualities any of the arsenicals and at the same time gives a higher mortality. In action it is somewhat slower than Paris green, but it gives better results in the end. The writer would not recommend, however, that zinc arsenite be used on plants that are nearly ready for market, for the poison does not wash off easily.

FERROUS ARSENATE AS AN INSECTICIDE.

Ferrous arsenate has given very good results in combination with cactus to increase its adhesive powers. No serious effects from its use on the most delicate foliage have been observed. The cost of the product at the present time places it beyond general use as an insecticide. The ferrous arsenate in the powder form is very easily brought into suspension, requiring less time than some of the other arsenicals now more extensively used to destroy biting insects. Another feature in the use of this arsenical is that it remains in suspension exceedingly well and settles very slowly to the bottom of the tank. This makes it a most desirable poison for use with small sprayers not equipped with agitators.

IRON ARSENITE AS AN INSECTICIDE.

Iron arsenite was given a trial against the belted cucumber beetle only, and was found to give varying results. The powder was made into a spray and applied both with cactus as an adhesive and without the cactus. The iron arsenite is quite hard to bring into suspension and soon settles to the bottom of the spray tank unless constantly agitated. Its effectiveness as an insecticide was disappointing; in fact, it is so low that it is doubtful that this arsenical can ever come into general use as a spray. Much difficulty was experienced in obtaining uniform distribution over the surfaces sprayed, even when used with cactus. The cactus increased its adherence and spraying qualities, but not sufficiently to remedy matters completely. The foregoing experiments show its effectiveness as compared with ferrous arsenate, zinc arsenite, lead arsenate, and Paris green.

FINAL RESULTS FROM SPRAYING.

The pot experiments carried on in the insectary for the belted cucumber beetle and the other species concerned were undertaken to assist in checking up results in the field. They served for more than this, however, for in a short time it was possible to accumulate much data as to the effectiveness of each spray that otherwise could not have been secured in nearly so short a time, while the estimates as to mortality in each of the experiments made would have been much less conservative.

It was found that the beetles could be best controlled by spraying with zinc arsenite or with Paris green. The other arsenicals employed, while effecting a control in most cases, did not give as high mortality as the two arsenicals mentioned. The number of applications rendered necessary varied with the location of the sugar beets, i. e., their distance from crops where the beetles were breeding in large numbers. One plat of sugar beets was sprayed only once, while on the other hand several plats of beets, spinach, and cabbage were sprayed from two to four times in order to prevent the crop from being badly stunted in growth. The greatest damage is done from the time the beets begin coming up until the leaves have reached a height of 10 inches. Attention should be given the crop from the time the seeds are planted, in order that no serious damage may be done before remedial measures can be put to practice.

RECOMMENDATIONS FOR CONTROL.

The control of such pests as the belted cucumber beetle does not require the attention necessitated by some of the noxious caterpillars and sucking insects. But to keep the injury down to the minimum frequent observation should be made while the plants are small, as this is the time when the beetles are capable of doing the greatest amount of damage.

If the beetles are present in sufficient numbers partially to defoliate a few plants, it is time to begin spraying. It may be necessary to spray only once in order to effect control, but this will depend upon the surrounding vegetation as well as upon the weather conditions.

Any of the arsenicals may be used in the form of a spray to control this beetle. If arsenite of zinc in paste form is to be used, the writer will recommend 3 pounds to 50 gallons of water, in combination where possible with some adhesive, in order that best results may be obtained. In the Southwest the prickly pear serves the purpose best, because better results have been obtained where it was used than with any one of several other adhesives. From an economic standpoint, also, it has first rank as an adhesive and spreader. It has been ascertained that zinc arsenite in the powder form in the proportion of 1 pound to 50 gallons of water in combination with cactus gives a little higher mortality than 3 pounds in the paste form, and a more extensive use of this powdered form is to be recommended, particularly in the cactus-growing region or where the glutinous matter of this plant can be had for use in the spray.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 161

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
December 18, 1914.

THE MEDITERRANEAN FRUIT FLY IN BERMUDA.

By E. A. Back,

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INTRODUCTION.

This paper is the result of an investigation of the fruit-fly situation in Bermuda, made by the writer during December, 1913, at the request of Mr. C. L. Marlatt, Assistant Chief of the Bureau of Entomology and chairman of the Federal Horticultural Board, in order to gain at first hand information that might be of value to the Horticultural Board in framing its quarantine regulations against this pest.

HISTORY OF THE FRUIT FLY IN BERMUDA.

The Mediterranean fruit fly, *Ceratitis capitata* Wied., was not recorded in literature from Bermuda until 1890, when Riley and Howard[1] report receiving specimens of infested peaches from St. George. However, it had been known as a pest in Bermuda many years before this date, as Mr. Claude W. McCallan, who forwarded these specimens to Washington, stated in his accompanying letter of April of that year that peaches had been subjected to its ravages during the 25 years previous. About the year 1865 a vessel carrying a cargo of fruit from the Mediterranean regions, bound for New York, was forced by severe storms to discharge her cargo in Bermuda, and it is the general belief that at that time the pest gained its foothold in this English possession. But whatever the source of infestation, it is a well-known fact that for nearly 50 years the peach industry of these islands has been a ruined one, and that at the present time the fruit fly is generally distributed over the islands ready to infest all host fruits coming to maturity.

LIFE HISTORY.

Those wishing a detailed description and life history of the Mediterranean fruit fly should refer to the publication of Quaintance,[2] published by the Department of Agriculture.

[1] Riley, C. V., and Howard, L. O. The peach pest in Bermuda. (*Ceratitis capitata* Wied.) Order Diptera: Family Trypetidæ. In U. S. Dept. Agr., Div. Ent., Insect life, v. 3, no. 1, p. 5–8, 2 figs., August, 1890.

[2] Quaintance, A. L. The Mediterranean fruit fly. U. S. Dept. Agr., Bur. Ent. Circ. no. 160, 25 p., 1 fig., Oct. 5, 1912.

Note.—This bulletin discusses the history of the fruit fly in Bermuda, the life history of the insect, and the possibility of eradicating it from Bermuda; the bulletin is of interest to entomologists.

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EGG, LARVA, AND PUPA.

Col. W. R. Winter, in his bulletin entitled "The Fruit Fly," published by the Bermuda Department of Agriculture in 1913,[1] gives the only data secured in Bermuda on this pest up to that date. He states that he has found that to pass through the egg, larval, and pupal stages the fly requires from 17 days, during the heat of August, when the monthly mean temperature averages about 81° F., to 6 weeks in winter, when the mean temperature averages about 63.2° F.

With the assistance of Mr. E. J. Wortley, Director of Agriculture of the Bermuda Department of Agriculture, the writer found that the pupal stage alone in Bermuda, when the daily mean temperatures ranged between 62.5° and about 64.8° F., might be lengthened to about 31 days under normal conditions.

Back and Pemberton have found that a temperature varying from 58° to 62° F. increases pupal life to from 29 to 31 days. They have likewise found that while eggs hatch in from 2 to 3 days in Hawaii at a mean temperature of about 79° F., hatching may be delayed until 6 days after deposition when the mean temperature drops to about 71° F., or until 7 to 14 days when the temperature ranges from 54° to 57° F. It has also been found in Hawaii that while the larval stage may require a minimum of 5 to 6 days at a mean temperature averaging about 79° F., it requires from 36 to 53 days in apples at temperatures ranging from 56° to 57° F.

These data are given to substantiate the belief of the writer that the duration of life from the egg to the adult in Bermuda where the winter mean averages about 63° F. is somewhat over two months, and may even be three months under unfavorable circumstances.

THE ADULT.

In the Hawaiian Islands, where the summers are somewhat cooler and the winters slightly warmer than in Bermuda, adult flies have been kept alive over five months. While the majority do not live this long, the belief has been expressed that a few flies may live to be over six months of age, especially during such cool weather as obtains in Bermuda during the winter. Both sexes are sexually immature when they emerge from the pupa. At temperatures varying from 76° to 78° F., the sexes mate when 5 to 8 days old, though not until 2 weeks old at 61° to 64° F. One prolific female deposited on an average of about 4.5 eggs per day during the first 18 weeks of her life, and had not then reached her egg-laying capacity. As many as 25 eggs have been laid by a single female in one day. Female flies do not lay a large number of eggs at one time and then die, as many believe, but lay quite regularly a few eggs nearly every day throughout life.

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[1] Winter, W. R. The fruit fly. Bermuda, 1913. 14 p. (Bermuda Dept. Agr., E. J. Wortley, director.)

HOST FRUITS IN BERMUDA.

Col. W. R. Winter, in the bulletin previously mentioned, lists 47 fruits subject to attack. To this list for Bermuda should be added the ball kamani (*Calophyllum inophyllum*), the prickly pear (*Opuntia* sp.), and the acordia. While the list of host fruits given is so large that one receives the impression that the fruit fly has an abundance of fruit in which to develop, conditions are quite the opposite in Bermuda. After having carried on a clean-culture campaign against this pest in the Hawaiian Islands, where there exists a very great abundance of many host fruits, the writer was surprised at the scarcity of host fruits in Bermuda. In Table I is recorded the vegetation found growing in portions of the city of Hamilton.

TABLE I.—*Vegetation in Hamilton, Bermuda, with reference to host fruits for the Mediterranean fruit fly.*[1]

Kind of tree.	Number of different trees on various properties.[2]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Apple	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Acalepha	1	1	1	....	1	1	1	1	1	....	1	10	6	7
Anona	....	....	....	....	....	....	....	1	....	....	1	....	2	1
Aracaria	....	....	1	....	....	....	....	....	....	....	....	....	3	....
Avocado	....	1	....	....	....	....	....	....	1	....	1	2	6	11
Banana	....	....	....	1	....	....	1	1	1	1	1	75	24	65
Cedars	1	1	1	....	....	1	1	1	1	1	....	2	23	1
Chinaberry	1	....	....	....	1	....	1	1	1	....	....	2	8	15
Citrus	....	....	....	....	....	....	....	....	1	....	....	....	....	....
Coffee	....	....	....	....	1	....	....	....	....	....	....	....	....	....
Crape myrtle	....	....	....	....	1	....	1	....	....	1	....	....	3	1
Croton	....	....	....	....	....	....	1	....	1	....	1	10	6	4
Eugenia	1	1	....	....	....	....	1	....	....	1	....	....	2	....
Fiddlewood	....	1	....	....	....	....	....	....	1	....	....	3	9	....
Guava	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hibiscus	1	1	1	1	1	1	....	....	1	....	....	12	6	4
Kamani, ball	....	....	....	....	1	....	....	....	....	....	....	1	....	1
Kamani, winged	....	....	....	....	....	....	....	....	....	....	....	1	....	....
Loquats	....	1	....	1	....	....	....	1	1	....	1	12	22	10
Mango	....	....	....	1	....	....	....	....	....	....	....	....	....	1
Mulberry	....	....	....	1	....	....	....	....	....	....	....	....	....	1
Oleander	....	1	1	....	....	1	1	1	1	....	....	2	8	3
Pandanus	1	....	1	....	1	....	....	....	....	....	....	1	....	....
Papaya	....	....	1	1	....	....	1	1	1	1	....	3	12	27
Peach	....	....	....	....	....	....	....	1	....	....	....	....	10	....
Pigeonberry	....	....	....	....	....	....	1	1	....	....	....	2	2	4
Poinciana	....	....	....	1	1	....	....	....	....	....	....	....	1	1
Roses	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Rubber tree	1	....	1	....	....	....	1	....	....	....	....	....	1	1
Sapodilla	....	....	....	....	1	....	....	1	....	....	....	1	....	....
Thevetia	....	....	....	....	1	....	....	....	....	....	....	....	....	....

[1] All trees and shrubs were recorded except the following nonhost plants: Bamboo 5, buttonwood 5, Dracaena 3, elder 1, Lantana 3, Mimosa 2, pomegranate 1, privet 2, Australian pine 2, tamarind 1, sea grape 2, coconut palm 1, palmetto 8, date palm 8, sago palm 3, Poinsetta 2, Euphorbia 7, Althea 1. Host plants of the Mediterranean fruit fly are in italics.

[2] Nos 1 to 11 represent private premises; Nos. 12 to 14, city blocks.

The number of trees and shrubs in Bermuda which bear fruit subject to attack is very small. Out of 9,828 acres of land only 2,636 acres were recorded under cultivation in 1901, and this acreage has but slightly increased. The principal products raised for export, potatoes, onions, arrowroot, lily bulbs, and garden vegetables, except peppers, are not subject to attack. On the uncultivated areas the host fruits are mainly conspicuous by their absence. In such areas the escaped Surinam cherry (*Eugenia micheli*) and a small species of prickly pear (Opuntia) are to be found in varying numbers. In the Tuckerstown district the former is quite abundant, while the latter is plentiful in sandy locations, as noted especially in Southampton Parish along the south shore. The soil of Bermuda, being very shallow, does not support dense vegetation. Cedar trees are so generally distributed over the islands that the landscape, as viewed from a tower, appears blackened by them. One can often walk among them long distances, as distances go in Bermuda, without seeing a single tree bearing fruit subject to attack. Often the cedar, fiddlewood (*Citharexylum quadrangulare*), the oleander (*Nerium oleander*), the Lantana (*Lantana odorata* and *L. crocea*), the life plant (*Bryophyllum calycinum*), grasses, and a few weeds are all that one sees. Some of the small islands of the group were found to support nothing subject to attack. In and about Tuckerstown and the adjoining limestone region the vegetation is more dense, and progress through the woods is made difficult by the presence of rocks and vines. In this region are to be found many neglected bittersweet oranges, whose fruits, according to Col. W. R. Winter, are quite eagerly gathered for marmalade, although often the trees are difficult of access.

It was found that the principal fruits supporting the fruit fly in Bermuda were:

(1) The loquat or Malta plum (*Eriobotrya japonica*), which ripens during January, February, and March.

(2) Peaches, which ripen during late March, April, May, June, and early July.

(3) Surinam cherries (*Eugenia micheli*), the first crop of which ripens during May and the second crop throughout summer and early fall.

Director of Agriculture Wortley informed the writer that the cultivated bell pepper was also a source of food for the fruit fly during the summer months.

AMOUNT OF FRUIT.

No large amount of fruit subject to infestation by the fruit fly is to be had in Bermuda at any season of the year unless it be during the time when Surinam cherries are in season. It would not be just to Bermuda horticulturists for one visiting these charming islands for so short a time during the winter to state that many of the more tropical fruit trees appeared stunted and grown only with great care in favored gardens; yet it so seemed to the writer. It would be very easy to count the number of apple, guava, mango, and bestill trees (Thevetia) in the islands. One common guava was pointed out in a beautiful garden as a curiosity. Only one winged kamani, one sweet almond (Terminalia) and one apple tree were seen. The avocado, citrus, papaya, and peach trees were more numerous, though by no means plentiful. The loquat seemed to be the most abundant cultivated fruit, but few of the trees were as large or as well developed as those in Florida or Hawaii, and their ripening fruit was, at the time of the writer's visit, everywhere generally infested. Experimenters wishing to rear flies in large numbers for scientific purposes would be forced, in the opinion of the writer, to depend upon imported fruits, such as apples, in order to have a constant and satisfactory supply.

POSSIBILITY OF ERADICATION.

From the experience of the writer with clean cultural methods covering nearly two years in the city of Honolulu, Hawaiian Islands, he believes that the Mediterranean fruit fly can be eradicated from Bermuda within three years at the longest without the expenditure of a prohibitive amount of money. If the fruit flies were not capable of living so long in the adult stage, it is probable that the work of eradication could be accomplished in less time. There is probably no country in the world where the fruit fly exists in which the work of eradication could be undertaken with such assurance of success, provided the work were placed in the hands of a persistent, well-informed, intelligent person who could carry on an uninterrupted campaign authorized by adequate legislation. The fruits infested at the present time are such that no citizen would be forced to bear any real financial loss as the result of such a campaign. The peach and loquat fruits are practically all destroyed yearly by the fly, and the Surinam cherries are of no commercial value. By the judicious use of axe and saw and by thorough cutting of flowers or young fruit on those few trees that can not for various reasons be either cut down or prevented temporarily from bearing by severe pruning, the host fruits could be eliminated. It has already been shown that oranges and grapefruit act more as traps for the fruit fly than as hosts if allowed to remain on the tree until sufficiently ripe for table purposes, and such trees of value need not be destroyed provided the fruit be gathered before it becomes overripe.

The Bermuda agricultural authorities had already secured the passage of legislation against this pest and started clean cultural work as early as March, 1907, when the board of agriculture, as stated by Col. Winter in a letter to the writer under date of February 20, 1914, was given the power to "prohibit the growing of any fruit or vegetable, to clear off fruit, cut back or destroy as necessary any trees or vegetables, and to clean up the ground beneath them." The inspection work was already yielding good results when the fruit fly destruction act of 1907, under which it was being carried on, lapsed on December 31, 1910. No work was done during 1911 and 1912, although a new act was passed in June of the latter year. During 1913 inspections were again started, but apparently had accomplished little in controlling the fruit fly, as evidenced by the general infestation noted by the writer in ripe loquats and Thevetia in December of that year.

In other words, the money appropriated in Bermuda for inspection work against the fruit fly has not yielded practical results. The small amount of fruit grown in the islands does not warrant the expenditure of money except with the object of extermination in view. It is only by extermination that fruit growers in Bermuda can hope to produce those fruits which her climate makes possible without maintaining a system of inspection that at best will yield but temporary results and at the same time be a source of perpetual expense amounting to more than the fruits now grown are worth. The work carried on by the Federal Government in Hawaii has clearly demonstrated the fact that no clean cultural method will lead to any lasting beneficial result unless the person in charge of such work be given the power, either personally or through able inspectors, to plan the destruction of all fruit before it begins to ripen, either by the destruction or severe pruning of host trees or the gathering of fruit before it is sufficiently developed to become infested. Just so long as notices are served on residents demanding them to destroy fruits on their properties already known to the inspector to be infested with the fruit fly, just so long will failure attend clean-culture work. The director of a clean-culture campaign must have full power to destroy fruit whenever he knows that the facts demand it. Human nature is the same the world over. Lack of interest on the part of a few citizens when the destruction of fruit is left in their hands can defeat and has defeated the plans of the most able directors. These statements regarding clean-culture work are based upon the results following the expenditure of many thousand dollars in similar work in the Hawaiian Islands and elsewhere.

BERMUDA AS A SOURCE OF DANGER TO THE UNITED STATES.

If Bermuda were in direct communication with the southern Atlantic ports of the United States, to which she is so closely situated, she would be a source of great danger to the fruit interests of the Southern States. However, her only regular and direct communication is by means of vessels plying between Hamilton and New York, a distance of about 701 miles, for the passage of which about two days is required. Another line of steamers, equipped with limited passenger accommodations and running about every four weeks, connects London and Hamilton. The vessels of this last company usually continue on to Cuban ports, and thence to a southern port of the United States for freight before returning to England. Such small quantities of fruit are brought to maturity in an edible condition in Bermuda that there is very slight probability of any being carried to the United States. Native-grown fruit is scarce and a luxury even for the few who are able to grow it. Practically all the fruit consumed in Bermuda and on the ships plying between Hamilton and New York is grown in the United States. Furthermore, the climatic conditions in and about New York are known to be decidedly against the establishment of the fruit fly, even if it should be accidentally introduced. The fact that ships have been plying between New York and Bermuda for many years without the pest having become established on the mainland is an argument in itself. Practically all agricultural produce grown in Bermuda can not be marketed profitably in New York, where it is for the most part consumed, unless it is placed on the market before that grown in the Southern States is shipped north. Thus the bulk of Bermuda-grown vegetables, whether subject to infestation or not, arrives in New York at a season when the climate is too cold for the pest to survive. With the addition at the present time of the strict quarantine regulations against all Bermuda-grown fruits or vegetables subject to attack, to the restrictions already placed by nature and the market, it would appear that Bermuda is a source of very little danger to the United States from the fruit-fly standpoint.

CONCLUSION.

The Mediterranean fruit fly, *Ceratitis capitata* Wied., was introduced into the Bermuda Islands probably about 1865, when fruit supposedly infested by this pest was unloaded there from a storm-tossed vessel from the Mediterranean region. Since that time the fruit fly has spread over the entire 19½ square miles of rolling country of which these islands are composed, and long since has ruined the excellent peach industry enjoyed by Bermuda in the early days and has caused such discouragement among prospective fruit growers that at the present time native-grown fruit in Bermuda is a luxury.

While Bermuda is probably at present a source of comparatively small danger to the United States as a source of infestation by the Mediterranean fruit fly, both on account of her trade relations and the climatic conditions surrounding New York, the extermination of the pest in these islands will be decidedly to the advantage of both Bermuda and the United States. All parts of Bermuda are easy of access. The topography is cut up by harbors, lakes, and roads into small areas that can be easily inspected; the trees and shrubs, the fruits of which are subject to infestation, are surprisingly few numerically, and a large portion of the uncultivated lands supports little that is subject to attack.

Experience in all countries where clean cultural work has been undertaken, but especially in the city of Honolulu, has shown that no lasting beneficial results will follow such work as has been carried on in Bermuda unless extermination is the object in view. The value of the fruit grown in Bermuda is not sufficient to warrant work being carried on with any other object. In no country where the fly now exists could work of extermination be undertaken with such assurances of success as in Bermuda. If clean cultural work were supported continuously by adequate legislation and undertaken by a person sufficiently conversant with the problem and eager to make a unique record in the entomological world, the Mediterranean fruit fly could be exterminated from Bermuda within three years, without the expenditure of a prohibitive amount of money.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 165

Contribution from the Bureau of Entomology, L. O, Howard, Chief.
December 31, 1914.

(PROFESSIONAL PAPER.)

QUASSIIN AS A CONTACT INSECTICIDE.

By William B. Parker,
Entomological Assistant, Bureau of Entomology.[1]

INTRODUCTION.

Quassia chips, the active principle of which is quassiin, have been employed for many years in the preparation of spray solutions for the control of the hop aphis (*Phorodon humuli* Schr.). Several formulas have been followed, and there are several methods of preparation according to these formulas. Several factors have brought about the variations in the formulas, (1) instability in the percentage of quassiin in the chips, (2) the total amount of available quassiin in the chips probably not extracted, due to the method of preparation, and (3) the fact that there appeared to be no fundamental data accumulated on this subject. The writer accordingly commenced the investigation, which has been taken up from an insecticidal standpoint, and any chemistry that is mentioned other than very simple matters is taken from the various sources. Acknowledgments are due to Prof. George P. Grey, of Berkeley, Cal., and Mr. G. H. P. Leichthardt, of Sacramento, Cal., for valuable suggestions, and to Mr. R. E. Campbell, of the Bureau of Entomology, who ably assisted the writer in determining the efficiency of the several formulas.

During the investigation of the life history and control of the hop aphis[2] it was observed that there were several formulas for the use of quassia chips. These all appeared to give satisfactory results when carefully prepared and applied, but it will be observed from the following formulas that if the weaker one killed the aphides, the use of the stronger one resulted in a waste of material and extra expense.

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[1] Resigned August 31, 1914.

[2] Parker, Wm. B., The Hop Aphis in the Pacific Region. U. S. Dept. Agr., Bur. Ent. Bul. 111, 39 p., 8 fig., 10 pl., May 6, 1913.

Note.—The results of an investigation to determine the most suitable solution of quassiin for use as a spray for the control of the hop aphis are discussed in this bulletin.

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The following formulas are typical examples of the variation in the amount of ingredients and the cost per 100 gallons:

	No. 1.	No. 2.	No. 3.
Quassia chips ... pounds..	2.8	8	9
Whale-oil soap ... do....	1.6	6	6
Water ... gallons..	100	100	100
Cost per 100 gallons ... cents..	31	69	74.2

These formulas are concocted differently by different growers. Some soak the chips 24 hours in a barrel of water and then boil them for 2 hours. Some boil them for 2 hours without previous soaking, and others boil them with the whale-oil soap. The several formulas and methods of preparation all have their advocates among the hop growers.

CHEMICAL LITERATURE ON QUASSIIN.

The quassia chips commonly used in preparing spray solutions are the wood of the Jamaica quassia (*Picrasma excelsa* Swz.). The literature on the chemical nature of quassiin, the active principle of quassia wood, was found to be very limited, but the few important references that the writer was able to obtain are discussed below.

The wood of *Picrasma excelsa* (Swz.) Planch. (*Quassia e* Swz.; *Q. polygama* Lindsay; *Piccaena e* Lindl.; *Simaruba e* D. C.) or of *Quassia amara* L. (Fam. Simarubaceæ).

Description.—Jamaica quassia. Occurring in various forms, usually chips, raspings, or billets, yellowish white or pale yellow, and of rather coarse texture; odor slight; taste intensely bitter; medullary rays containing tetragonal prisms or small, arrow-shaped crystals of calcium oxylate. Billets of Jamaica quassia are usually 12.5 cm. or more in diameter; in tangential section the medullary rays are mostly 3 to 5 rows of cells in width.

Surinam quassia. Occurring usually in billets not exceeding 7.5 cm. in diameter; the wood is heavier, harder, and more deeply colored than that of Jamaica quassia, and the medullary rays in tangential section are mostly 1 or 2 rows of cells in width.

Constituents.—Although Jamaica quassia is said to contain traces of a yellowish alkaloid, giving a fine blue fluorescence with acidulated alcohol, the important bitter principle is a neutral, crystalline substance, commonly known as quassiin, but determined by Massute to be a mixture of two crystalline bodies, which he denominated α– and β– picrasmin.

Quassiin is extracted by neutralizing the aqueous infusion with soda, precipitating with tannin and decomposing the precipitate with lead oxide or lime. It is commonly said to exist to the extent of only 0.05 to 0.15 per cent, but really exists in much larger amount, Wiggers says 0.75 per cent. This discrepancy is probably due to the fact that it is difficult to procure in the pure state, and that the purification processes involve considerable loss. Quassiin crystallizes in needles or prisms, and is soluble in alcohol and in chloroform and in 1,200 parts of cold water. Its bitterness is most intense. The α–picrasmin ($C_{35}H_{46}O_{10}$) melts at 204° C. The β–picrasmin ($C_{36}H_{48}O_{10}$) at 209° to 212° C. (408.2°–413.6° F.). The bitter principle of Surinam quassia is closely related and of similar action, but not identical.[1] To it the name *quassin* is commonly applied.

[1] Hare, H. A., Caspari, C., and Rusby, H. H. National Standard Dispensatory, ed. 2, revised and enlarged, p. 1334, Philadelphia, 1909.

Quassine, the active principle of *Quassia amara*, is amorphous or crystalline. It has been isolated by Winkler. It is colorless, inodorous, opaque, and inalterable in the air, slightly soluble in water, much more soluble in water charged with salt or organic acids, and in alcohol.

Action on plants: Plants are not injured by spraying with aqueous extracts of quassia.[1]

Quassia.—Constit.: Wood: Picrasmin, $C_{35}H_{46}O_{10}$: quassin, $C_{10}H_{12}O_3$ (or, $C_{32}H_{42}O_{10}$ [?]); quassol, $C_{40}H_{70}O$—H_2O; alkaloid; resin; mucilage; pectin.—Bark: Quassin; alkaloid; resin; pectin. (*Quassia amara* contains 4 bitter principles; *Picræna excelsa* contains only 2): quassol,—[2]

"Quassiin ($C_{32}H_{42}O_{10}$) may be obtained in a fairly pure state by exhausting quassia-wood with hot water, precipitating the solution with neutral lead acetate, removing the excess of lead from the filtrate by sulphuretted hydrogen and shaking the filtered liquid with chloroform. On evaporation, the quassiin is obtained nearly colorless, and, with some difficulty, in a distinctly crystalline condition. Quassiin has an intensely and very persistent bitter taste. It is sparingly soluble in cold water, more readily in hot water, and is easily soluble in alcohol. Its best solvent is chloroform, which extracts quassiin readily from acidulated solutions.

An aqueous solution of quassiin does not reduce Fehling's solution or an ammonio-nitrate of silver. The solid substance gives no coloration (or merely yellow) when treated with strong sulphuric acid, or with nitric acid 1-25 sp. gr.; nor is any color produced on warming. * * *

A solution of quassiin gives a white precipitate with tannin. The reaction is used by Christensen, Oliveri, and others, to isolate quassiin from its solutions, and by Enders to separate it from picrotoxin. In the author's hands the reaction has not proved satisfactory. The liquid is very difficult to filter, and the filtrate still retains an intensely bitter taste, showing that the precipitation is very incomplete. As an analytical method the reaction is useless, but it is of some value as a qualitative test. The test must be made in cold solution. Possibly a more complete precipitation of quassiin by tannic acid might be effected in an alcoholic solution.

Quassiin gives a brown coloration with ferric chloride. The reaction is best observed by moistening a quassiin residue in porcelain with a few drops of a weak alcoholic solution of ferric chloride, and applying a gentle heat. A fine mahogany-brown coloration is produced." [3]

The quassiin used in the following experiments was extracted according to directions given by Allen.[4] It was further found that when boiled in alcohol a precipitate formed. This was filtered off, the filtrate evaporated to dryness over a water bath, and the resulting dark resinous material extracted with boiling water. When extraction was complete a dark brown crusty material remained. The resulting extract was light yellow and perfectly clear. It was found to be intensely bitter.

When cool this aqueous solution was extracted with chloroform, evaporated over a water bath, and weighed and made into a percentage solution.

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[1] Bourcart, E., Insecticides, Fungicides and Weedkillers, p. 376. London, 1913.

[2] Merkes 1907 Index, ed. 3, p. 366. New York, 1907.

[3] Allen, A. H., Commercial Organic Analysis, ed. 2 revised and enlarged, v. 3, pt. 3, p. 187-188, Philadelphia, 1896.

[4] Except the solution was not acidulated before extraction with acid.

In studying the use of quassiin as a contact insecticide it became desirable to determine in what solvents and solutions this compound was soluble. Table I gives the results of the experiments which were carried out with this purpose in view.

TABLE I.—*Results of solubility tests for quassiin.*

No.	Material.	Action.
1	Chloroform	Readily soluble.
2	Ether	Not soluble.
3	Methyl alcohol	Readily soluble.
4	Ethyl alcohol	Do.
5	Hot water	Do.
6	Cold water	Sparingly soluble 1-1,200.
7	Kerosene	Not soluble.
8	Gasoline	Do.
9	Carbon tetrachlorid	Do.
10	Benzine	Do.
11	Turpentine	Possibly soluble.
	RESULTS OF TESTS WITH SOLUTIONS.	
12	Potassium hydroxid	Readily soluble, solution yellow.
13	Sodium hydroxid	Do.
14	Calcium hydroxid	Do.
15	Potassium cyanid	Do.
16	Sodium carbonate	Do.
17	Hydrocyanic acid	Do.
18	Ammonium hydrate	Do.
19	Whale-oil soap (alkaline)	Do.
20	Sodium chlorid	Apparently insoluble.
21	Hydrochloric acid	Do.
22	Sulphuric acid	Do.
23	Nitric acid	Do.
24	Acetic acid	Do.

The foregoing table represents the results of experiments which were conducted with quassiin in an attempt to determine some cheap solvent or solution, other than hot water, by which it could be extracted from the wood.

EXTRACTION OF QUASSIIN FROM SOLUTIONS.

It was found that when the solutions of potassium hydroxid, sodium hydroxid, sodium carbonate, etc., with quassiin, were acidulated with sulphuric acid, the quassiin could be readily removed in chloroform. This process would apply when testing the percentage of quassiin in such solutions.

DETERMINATION OF PURITY OF QUASSIIN USED.

Since the purity of the quassiin used in spraying experiments is an important factor in figuring proportions, an attempt was made to determine the amounts of material other than quassiin which might be present in the stock solution.

Following a suggestion in Allen, tannin was added to an aqueous solution of quassiin taken from the stock solution. A fine precipitate appeared, but unfortunately it passed through an ordinary filter paper.

It being observed that tannin is not extracted from an aqueous solution by chloroform, an attempt was made to collect the chloroform-soluble material which was not precipitated by the tannin. The solution was accordingly shaken with chloroform, and the chloroform separated in a separating funnel. When replaced in aqueous solution, the extracted material was found to be intensely bitter and gave all the appearance of being quassiin. It is evident that all of the quassiin is not precipitated by tannin.

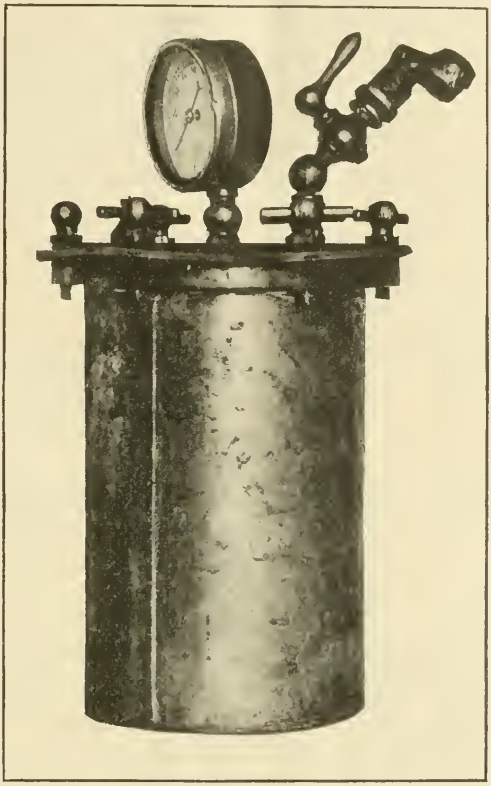

Fig. 1.—Compressed-air spray machine used in applying quassiin solution. (Original.)

Because the material used proved effective as an insecticide at dilutions of 0.4 grams to 1,500, 1,800, and 2,000 cubic centimeters, the writer believes that it was comparatively pure quassiin.

INSECTICIDAL VALUE OF QUASSIIN.

The determination of the insecticidal value of quassiin is the main object of this investigation. In accomplishing this object an attempt is made to compare the action of quassiin to the action of a standard contact insecticide. Nicotine sulphate is taken as the standard, and in these experiments is used at the rate of 1–2,000. The nicotine sulphate used was standardized to 40 per cent and the solution of quassiin was used so that it would correspond with the 40 per cent solution of nicotine sulphate. For instance, instead of using 1 gram of quassiin to 2,000 cubic centimeters of water, 0.4 gram was used to 2,000 cubic centimeters of water.

During the early part of the work it was discovered that the whale-oil soap, even when used at the greatest dilution at which it had any spreading effect (1 pound to 100 gallons), killed a certain percentage of the aphides. Since a spreader is necessary, experiments were inaugurated to find one that would have no effect upon the insects treated. It was found that the soap bark solution which was being used in some other work was an excellent spreader and did not affect the insects in the least. In all of the following experiments a water decoction of this material was used at the rate of 2 pounds of soap bark to 100 gallons of water.

In applying the solutions, a compressed-air spray machine (fig. 1) which maintained 50 pounds pressure and handled as small an amount as 200 cubic centimeters was used. A fine mist nozzle was so adjusted to this pressure of 50 pounds that a washing rather than a mist spray was produced.

In conducting the experiments detailed in Table II prune twigs infested by the hop aphis (*Phorodon humuli* Schrank) and the prune aphis (*Hyalopterus pruni* Fab.) were brought from the field and, after being sprayed with the solutions, were set in moist sand. By placing the pots of sand containing the sprayed twigs on sheets of paper the percentage of the insects that were killed by the solutions were readily obtained. Check twigs were kept to make sure that there was not a marked mortality from some other cause.

Table II gives the results of the spraying experiments with quassiin in aqueous solution and also in solutions of certain alkaline substances.

TABLE II.—*Results of experiments with quassiin as a contact insecticide.*

Formula.	Number of aphides sprayed.	Per cent of aphides killed.
SERIES NO. 1. WITH SOAP BARK IN LABORATORY.		
0.4 grams to 3,000 cc	904	85.1
0.4 grams to 2,000 cc	8,060	93.02
0.4 grams to 1,800 cc	1,119	94.6
0.4 grams to 1,500 cc	1,310	93.9
0.4 grams to 1,000 cc	1,831	99.7
SERIES NO. 2. WITH WHALE-OIL SOAP IN FIELD.		
0.4 grams to 2,000 cc	1,776	99.4
0.4 grams to 1,800 cc	3,197	99.8
0.4 grams to 1,500 cc	3,546	99.8

TABLE II.—*Results of experiments with quassiin as a contact insecticide*—Continued.

SERIES NO. 3. WITH SOAP BARK ON PRUNE APHIS IN FIELD.

Formula.	Number of aphides sprayed.	Per cent of aphides killed.
0.4 grams to 2,000 cc	1,923	97.5
0.4 grams to 1,800 cc	721	99.2
CHECK SERIES.		
Whale-oil soap, 3 pounds to 100 gallons	1,030	[1] [2] 84.6
Soap bark, 2 pounds to 100 gallons	1,202	[1] 21
Nicotine sulphate, 0.4 grams to 2,000 cc., with soap bark, 2 pounds to 100 gallons	930	96.9

[1] These were the largest percentages obtained for the check materials.
[2] In field.

From the foregoing table it will be readily seen that quassiin used at the rate of 0.4 grams to 2,000 cubic centimeters, or 6½ ounces of 40 per cent solution to 100 gallons, was almost as effective against the hop aphis and the prune aphis as nicotine sulphate, 0.4 grams to 2,000 cubic centimeters, or 6½ ounces to 100 gallons. The difference is approximately 3 per cent, while quassiin, 0.4 grams to 1,000 cubic centimeters, is fully as effective.

The writer has not so far tested this material upon insects other than those mentioned, but believes that it will prove effective elsewhere if used in proportions corresponding to the amounts of nicotine sulphate that are known to be effective.

CONCLUSION.

Picrasma excelsa Swz. (quassia wood) is a native of Jamaica, and, according to data obtained, is available in considerable quantities.

The percentage of quassiin in the quassia wood varies somewhat, and does not appear to be definitely known. Supposing it to be 0.75 per cent, as given by one author, to use the quassiin at an effective rate of 0.4 grams to 2,000 cubic centimeters, it would take only 1½ pounds of the chips to 100 gallons of spray. To be on the safe side, double the amount of chips calculated to be necessary, and we have the following formula [1] and cost per 100 gallons of spray:

Quassia chips, 0.75 per cent quassiin, 3 pounds, at $0.04	$0.12
Whale-oil soap, 3 pounds, at $0.04	.12
Total cost of materials per 100 gallons	.24

Quassiin can be readily extracted from quassia wood, *Picrasma excelsa* Swz., in a comparatively pure form. (See p. 3.) It probably could be more cheaply extracted in an impure water-soluble form by using sodium carbonate solution. The percentage of quassiin could be determined and the material evaporated until a standardized solution was made. Such a material could be diluted and used with

[1] This formula corresponds very closely to formula No. 1, page 2.

whale-oil soap, or some other spreader, as in the case of nicotine sulphate. The writer believes that quassiin has possibilities as a commercial insecticide and that it could be cheaply prepared and possibly sold at a lower price than some of the materials that are now on the market.

The foregoing data were obtained under conditions existing at Sacramento, Cal., and may not hold for a more humid climate. The efficiency of the quassiin should be determined for some other locality before a commercial recommendation is made.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 167

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
February 10, 1915.

(PROFESSIONAL PAPER.)

PARA-DICHLOROBENZENE AS AN INSECT FUMIGANT.

By A. B. Duckett,
Scientific Assistant, Truck Crop and Stored Product Insect Investigations.

INTRODUCTION.

The purpose of the following pages is to determine the insecticidal value of para-dichlorobenzene as a fumigant, as well as to ascertain the injury, if any, to cloth fabrics and the effects of the vapors on plant life as well as upon the germination of seeds.

Para-dichlorobenzene is a definite chemical compound, known for many years, but only recently used as an insecticide. It is a colorless, crystalline substance which volatilizes very readily as a colorless vapor with a peculiar ether-like odor. The vapor is harmless to human beings and domestic animals under ordinary conditions, but in many instances it is a specific poison for insects. It has an additional advantage over the many other fumigants in that the odor does not cling to fabrics, etc., the characteristic ether-like smell rapidly disappearing upon exposure of the fumigated substances to the open air. Probably the greatest advantages that para-dichlorobenzene possesses over other fumigants are its absolute noninflammability and its comparatively low cost of purchase and application in proportion to the result obtained.

EFFECTS OF INHALATION OF THE VAPOR.

As stated, para-dichlorobenzene possesses only a weak ether-like smell, which, owing to the volatile nature of the substance, will pass off in a few hours if exposed to the air. Dr. Curschman, at the Greppin Works in Germany, concludes from a series of experiments that para-dichlorobenzene, when used as an exterminator for moths, etc., is virtually harmless to human beings, perhaps even superior to naphthalene in this respect. He goes further by stating that poisoning by para-dichlorobenzene to human beings through contact with the skin is impossible and that inhalation of the vapors of this product is perfectly harmless. According to him, para-dichloro-

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benzene is harmful to human beings only in cases of internal application of large quantities, say from 30 to 40 grains.

It is not advisable for sensitive persons to remain for a long time in a closed room where para-dichlorobenzene is freely exposed, as the odor may cause annoyance. On the other hand, para-dichlorobenzene can be used in closed or occasionally opened cupboards and even in sitting rooms without causing any inconvenience whatsoever.

PARA-DICHLOROBENZENE AS AN INSECTICIDE.

Experiments were conducted by the writer with para-dichlorobenzene to ascertain the practicability of its use and its insecticidal value against various insects. Para-dichlorobenzene as an insecticide is applicable to a large variety of insects, but under certain conditions depending on the variations in life history and environment, and therefore necessitating specific methods of application.

In a general way para-dichlorobenzene is effective only where its vapors can be closely confined, and when used in a higher temperature than 74° F.; furthermore, it is recommended only where poison bait and contact sprays are either impractical or undesirable. The vapor is diffused through the air very rapidly and must, therefore, be closely confined in order to maintain a sufficient proportion in the air to prove fatal to insect life.

The amount of material required, under ordinary conditions, to bring about the desired effect is about 12 ounces of para-dichlorobenzene to every 100 cubic feet of space. The writer, however, suggests the use of a larger amount, 1 pound to 100 cubic feet, which will take effect more quickly and diminish the chances of revival, although revival is aberrent. At temperatures between 75° and 85° F. an exposure of at least 36 hours is necessary for best results. Temperatures above 85° F. require only 24 hours exposure, due to the fact that heat facilitates the diffusion of the vapors.

Most warehouses and repositories contain several species of insects which possess very great tenacity of life, either in the adult or larval stages. In view of the fact that unless para-dichlorobenzene is used in enormous quantities or is permitted to remain in the respository over 48 hours, it does not injure plant life or render fruit, etc., inedible, we should, by preference, use as large a dose as possible for the complete eradication of the insects in the shortest possible time. As generally employed, the time would vary inversely to the amount of para-dichlorobenzene used. Since this substance is comparatively cheap and all unvolatilized material can be kept indefinitely, with very slight deterioration if the proper precautions are exercised, the additional amount of material required for a larger dose would be an insignificant item. Para-dichlorobenzene is insoluble in water and does not deliquesce when exposed to the air, but completely volatilizes, and should therefore be kept in an air-tight can or glass jar.

DIFFUSION OF THE VAPOR.

Para-dichlorobenzene is very volatile and the vapor is extremely heavy, being more than five times that of an equal volume of air and more than twice as heavy as carbon bisulphid vapor. Although it diffuses quite rapidly through the air, as evidenced by the perception of its odor, the vapors will, like carbon bisulphid, tend to work rapidly downward, outward, and eventually upward. From the foregoing fact it is ascertained that the greater density of vapor is at the lower levels. This property is obviously very beneficial when para-dichlorobenzene is used as a fumigant for bags of grain, stored products, carpets, and rugs, and in all cases where it is desirable to use a gas that will penetrate the lowest levels and force its way into cracks and crevices in floors, walls, and similar locations.

DIRECTIONS FOR USING.

Para-dichlorobenzene is applied in most instances in the same manner as camphor and naphthalene. It is not, however, necessary to sprinkle it around in corners or over rugs and other material, as is often the case with camphor and naphthalene, but merely to expose a sufficient quantity in one or two open or partially open receptacles, placed over, or higher, than the infested cases, goods, and material which require fumigation.

HOW PUT UP AND COST.

Para-dichlorobenzene at the present time is sold in 5, 10, 25, 50, and 100 pound and barrel lots, the prices for which are as follows:

23 cents per pound, in 5, 10, and 25 pound lots.
18 cents per pound, in 50-pound lots.
17 cents per pound, in 100-pound lots.
15 cents per pound, in barrel lots.

If any considerable quantity is to be used, it is much better to purchase of some wholesale druggist or direct from the manufacturers.

APPLICABILITY TO VARIOUS INSECTS.

Para-dichlorobenzene is applicable to many insect pests living under various conditions and environment, and therefore requires specific methods of application, and, unlike carbon bisulphid, it is at the present time used only indoors and in other places where its vapors can be closely confined. As there is a great variation in the tenacity of life among insects, the existing conditions should be carefully noted before para-dichlorobenzene is applied.

Beetles, such as the rice weevil (*Calandra oryza* L.), granary weevil (*Calandra granaria* L.), the confused flour beetle (*Tribolium confusum* Duv.), the cadelle (*Tenebroides mauritanicus* L.), the yellow mealworm (*Tenebrio molitor* L.), and a few others less common are particularly hard to kill when in the adult stage. The larvæ of the mealworms, *Tenebrio molitor* L., *Tenebrio obscurus* L., and closely allied species, are likewise found by experiment to possess great tenacity of life. It is therefore recommended that a proportionately larger amount of para-dichlorobenzene be used when combating these species. Moths, flies, roaches, ants, and aphides are readily killed by para-dichlorobenzene when used in the ordinary strength recommended under the heading "Para-dichlorobenzene as an insecticide."

The action of para-dichlorobenzene on insects is primarily upon their nervous systems. This property is readily manifested when a moth is exposed to the vapors for a few seconds. It first displays great excitement and uneasiness, followed closely by spasmodic convulsions, and finally turns over on its back. While in this position violent nervous and muscular reflex action is noticed until life is extinct.

The moths on which this gas has been tested include the Angoumois grain moth (*Sitotroga cerealella* Oliv.), Mediterranean flour moth (*Ephestia kuehniella* Zell.), Indian meal moth (*Plodia interpunctella* Hbn.), meal snout moth (*Pyralis farinalis* L.), and the case-bearing clothes-moth (*Tinea pellionella* L.).

EXPERIMENTS WITH PARA-DICHLOROBENZENE AS A FUMIGANT.

During the spring of 1914, while stationed at Washington, D. C., the writer, working under the direction of Dr. F. H. Chittenden, performed a series of experiments with para-dichlorobenzene as a fumigant for stored-product insects. The chemical was first used on a small scale, and results were afterwards checked up in a specially constructed air-tight fumigating box having a capacity of 100 cubic feet (Pl. I.) The average temperature was computed from the records of a thermograph placed in the box, and the para-dichlorobenzene exposed in shallow piepans or the tops of 5-gallon lard cans, since these shallow receptacles present a much larger surface of the chemical for evaporation. These pans were placed about 4 feet above the material to be fumigated, which was contained in muslin bags of variable capacity (see Pl. II) and which had previously been ascertained to be free from live insects. Into this material, consisting of wheat, cornmeal, flour, rice, and other cereals, were then introduced living insects, the number and species of each being recorded on an attached tag.

The respective amounts of para-dichlorobenzene used in each experiment and the tabulated results follow.

FUMIGATING BOX USED IN EXPERIMENTS WITH PARA-DICHLOROBENZENE. (ORIGINAL.)

BAGS CONTAINING INFESTED GRAIN READY TO BE FUMIGATED WITH PARA-DICHLOROBENZENE.
(ORIGINAL.)

Experiments with para-dichlorobenzene as a fumigant.

Experiment No. and date.	Insects introduced.	Average temperature.	Length exposure.	Date examined.	Paradichlorobenzene used.	Per cent killed.	Remarks.
		° *F.*	*Hours.*				
No. 1, Mar. 25, 1914.	Tribolium confusum Duv.; T. ferrugineum Fab.; Calandra oryza L.; C. granaria L.; Silvanus surinamensis L.; Rhizopertha dominica Fab.; Laemophloeus minutus Oliv.; Tenebrio molitor L.; Sitotroga cerealella Oliv.; Plodia interpunctella Hbn.; Ephestia kuehniella Zell.	52	72	Apr. 1	1 ounce.	None.	All revived. Preliminary ttest. Temperature too low. Vapors diffused very slowly. Eggs, larvæ, pupæ, and adults used in the case of Ephestia kuehniella and Plodia interpunctella. Capacity of fumigating box used, 7 cubic feet.
No. 2, Apr. 7, 1914.	Same as in experiment No. 1.	59	96	Apr. 13	8 ounces.	None.	All revived. Preliminary test. Temperature too low. Fumigating box used, 7 cubic feet.
No. 3, Apr. 18, 1914.	Same as in experiment No. 1.	65	96	Apr. 25	8 ounces.	20	Unsatisfactory. Preliminary test. Fumigating box used, 7 cubic feet.
No. 4, Apr. 28, 1914.	Tribolium confusum Duv.; T. ferrugineum Fab.; Calandra oryza L.; C. granaria L.; Silvanus surinamensis L.; Rhizopertha dominica Fab.; Sitotroga cerealella Oliv.; Plodia interpunctella Hbn.; Ephestia kuehniella Zell.; (Bruchus) Pachymerus 4-maculatus Fab.	81	24	May 5	2 pounds	100	100 cubic feet fumigating box used for this experiment.
No. 5, Apr. 29, 1914.	Roaches	80	24	May 2	2 ounces.	100	5 cubic feet fumigating jar used.
No. 6, May 1, 1914.	Mites on corn	78	28	May 5	2 ounces.	100	5 cubic feet fumigating jar used.
No. 7, May 4, 1914.	Slugs, snails, sowbugs, millipedes, ants.	82	36	May 9	2 pounds	100	100 cubic feet fumigating box used.
No. 8, May 11, 1914.	Tribolium confusum Duv.; Calandra oryza L.; Silvanus surinamensis L.; Sitotroga cerealella Oliv.; Plodia interpunctella Hbn.; Ephestia kuehniella Zell.; Laemophloeus minutus Oliv.; Tenebrio molitor L.	86	24	May 16	2 pounds	100	100 cubic feet fumigating box used in this experiment. Four bricks were heated to a high temperature and placed in box in order to obtain higher temperature.
No. 9, May 14, 1914.	Same as in experiment No. 8.	73	24	May 20	2 pounds	70	Unsatisfactory. Temperature too low.
No. 10, May 15, 1914.	Flies	81	20	May 16	8 ounces.	100	100 cubic feet space.
No. 11, May 18, 1914.	Aphides	80	20	May 19	8 ounces.	100	100 cubic feet space.

No. 12. May 19, 1914, 4 ounces of finely ground para-dichlorobenzene were sprinkled over pieces of woolen cloth and placed in a 100-cubic-foot fumigating box for a period of 24 hours, at an average temperature of 76° F. Upon examination it was discovered that the fine crystals adhered to the lint of the wool but were readily brushed off with a whisk broom. After two hours' exposure in the open air the odor of para-dichlorobenzene was barely perceptible.

No. 13. May 20, 1914, a test on the germination of seed was made. One pint of Argentine corn, about half of which had previously sprouted, was put in a 7-inch flower pot containing 4 inches of moist fertile soil. The pot was then introduced into a 100-cubic-foot fumigating box and exposed to the vapors of para-dichlorobenzene for 24 hours at an average temperature of 79° F. Two days later the seed was examined and showed no material injury from the experiment, sprouting about as usual.

NOTE.—Preliminary experiments with para-dichlorobenzene have been conducted along the following lines: 1. Para-dichlorobenzene introduced into insect collection boxes for the eradication of museum pests. 2. Para-dichlorobenzene in combination with formaldehyde and potassium permanganate as an insecticide and germicide. 3. Para-dichlorobenzene made into a paste by adding paraffin and resin in the presence of heat, as a substitute for grafting wax. The above paste to be applied in the burrows of borers in shade trees. 4. Further experiments on the effect of para-dichlorobenzene, if any, on tender plants. 5. The effects, if any, of para-dichlorobenzene on animals, when taken internally in small doses. In these experiments green food, such as kale, cabbage, and clover, were put in a jar heavily charged with para-dichlorobenzene vapors and fed twice daily to herbivorous animals, such as rabbits and guinea-pigs. In these experiments the writer has not as yet reached any definite conclusions, and therefore reserves their publication until further experiments along these lines are completed.

CONCLUSION.

From the foregoing observations and experiments the writer concludes that para-dichlorobenzene, used as directed in the preceding pages, acts as an excellent fumigant against the following insects:

(1) Stored-product insects.
(2) Case-bearing clothes moths.
(3) Roaches and ants.
(4) Museum pests.
(5) Miscellaneous house insects, including flies, carpet beetles or buffalo moths, book lice, silverfish, mosquitoes, centipedes, and miscellaneous larder insects.

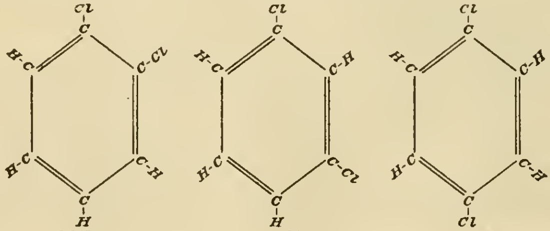
It is also an effective substitute for potassium cyanid in collecting bottles.

CHEMICAL AND PHYSICAL PROPERTIES OF PARA-DICHLOROBENZENE.

At the request of Dr. Chittenden the following data were kindly furnished by the Insecticide and Fungicide Laboratory, Miscellaneous Division, Bureau of Chemistry:

We have made an examination of the sample of dichlorobenzene submitted by you for examination on December 22, 1913, and find that this product is practically pure para-dichlorobenzene ($C_6H_4Cl_2$). We have looked up some references in the literature in regard to this substance and give you the following information based thereon:

Dichlorobenzene is a product derived from benzene by the replacement of two of the hydrogen atoms by chlorine. There are three dichlorobenzenes, designated ortho, meta, and para, the structural formulas of which are:



ORTHO META PARA

All three have the empirical formula $C_6H_4Cl_2$. Ortho and meta dichlorobenzenes are liquids, the former boiling at 179° C. and the latter at 172° C.

Beilstein, in his Handbuch der organischen Chemie, III Auflage, 1896, Band II, page 44, gives three methods for the preparation of para-dichlorobenzene (in the German, p-dichlorbenzol):

(1) By the action of chlorine on benzene (C_6H_6) in the presence of iodine. A little ortho-dichlorobenzene is also formed in this reaction.

(2) By the action of phosphorus pentachlorid on para-chlorophenol.

(3) By the action of phosphorus pentachlorid on para-phenolsulphonic acid.

He gives the melting point of this compound as 53° C. (127.4° F.) and its boiling point as 172° C. (341.6° F.), but quotes Mills (Phil. Mag. (5) 14, 27) as giving 52.72° C. for the melting point.

Para-dichlorobenzene crystallizes from alcohol in monoclinic leaves, it sublimes at ordinary temperatures, is soluble in hot alcohol in all proportions, and is easily soluble in ether, benzene, carbon bisulphid, etc.

In regard to physiological properties, Francis and Fortescue-Brickdale [1] state:

> The benzene halogen derivatives have a slight odor, are insoluble in water, volatilize without decomposition, and are very stable. * * * Corresponding to their stability it is found that the halogen is not split off in the organism, and that they do not show hypnotic properties. With the entrance of chlorine the antiseptic properties increase * * * Chlorbenzene acts on the spinal cord to a greater extent than benzene.

The following figures in regard to para-dichlorobenzene are from calculations made by R. C. Roark:

Molecular weight	146.952	
Density of the vapor	4.592	if oxygen equals 1.
	72.892	if hydrogen equals 1.
	5.1025	if air equals 1, assuming the molecular weight of air to be 28.8.

In other words, assuming no dissociation or association, a given volume of para-dichlorobenzene in the form of a vapor would be 5.1025 times as heavy as an equal volume of air at the same temperature and at the same barometric pressure.

The vapor of para-dichlorobenzene will flash at about 70° C. (158° F.), but even when held in a very hot flame and ignited the substance will not continue to burn after the flame is removed. Thus the substance is not combustible, but is decomposed by heat into substances which partially burn with copious deposition of soot when directly in a flame.

As the vapor pressure of para-dichlorobenzene has never been determined, it is impossible to state how much of its vapor air at any temperature short of 172° C. (341.6° F., its boiling point) would take up. At 172° C. (341.6° F.), barometer 760 mm., 1 liter of para-dichlorobenzene gas would weigh 4.0257 grams, or 1 cubic foot would weigh 4.0208 avoirdupois ounces.

[1] Francis, Francis, and Fortescue-Brickdale, J. M. The Chemical Basis of Pharmacology, p. 99, London, 1908.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 170

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
February 9, 1915.

THE EUROPEAN PINE-SHOOT MOTH; A SERIOUS MENACE TO PINE TIMBER IN AMERICA.

By August Busck,
Entomological Assistant, Forest Insect Investigations.

INTRODUCTION.

One of the most injurious insects to pine forests in Europe is a small orange-red moth, the larva of which eats out the new buds and kills or deforms the young twigs of pine trees, so as seriously and permanently to lower their timber value. This European pine-shoot moth, which is known under the scientific name *Evetria buoliana* Schiffermiller, has within very recent years been accidently introduced into America on imported European pine seedlings and has unfortunately become established in several widely separated localities in the eastern and middle western States.

Early last summer (1914), a correspondent of the Bureau of Entomology complained of a serious insect injury to European pines under his surveillance on Long Island, and sent examples of the injury and of the larvæ causing it; the latter could not be identified as those of any of our known American pine pests, and the writer was therefore authorized to visit the affected localities in order to ascertain the extent of the injury and to obtain sufficient live material for study and rearing. From this material a large number of moths emerged during the latter part of June and these were at once recognized as the famous European pine-shoot moth.

Subsequent surveys, undertaken by the bureau through Mr. Carl Heinrich and the writer, established the fact that the species has been repeatedly introduced on European nursery stock, and that it has become established in nurseries and parks in several localities scattered over nine States.

In view of the experience with other introduced European insects, and considering the very serious financial loss caused abroad annually by this insect, its introduction into this country gives just cause for alarm, because incalculable injury may result to the vast American forest interests if this insect is permitted to become generally established on our native pines.

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Some idea of the extent and permanent character of the injury which this insect is capable of inflicting may be gained from the illustration (Pl. I) of a European pine forest which has been infested by it for several years in succession, with the result that a majority of the tree trunks are so twisted and crooked that their value as timber is materially lessened.

HISTORY OF THE SPECIES IN EUROPE.

The species is a constant menace to pine forests in Europe and annually causes serious depredations, especially to young plantations of pine, in spite of continual preventive work against it. It has been the subject of much study and of an extensive literature from the time it was first described by Schiffermiller in 1776 to the present day. The species was named in honor of a Vienna entomologist, Baron Buol, who studied its injurious work during the latter part of the eighteenth century; since then numerous accounts have appeared of particularly severe outbreaks in many parts of Europe, from England to Russia, and from Scandinavia to southern France. It also occurs in Siberia.

One such outbreak in Denmark, in 1805–1807, is recorded by Niemann (1809).[1] This was so serious as nearly to cause pine culture to be abandoned in that country as hopeless. It is interesting to note that at that time the same preventive means were resorted to as are now employed against the insect, namely, the wholesale pruning and burning of all infested twigs.

The German forest entomologist, Ratzeburg, counted *Evetria buoliana* one of the most injurious forest insects and gave a detailed account (1840) of the life history, structure, and economic importance of the species. He mentioned especially an unusual outbreak in 1836–1838, which covered many parts of Europe. In the province of Furstenau the Rochesberg Mountain, which was covered with pines, became so seriously infested that it was under consideration by the authorities to burn it off and plant new trees. Other localities were only saved by strenuous systematic collecting of the infested twigs; thus, in the small province of Kesternich alone, 150,000 larvæ were gathered and destroyed.

Judeich and Nitsche (1895) state that the injury caused by *Evetria buoliana* is often fatal to the pine plantations. To quote from these authors, "If the attack is slight, it results in the branching of the tree, but if the attack is more severe and continued for several years, as we have seen it, then hardly any bud is spared and the pines become stunted into miserable small bushes from which numerous

[1] Dates in parentheses refer to "Literature," pp. 10–11.

branched shoots and large needle tufts stick out." These authors record many severe outbreaks and mention especially one in 1883–1885, in the Royal Forest Reserve, Pillnitz in Saxony, where nearly 75 acres of young pines planted in 1878 became infested to such an extent that hardly a shoot was spared, and in 1884 the entire plantation presented a pitiful, crippled appearance.

J. E. V. Boas (1898), who has made original investigations of the insect in Denmark, considers it one of the most injurious insects affecting forest trees. Among other outbreaks he mentions one in Jutland, Denmark, extending through several years around 1870, which "threatened the total destruction of the pine plantations."

The Belgian authority on forest insects, G. Severin (1901), regards *Evetria buoliana* as the most injurious insect to pines in Europe, and emphasizes the lasting injury to the timber resulting from even slight attacks of this insect.

All other European handbooks on entomology or on forestry contain similar accounts of this insect and express the same opinion as to its destructiveness to pine.

FOOD PLANTS.

Evetria buoliana is confined to pine and does not attack other coniferous trees, as spruce or larch, even though these grow alongside of the infested pines. While the species is most often mentioned on the yellow pine, or Scotch pine,[1] in Europe, because this is preeminently the forest tree of importance there, it attacks all species of Pinus indiscriminately, according to Ratzeburg and other authorities, and the American infestations have come in on European seedlings of the Austrian pine[2] and on mughus pine[3] quite as often as on Scotch pine.

According to Ratzeburg and Severin, it also attacks and is equally injurious to American white pine,[4] which is cultivated in Europe; and Mr. Carl Heinrich found the species on a small lot of another native American pine,[5] which was growing immediately surrounded by infested European pine seedlings.

These latter records are particularly significant, as they prove beyond question that the pest will spread to our native American pines if not prevented.

The species attacks mainly young trees between 6 and 15 years of age, but it is often excessively destructive to younger plantings and seedlings and injurious also to older trees, though trees of 30 years or older are rarely seriously affected.

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[1] *Pinus sylvestris.*
[2] *Pinus laricis* var. *austriaca.*
[3] *Pinus montana* var. *mughus.*
[4] *Pinus strobus.*
[5] *Pinus resinosa.*

INTRODUCTION AND DISTRIBUTION IN AMERICA.

American nurseries have imported many thousands of pine seedlings annually from Europe, especially from France, Belgium, Holland, Germany, and England. Importations normally take place in the fall, winter, and early spring. At this time of the year the young larvæ of the pine moth lie dormant within the buds, so that an infestation is easily overlooked. It is evident that the pest has been present in a number of shipments of late years and that it thus has been introduced repeatedly into American nurseries. In a great majority of these cases, however, the species has been unable to establish itself and has died out during the first year. Many of the larvæ die from overheating en route, or from various other unfavorable circumstances incident to the handling and transplanting of the seedlings under different climatic conditions. Only by a combination of favorable conditions would the few surviving larvæ have been able to develop into moths and succeed in establishing the species in this country. This is probably the reason why the species as yet has become established in comparatively few American localities. It appears that such established infestation has taken place only in very recent years and especially within the last two years, or since the demand for European pines has become general.

Up to the present time the European pine moth has been discovered in only 32 nurseries and private estates, representing 20 localities in 9 States, namely:

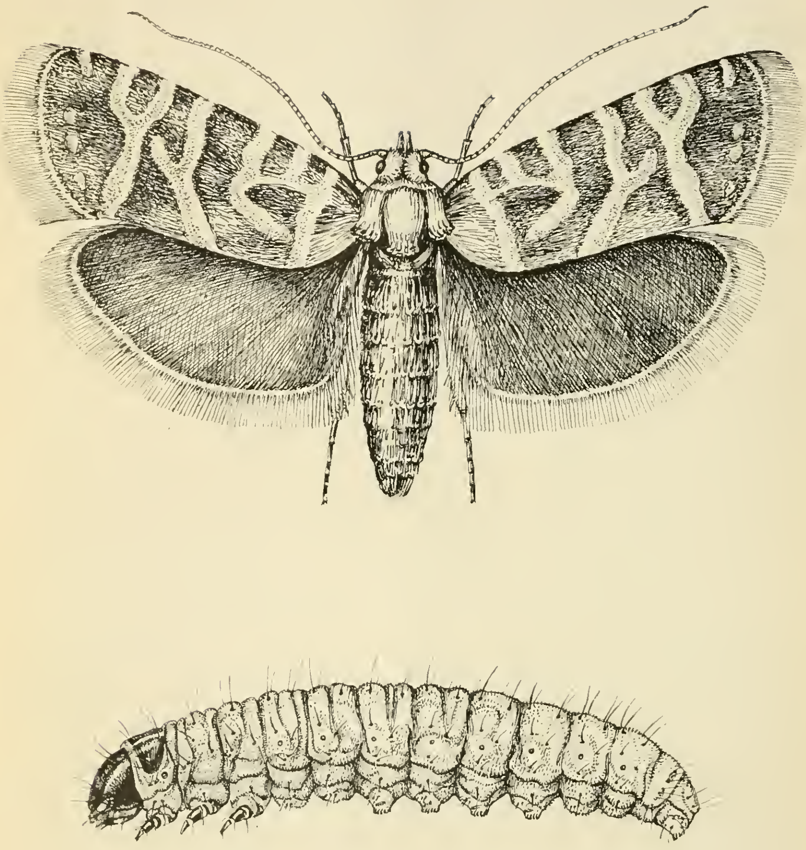
State.	Locality.	Discovered in—
Illinois	Chicago	Private grounds.
Do	Glenview	One nursery.
Do	Dundee	Do.
Do	Western Springs	Do.
Do	Deerfield	Do.
Do	Kenilworth	Two private grounds.
Do	Bloomington	One nursery.
Ohio	Tippecanoe City	Do.
West Virginia	Elm Grove	Do.
Pennsylvania	Pittsburgh	Private grounds.
Do	Philadelphia	One nursery.
New Jersey	Somerville	One estate.
New York	Long Island	Nine nurseries and estates.
Do	Tarrytown	One nursery and one estate.
Do	Elmsport	One estate.
Massachusetts	Dedham	One nursery.
Do	North Abington	Do.
Do	Worcester	Do.
Connecticut	New Canaan	Do.
Rhode Island	Newport	Two nurseries and one estate.

In none of these localities, except on Long Island, has the species existed for more than the last two years, and in most of them it has become established only within the last year.

But the survey for this insect has so far covered only about 60 localities, which could be reasonably suspected to harbor the pest because it was known that importations of European seedlings had

WORK OF THE EUROPEAN PINE-SHOOT MOTH (EVETRIA BUOLIANA).

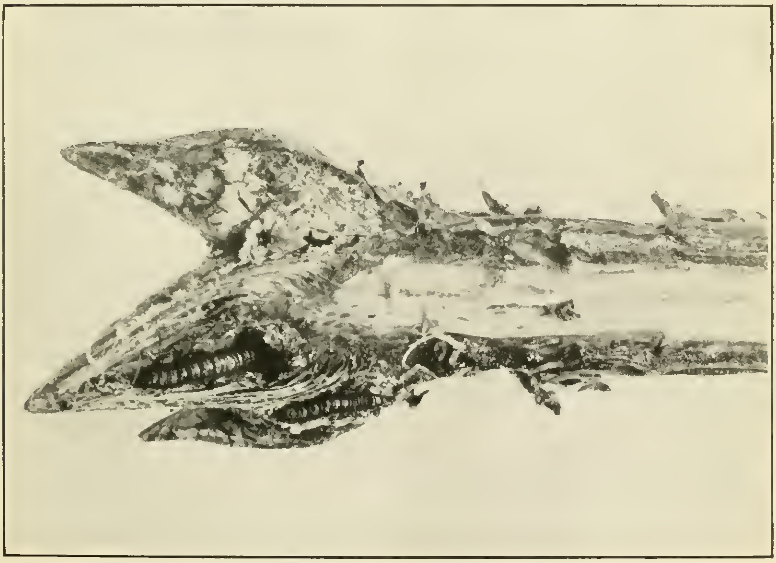
Section of European pine forest showing deformations in the trunk of *Pinus sylvestris* resulting from several consecutive years' injury. (After G. Severin.)



STAGES OF THE EUROPEAN PINE-SHOOT MOTH.

Moth and full-grown larva; both greatly enlarged. (Original.)

[Drawings by Miss Mary Carmody.]

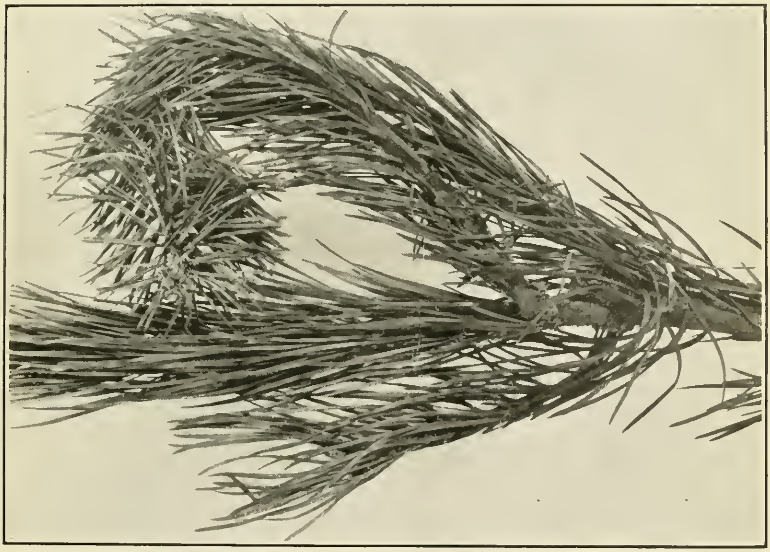


WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Fall work of the young larvæ in the buds of *Pinus sylvestris*. (Original.)

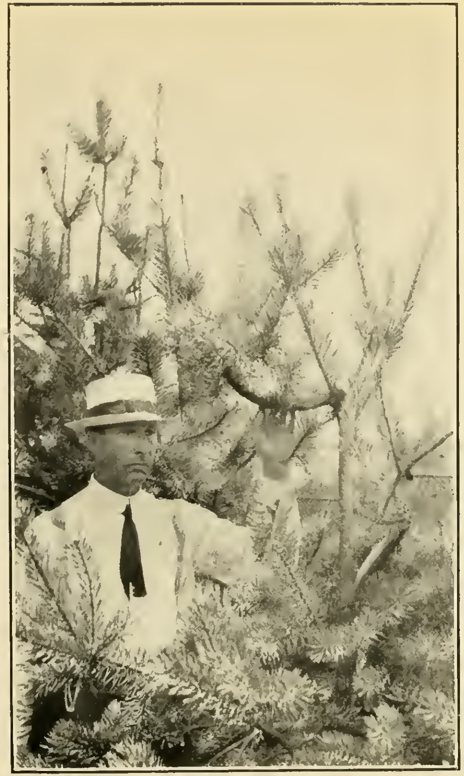
WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Malformations in pine resulting from injury by this pest. (Original.)



WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Twisted growth of European pines caused by the work of this insect. (Original.)



WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Typical first, second, and third years' growth of pine, after the primary injury by this insect, known as "baionnette" or "posthorn." (Original.)

[Photographs by Mr. H. C. Sands, of the New York Department of Agriculture.]

taken place, and the indications are very strong that the pest has become established in several other widely distributed localities, either by direct importation from Europe or by distribution from infested American nurseries. This is particularly to be suspected of localities where large importations and plantings of European pines have been made.

As yet the pest has been found only in nurseries and private parks supplied by these infested nurseries. In no case has it yet been found on forest trees in America. The species is therefore at present mainly a nursery problem in this country and consequently may yet be controlled and possibly even eliminated by proper measures under Federal and State supervision. That this condition can not long endure and that the pest, if not checked, will soon multiply and spread to native pines outside of nurseries and pass beyond the possibility of elimination is clearly indicated by all the evidence on hand.

LIFE HISTORY.

In Europe the moths (Pl. II, upper figure) issue in July, sometimes as early as the end of June, and in the warm evenings they swarm around the pines in large numbers. During the day they sit quietly on the branches, as can be ascertained by giving the tree a sharp jolt, which will cause the moths to fly out. When the insect sits still on the food plant it is not easily discovered, for the apparently striking orange-red color blends well with the natural surroundings and therefore must be classed as a protective coloration. Early in August the eggs are laid singly on the new buds for next year's growth, the terminal cluster of buds being nearly always chosen for oviposition. The young larva soon hatches and eats its way into the bud, making itself a roomy cell by devouring the live inside part. It attains a length of only a few millimeters during the fall months, and overwinters within the hollow bud. At this stage its presence is easily overlooked, though a trained eye will discover a small exudation of pitch over the entrance hole differing from the normal exudation of the buds. (See Pl. III.)

In May, as soon as the sap begins to rise in the trees, the larva
the buds. (See Pl. III.)
leaves its winter quarters and bores into the bud next thereto, in turn destroying this and as many others as it needs for food. As the remaining buds adjoining begin to grow into young shoots the larva attacks them. It eats the entire inside of the youngest shoots and these consequently die. The more developed shoots are injured only on one side, and these sometimes continue to grow, but are bent downward at the injured spot. The larva (Pl. II, lower figure) feeds only on the soft growth on which the needles have not yet appeared, and by the time the needles have developed all, or nearly all, of the shoots in the infested cluster have become dead or injured. The

larva then makes a silk-lined chamber within one of the hollow shoots and here it pupates. After about three weeks the spiny pupa pushes itself half way out through the dry wall of its chamber and the moth, or adult, issues.

The full life history of the species in America has not been ascertained, because a full year has not elapsed since it was first discovered here. While in the main it is the same as in Europe, a very distinct difference has already been noticed, due to the longer and warmer summer and fall in this country. In Europe the young larva attacks only one bud and attains very little growth before it enters the dormant winter season, but in the warmer climate of America the larva eats out two, three, or more buds and attains nearly half of its growth before winter. This, of course, tends to make the species even more injurious here than it is in Europe.

While it is altogether probable that the species has here only one generation annually, as in Europe, the possibility is not absolutely excluded that on account of the longer season it may eventually develop two generations annually like the allied native species. This, of course, would greatly increase its power for injury.

CHARACTER OF INJURY.

During the entire spring the infested twigs are very noticeable by reason of the dead and injured buds and young shoots, and the empty pupa skin sticking out of the destroyed shoot is also a familiar and easily noticed sight during the summer months; but the extent of the injury caused by this insect is only realized later in the season, when the new growth is found to be either quite destroyed or permanently injured.

As may be gathered from the foregoing account of the life history, each one of these insects does very considerable damage, not only by destroying a large number of buds and young shoots but by injuring the adjoining shoots which remain and which normally should supplant the destroyed leaders; thus the trees are permanently disfigured. These injured shoots bend downward and outward and afterwards grow upward again in a curve, in the attempt to continue the normal upward growth of the tree. This results in a characteristic malformation (Pls. IV, V, VI), so familiar in European pine forests that it has a popular name in each country—as "posthorn" and "waldhorn" in Germany and Holland and "baionnette" in France, while the few examples which have so far occurred in America have suggested the name "Dutch pipe" to those who have noticed it. This injury does straighten out somewhat during the successive years' growth, but never can be fully remedied and will always be noticeable and a serious detriment to the timber (Pl. I). Injury of this character is the result even when the species is present in only small numbers, the repeated infestation of the leading twigs during several consecutive seasons producing additional malformations which result in a much distorted tree of little commercial value. If the pest becomes more abundant, then the trees are transformed by the effect of the injury into unsightly crippled bushes with no commercial value.

DESCRIPTION.

THE ADULT.

(Pl. II, upper figure.)

The European pine-shoot moth is a small, gayly colored moth, about one-half inch long and measuring about three-fourths of an inch across with the wings extended. The head and its appendages and the thorax are light orange-yellow, and the abdomen is dark gray. The forewings are bright ferruginous orange, suffused with dark red, especially toward the tips, and with several irregular, forked anastomizing, silvery crosslines and costal strigulæ; the hindwings are dark blackish brown. The legs are whitish, the anterior ones reddish in front.

THE EGG.

The egg is very small, flat, whitish in color, and is laid singly at the base of a bud. Dissection of a female abdomen proves that upwards of a hundred eggs are laid by each female; this is a rather greater fecundity than is normal in this group of insects.

THE LARVA.

(Pl. II, lower figure.)

The young larva is dark brown with deep black head and thoracic shield, the latter divided by a narrow central line. The body of the older larva becomes somewhat lighter, but is still much darker than the larva of any of our allied native species. The full-grown larva is two-thirds of an inch long.

THE PUPA.

The pupa is stout, robust, light chestnut brown with darker head and back. The wing covers reach to the end of the fourth abdominal segment. The abdominal segments are armed with rings of short, sharp, blackish-brown spines.

ALLIED AMERICAN SPECIES.

There are in this country several indigenous species closely allied to *Evetria buoliana*, and like it confined to pine. Some of these already constitute a serious problem and periodically do considerable damage to pine forests and more often to pine nurseries. They are the more capable of injury because there are two generations annually and they thus have two chances each year to accomplish their damaging work. None of these native species can, however, even with this advantage, be compared in destructiveness to the European species just introduced. This is partly due to the larger size of the introduced species and to the greater voracity of the larva, but is mainly due to the difference in the attack, which causes a different reaction of the tree.

The larva of the native species of the genus confines itself to a single twig and finds its food within this or within a single bud, or at most a few buds. This bud or twig dies, but the tree responds with the natural growth of the next set of buds and very often recovers from the injury without permanent disfigurement. The resulting injury to the trees is serious only when these native species are present in unusually large numbers. Moreover, each of the native American species is more or less confined to a single or a few species of Pinus, but the European pine-moth thrives indiscriminately on all species of Pinus and has consequently a greater chance to become excessively abundant. While several of the native species are continually of some economic importance and periodically become a serious menace even to larger trees, it is mainly when they occur in large numbers in nurseries that they become really troublesome. Large trees become checked in their growth by the loss of terminal twigs, but are not necessarily seriously deformed in their future growth, although an undesirable forking of the tree top is a quite common result.

On the other hand, the larva of the European pine-shoot moth is very voracious and not only destroys a number of buds and young sprouting shoots by eating their interior, but it invariably damages the remaining shoots in the cluster by nibbling their bases on the inner side. The subsequent growth of these injured shoots, in the effort to supplant the destroyed leader, causes greater permanent injury to the value of the tree than if they were entirely removed.

NATURAL ENEMIES.

Evetria buoliana in Europe is, to some extent, kept in check by a large number of parasitic enemies. As early as 1838 Hartig[1] recorded 14 ichneumonid wasps and 1 tachinid fly[2] which he had reared from pupæ of the pine-shoot moth. It has since been ascertained that there are several other parasites; among the ichneumonids Ratzeburg considered the following three, which he himself had reared, as the more important: *Pristomerus vulnerator* Panz., *Cremastus interruptor* Grav., and *Orgilus obscurator* Hald.

[1] See "Literature," p. 10. [2] *Actia pinipennis* Fallen.

To promote the good work of these parasites specially constructed rearing houses have been erected in Europe during bad outbreaks of the pine moth. The infested twigs are collected in these small houses, which permit the escape of the parasites but not of the moths.

It is reasonable to suppose that some of the native parasites on some of the native species of Evetria will in time also attack *Evetria buoliana* in this country—in fact, parasitized larvæ have already been observed—but these native parasites can not be relied upon to keep in check their natural hosts, the American pine moths, which sporadically become very abundant and injurious in spite of the parasites, and presumably will be less effective in controlling the newly introduced host.

METHOD OF CONTROL.

The larva of the European pine-moth is so effectively protected within the buds that it can not be reached by any insecticide, and the only method of combating it is that used in Europe for more than a hundred years, namely, the pruning and destruction of the infested buds and twigs together with the larvæ they contain. Such hand picking is practiced every year in the government-controlled forest reserves of Europe.

This pruning must be done while the insect is within the twigs, and while it may be done throughout the entire year, except during the midsummer months when the insect is in the adult stage, it can be most profitably done in the fall and winter months while the young larvæ are yet within the undeveloped buds, because the pruning at this time will enable the secondary set of buds to develop in the spring without delay. The only drawback to the collecting of the larvæ in the fall and winter is that the infested buds are then less noticeable than in the spring when the injury is further developed. A little practice, however, soon enables instant recognition of the infested buds, even by an unskilled laborer; the slight exudation of pitch at the base of the bud covering the entrance hole of the larva (Pl. III) is very characteristic and easily recognized when once known.

In the spring, when the buds develop into young shoots, the injury is very much more apparent, and anybody can then distinguish the infested twigs at a glance. For this reason it is advisable to have the trees gone over again in the spring, so as to remove any infestation which has been overlooked in the fall. In America the work of the larva in the fall (September, October, and November) has progressed far more and is much more easily discovered than is the case in Europe, where the larvæ have attained very small proportions and have attacked only one or two buds before the winter resting period intervenes.

The fact that this species is stationary during the greater part of the year and only found within definite parts of certain kinds of trees, namely, in the next year's buds of pines, makes effective control work much easier than is the case with insect pests which are general feeders and which are not confined to definite parts of the food plant, as, for example, the gipsy moth or the browntail moth. While the European pine-shoot moth is confined to nurseries and private parks and has not spread to the native pines, it should prove a comparatively easy task to eradicate the species absolutely within any limited area. At the present time it would even seem possible completely to stamp out this dangerous pest in America, and forestall the infestation of our native pine forests, provided that the danger of new infestation is removed. But when once the species has multiplied sufficiently to become generally distributed on the native pines the possibility of eradication will be past.

SYNONYMY OF EVETRIA BUOLIANA SCHIFFERMILLER.

Tortrix buoliana Schiffermiller, Syst. Verz. d. Schmett., p. 128, 1776.

Coccyx buoliana Treitschke, Schmetterlinge von Europa, vol. 8, p. 140, 1830.

Tortrix (Coccyx) buoliana Ratzeburg, Die Forst-Insecten, vol. 2, p. 202, 1840.

Retinia buoliana Guénée, Europaeorum Microlepidopterorum index methodicus, p. 46, 1845.

Coccyx buoliana Herrich-Schäffer. Bearb. d. Schmetterlinge von Europa, vol. 4, p. 221, 1849.

Evetria buoliana Meyrick, Handbook of British Lepidoptera, p. 470, 1895.

Evetria buoliana Rebel, Catalog der Lepidopteren des palaearctischen Faunengebietes, T. II, No. 1851, 1901.

LITERATURE.[1]

1776. Schiffermiller, I. Systematisches Verzeichniss der Schmetterlinge der Wiener Gegend. Wien.

Original description of *Evetria buoliana*.

1809. Niemann, E. Forststastistik der Danischen Staaten, Altona.

Describes outbreak in Denmark in 1805–1807, and the collecting of larvæ in the effort to control the species.

1838. Hartig, T. *Tortrix buoliana*. *In* Jahresberichte über die Fortschritte der Forstwissenschaft und forstlichen Naturkunde, Jahrg. 1, Heft 2, p. 267–268, Berlin.

Records the rearing of 15 species of parasites from *Evetria buoliana*.

1840. Ratzeburg, J. T. C. Die Forst-Insecten, T. 2, p. 202–207, Taf. XIV, fig. 4. Berlin.

Detailed account with illustrations of the life history, work, economic importance, remedies, natural enemies, and literature of the species, with notes of severe outbreaks in Germany, 1835–1838.

[1] This is not intended to be a complete bibliography of *Evetria buoliana*; a large number of special articles have appeared in various publications in Europe, and every handbook on insects or forestry contains more or less exhaustive accounts of this pest.

1895. Judeich, J. F., and Nitsche, H. Lehrbuch der mitteleuropaischen Forstinsektenkunde, Bd. 2, p. 1004–1008. Wien.

Condensed (5 pages), life-history and economic importance with original figure of the injury done by the species.

1897. Lovink, H. J., and Ritzema Bos, J. Schade in jonge dennen bosschen teweeg gebracht door rupsen uit het bladrollergeslacht *Retinia* Gn. ("dennenknoprups" "dennenlotrups" "harsbuilrups"). *In* Tijdschr. Plantenziekten, Jahrg. 3, Afl. 4, p. 83–133, figs. 6, pls. V–VII, Oct.

Detailed account of the species and its injury, with colored plates.

1897. Severin, G. Insectes. Extrait du Catalogue détaillé et illustré du Pavillon des eaux et forêts à l'Exposition internationale de Bruxelles-Tervueren, p. 46–49, pl. X. Bruxelles.

Contains short illustrated account of *Tortrix* (*Retinia*) *buoliana* Schiffermiller and its injury: Plate 1 of the present paper has been copied from this article.

1898. Boas, J. E. V. Dansk Forstzoologi. Copenhagen.

Condensed life history, injury, and references, with original observations and figures.

1898. Hess, R. A. Der Forstschutz, ed. 3 enl., v. 1, p. 492–494, figs. 174–175. Leipzig.

Condensed handbook information on *Tortrix* (*Retinia*) *buoliana* Schiff.

1901. Severin, G. Le genre *Retinia*, Pyrale des pommes, des bourgeons, de la résine. *In* Bul. Soc. Cent. Forest. Belg., t. 8, p. 598–605, 674–685, 2 pls., 7 figs.

Monographic account of the three most important injurious species of the genus *Evetria* in Europe, with text figure and colored plate of *Evetria buoliana*. It should be noted that the larva figured under and credited to *Evetria buoliana* belongs to *Evetria resinella*, figured on the next colored plate, and vice versa.

1912. Gillanders, A. D. Forest Entomology, ed. 2. Edinburgh and London.

Condensed handbook information.

1913. Nüsslin, O. Leitfaden der Forstinsektenkunde, 2. neubearb. und verm. Aufl., p. 417–418, figs. 350, 352. Berlin.

Condensed handbook information on *Grapholitha* (*Evetria*) *buoliana* Schiff.

1914. Busck, August. A destructive pine-moth introduced from Europe (*Evetria buoliana* Schiffermiller). *In* Jour. Econ. Ent., v. 7, no. 4, p. 340–341, pl. IX, August.

First notice of the pest in America.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 173

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. | PROFESSIONAL PAPER | April 13, 1915

THE LIFE HISTORY AND HABITS OF THE PEAR THRIPS IN CALIFORNIA

By

S. W. FOSTER and P. R. JONES, Entomological Assistants
Deciduous Fruit Insect Investigations

CONTENTS

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

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April 13, 1915.

(PROFESSIONAL PAPER.)

THE LIFE HISTORY AND HABITS OF THE PEAR THRIPS IN CALIFORNIA.

By S. W. Foster [1] and P. R. Jones,[2] *Entomological Assistants, Deciduous Fruit Insect Investigations.*

INTRODUCTION.[3]

The so-called pear thrips, (*Euthrips*) *Tæniothrips pyri* Daniel, first attracted attention during the spring of 1902 in a prune orchard near San Jose, Cal. Its injuries rapidly increased in the Santa Clara Valley, and the insect spread to other orchard sections in the San Francisco Bay region. Its increasing destructiveness and spread led to the establishment by the Bureau of Entomology of a laboratory in the Santa Clara Valley to determine the life history and habits of the pest and to determine, if possible, measures for its control in orchards. The laboratory thus started during the summer of 1907 was continued to the fall of 1912.

Mr. Dudley Moulton, an agent of this bureau, who, as Santa Clara County entomologist, had previously had experience with the insect, was placed in immediate charge of the work, in which position he continued until September, 1909. During his period of service Mr. Moulton was assisted in the Santa Clara Valley at one time or another by Messrs. C. T. Paine, S. W. Foster, and P. R. Jones.

In the fall of 1908 owing to the rapid dissemination of the pear thrips to the northward an additional laboratory was established in Contra Costa County, with headquarters at Walnut Creek. This work was placed under the immediate direction of Mr. S. W. Foster, who also had charge of operations in the infested counties to the north. During the spraying season of 1909 Mr. Fred Johnson collaborated with Mr. Foster in experimental and demonstration spraying in

[1] Resigned Oct. 10, 1912.

[2] Resigned Sept. 30, 1912.

[3] By A. L. Quaintance, In Charge of Deciduous Fruit Insect Investigations.

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orchards, and in July of the same year Mr. E. J. Hoddy was assigned to the Walnut Creek laboratory and assisted in certain cultivation experiments at Suisun in the fall of 1909, and with Mr. R. W. Braucher assisted in the demonstration spraying operations at Suisun and Courtland during the spring of 1910. During the spraying season of 1911 Mr. Foster was assisted by Messrs. E. L. Jenne and R. L. Nougaret.

Upon the resignation of Mr. Dudley Moulton Mr. P. R. Jones was placed in charge of operations in the Santa Clara Valley and was assisted during the spraying season of 1910 by Mr. E. L. Jenne and during the spraying season of 1911 by Messrs. A. G. Hammar and W. M. Davidson.

During the spraying season of 1912, owing to the absence from California of Mr. Foster, Mr. Jones was charged with all of the pear-thrips operations in California and was assisted in the work by Messrs. W. M. Davidson and L. L. Scott, located at Courtland, by Mr. R. L. Nougaret at Suisun, and by Mr. E. L. Jenne at Walnut Creek.

The manuscript for the present report has been prepared as follows: All of the data relating to Contra Costa County and counties to the northward have been prepared by Mr. Foster, the senior author. Report of operations in the Santa Clara Valley, as well as much of the life-history matter, has been prepared by Mr. Jones. The remaining chapters were written jointly by Messrs. Foster and Jones.

Especial acknowledgment is due to the supervisors of Contra Costa County and Santa Clara County for their assistance in furnishing facilities for work during the season of 1909, and for supplementing the bureau's funds before the special appropriation from Congress was available. The bureau desires also to acknowledge its obligations to many orchardists in the thrips-infested territory, who placed at the disposal of the Department of Agriculture their orchards and facilities for experimental and demonstration purposes. The success which many orchardists have obtained in the control of the pear thrips by the adoption of the recommendations of the bureau, as well as the large-scale spraying demonstrations which the bureau has conducted, has fully demonstrated the effectiveness and practicability of the methods recommended. Especial acknowledgment is made also to Mr. W. S. Ballard, of the Bureau of Plant Industry of the United States Department of Agriculture, for much valuable assistance and numerous courtesies rendered during the course of the work at Suisun.

The present paper deals with the life history and habits of the pear thrips, the results of experiments and demonstrations with sprays and other remedial operations having been given in Circular No. 131 of the Bureau of Entomology.

HISTORY.

LITERATURE.

The first reference in literature to the pear thrips is the original description of the insect by Miss M. Daniels in Entomological News for November, 1904.[1] The type specimens were taken on pear near San Leandro, in Alameda County, Cal., for which reason it was given the common name "pear thrips."

Dudley Moulton,[2] in 1905, published the first account dealing with the economic importance of this species. He described its different stages and the nature and extent of injury caused by it, and included a discussion of its life history. No advice was given as to remedial measures, except that early winter plowing was advocated.

The third reference to the pear thrips in literature was by the same author in Bulletin 68, Part I, of the Bureau of Entomology.[3] This contained practically all that was included in the former publication, with additional information accumulated, making a more complete account of the pest. It was illustrated with appropriate figures of all stages, including the eggs and pupa, which had not theretofore been figured. No successful remedial measures, however, had been determined.

The next publication was also by Moulton, and was issued as Bulletin 80, Part IV, of this bureau.[4] It gave an extended account of the life history of the pear thrips, with recommendations for early fall plowing and cross-plowing, to be followed by spraying in the spring for the adult and an application against the larvæ after the falling of the petals. Tables were given showing the actual number of thrips killed in the plowed as compared with the unplowed areas.

The next account was published as Circular 131 of the Bureau of Entomology,[5] and is a concise abstract of the present paper.

The Journal of the South-Eastern Agricultural College, Wye, Kent County, England, No. 19, for 1910 (published in 1911), contains an article by F. V. Theobald[6] dealing with thrips in general, in which this species receives considerable prominence.

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[1] Daniel, S. M. New California Thysanoptera. *In* Entomological News, v. 15, no. 9, p. 294–295, November, 1904.

[2] Moulton, Dudley. The Pear Thrips (*Euthrips pyri*). California State Horticultural Commission, Publication, Sacramento, 1905. 17 p., 8 figs.

[3] Moulton, Dudley. The Pear Thrips. (*Euthrips pyri* Daniel.) U. S. Dept. Agr., Bur. Ent., Bul. 68, pt. 1, 16 p., 8 figs., 2 pls., June 10, 1907.

[4] Moulton, Dudley. The Pear Thrips and its Control. (*Euthrips pyri* Daniel.) U. S. Dept. Agr., Bur. Ent., Bul. 80, pt. 4, p. 51–66, figs. 13–17, pls. 4–6, Sept. 4, 1909.

[5] Foster, S. W., and Jones, P. R. How to Control the Pear Thrips. U. S. Dept. Agr., Bur. Ent., Circ. 131, 24 p., 14 figs., Jan. 9, 1911.

[6] Theobald, Fred. V. Report on economic zoology for year ending Sept. 31, 1910, p. 57–67, fig. 5, Pls. XXV–XXVIII. *In* Jour. Southeast. Agr. Col., Wye, no. 19, 1911.

Also in 1911 Mr. P. J. Parrott[1] published an account of the appearance of this species in New York State, and in January, 1912, he issued a more extended account of the pear thrips in New York.[2]

HISTORY IN ORCHARDS AND DISTRIBUTION.

The first reported injury caused by the pear thrips was noticed in the year 1902, in an orchard owned by Judge S. F. Leib and Mr. G. M. Bowman. This orchard was situated in the Berryessa district of the Santa Clara Valley, near San Jose, and consisted chiefly of the Imperial variety of prunes. The injury was noticed at first on about 20 or 30 acres of the 200 acres of orchard, and the cause of the trouble at that time was unknown. In the spring of 1904 every other row of this orchard was top-worked with sugar prunes, chiefly to secure better cross-pollination with the Imperial variety of prunes, the lack of which was supposed to have been the cause of failure of the crops in the past. During a drive through 100 acres of this orchard the fruit buds were observed to be just beginning to show the white tips of the petals, and the prospects seemed excellent for a good crop. When revisiting the place five days later, the owner found to his utter astonishment that the whole orchard had the appearance of having been scorched with fire and that there was not an average of a dozen blossoms to the tree.

The thrips were discovered this same year (1904) in the orchard of Mr. R. K. Thomas, on Cypress Avenue, near Stevens Creek Road, about 7 miles distant in an air line from the Leib orchard. From these two orchards infestation has, with the exception of a few acres, spread all over the Santa Clara Valley and into other valleys surrounding the San Francisco Bay.

No exact information is available as to the first appearance of the thrips in other counties, but many orchardists claim that it has been in Contra Costa County since 1904 and in Solano County at least since 1906. In addition to these centers of infestation in Santa Clara, Contra Costa, and Solano Counties, the insect is now present in considerable numbers in Alameda, Sacramento, Yolo, Napa, Sonoma, San Joaquin, and San Benito Counties. The general area of infestation in California is indicated in the accompanying map (fig. 1).

There have been several reported outbreaks of this species in other parts of the State, notably from the Sierra Nevada foothills near Newcastle and Auburn, near Red Bluff and Anderson in the Sacramento Valley, and from the fruit districts of Tulare and Fresno Counties in the San Joaquin Valley. The species in question, how-

[1] Parrott, P. J. Occurrence of *Euthrips pyri* Daniel in New York State. *In* Science, n. s., v. 34, no. 864, p. 94, July 21, 1911.

[2] Parrott, P. J. The Pear Thrips. N. Y. Agr. Exp. Sta., Geneva, N. Y., Bul. 343, p. 341–366, 4 figs., pls. 30–33 and 1 col. pl., Jan., 1912.

ever, were found to be (*Euthrips*) *Frankliniella occidentalis* Pergande and (*Euthrips*) *Frankliniella tritici* Fitch, neither of which is particularly injurious to deciduous fruits. Reports of injury supposed to have been caused by this species were received from the Rogue River Valley in Oregon, but a critical examination, in 1909, showed no signs of the work of the pear thrips. In the spring of 1910 many larvæ of (*Euthrips*) *Frankliniella tritici* were found, but none of the species under consideration could be obtained.

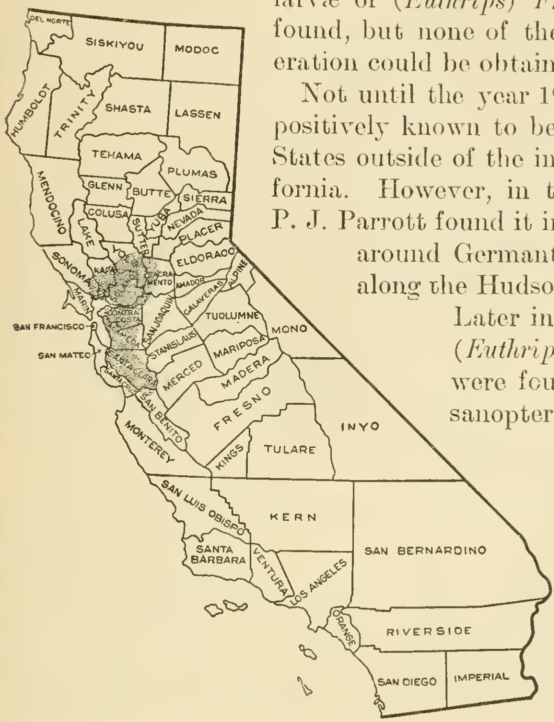

FIG. 1.—Map showing general area of infestation by the pear thrips in California. (Authors' illustration.)

Not until the year 1911 was the pear thrips positively known to be present in the United States outside of the infested districts of California. However, in the spring of 1911 Mr. P. J. Parrott found it in considerable numbers around Germantown and other points along the Hudson River in New York.[1] Later in the year specimens of (*Euthrips*) *Tæniothrips pyri* were found among some Thysanoptera which had been collected in the spring by Mr. Parrott in the vicinity of Geneva, N. Y.

In May, 1912, Mr. A. L. Quaintance sent the authors a number of specimens of thrips collected in pear blossoms from six different orchards by Mr. Fred Johnson at North East, Pa. All proved to be the pear thrips, (*Euthrips*) *Tæniothrips pyri*.

In 1909 Bagnall[2] reported that numerous examples of this very injurious species, taken in plum blossoms at Evesham, England, had been sent to him by Mr. Walter Collinge. So far as we know, this and the previously mentioned account by Theobald are the only published reports of the occurrence of this species outside of the United States.

Two other species of Thysanoptera (*Thrips physapus* L. and *T. flava* Schrank) are mentioned by Carpenter as the "pear-blossom thrips"

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[1] Parrott, P. J. Occurrence of *Euthrips pyri* Daniel in New York State *In* Science, n s., v. 34, no. 864, p. 94, July 21, 1911.

[2] Bagnall, Richard S. A contribution to our knowledge of the British Thysanoptera (Terebrantia), with notes on injurious species. *In* Jour. Econ. Biol., v. 4, no. 2, p. 33–41, July 7, 1909.

in his report before the Royal Dublin Society for 1900,[1] and as the "pear thrips" in his report to the same society for 1901.[2] In the report for 1900 he states that these two species were found feeding in unopened pear blossoms near Dublin, and he attributes the failure of the fruit that season to the work of these insects. The report for 1901 states that a Dr. Barton tried a dressing of kainit around the trees, with very satisfactory results.

In December, 1914, Mr. W. M. Scott[3] reported the occurrence of the pear thrips in a Kieffer pear orchard near Baltimore, Md. The insect was so abundant as completely to destroy the crop of fruit.

THEORIES AS TO ORIGINAL HOME.

Various ideas have been advanced as to the original home of the pear thrips. Dr. Pietro Buffa, a well-known student of Thysanoptera, in private correspondence under date of April 17, 1909, suggested that while it is a good species it should be put only in the genus Physopus, and expressed the belief that it was not a European species. Prof. Silvestri suggested that it was introduced from China or was of other oriental habitat. Several leading fruit growers have expressed the belief that the insect was introduced into this country from France or England, giving as the reason its apparent partiality to prunes, which are varieties of European plums.

The occurrence of the pear thrips in England lends some weight to the theory that it is of European origin. It may be that natural conditions hold it in check in England and that its advent into California under conditions more suitable for its rapid increase explains its presence there in such enormous numbers. Now, however, that its presence is definitely established in the eastern United States, it is probable that the insect had been in this country for years before it was discovered.

It may be possible that the pear thrips is native to the Santa Cruz Mountains, with some wild rosaceous plant as its original food plant. Upon this supposition it is probable that it has been present in the Santa Clara Valley for many years, and that it first became notoriously destructive with the advent of favorable conditions. While this species has been taken upon a great variety of plants and has been found to be able to subsist on many of them, it is distinctly an enemy of deciduous fruits, to which it shows a decided preference.

COMMON NAMES.

Many common names have been assigned to this insect, as "pear thrips," "prune thrips," "cherry thrips," etc. The first mentioned,

[1] Carpenter, G. H. Report on economic entomology for the year 1900, p. 96–97. Reprinted from the Report of the Council of the Royal Dublin Society for 1900.

[2] Carpenter, G. H. Injurious insects observed in Ireland during the year 1901, p. 153–154. *In* The Economic Proceedings of the Royal Dublin Society, v. 1, pt. 3, no. 5, July, 1902.

[3] Jour. Econ. Ent., v. 7, No. 6, p. 478–479, Dec., 1914.

namely, "pear thrips," has been more extensively used, following the original designation of the insect, because the species was first described from specimens taken upon pear trees. The word "thrips" is a general term for the species of the order Thysanoptera and is sometimes erroneously applied to certain other insects, as the grape leafhopper (*Typhlocyba comes* Say). The word "thrips" is both singular and plural.

ECONOMIC IMPORTANCE.

DESTRUCTIVENESS.

This minute insect, which until 1904 was unknown to science, is at present one of the most important insect pests with which the growers of deciduous fruits in the San Francisco Bay region and adjoining counties have to contend. The rapidity with which the insect spreads, its suddenness of attack and complete blasting in a few days of all prospects for a crop of fruit, and the difficulty experienced in its control, combine to make its subjugation a matter of considerable difficulty. Moreover, as the insect is each year developing an ability to subsist on other and new food plants, its capabilities for dissemination become correspondingly increased. There is no reason to believe that the thrips will disappear in a few years, and it should be at once realized that only the most careful attention each year to necessary control measures will make it possible to continue the profitable culture of fruit in regions where this insect is present in any considerable numbers.

In the Santa Clara Valley this insect has been worse some years than others, notably in 1905, 1907, 1908, 1909, and 1910, but it is safe to say that from now on the maximum prune crop possible for this valley will never again be reached unless every orchardist does the utmost in his power to control the thrips. While it may be possible for unfavorable weather conditions to reduce the possibility of a good crop of 100,000,000 pounds of dried prunes for this valley to something like 40,000,000 or 50,000,000 pounds, the thrips, in a great measure, has been responsible for the small crops since 1907, and will continue to be so, first, by killing the fruit buds before they bloom; secondly, by depositing the eggs in the fruit stems, and, thirdly, by the feeding of the larvæ on the fruit, causing it either to drop prematurely or to develop misshapen and scarred on the trees. While the thrips is doing much serious work in the Santa Clara Valley to cherries and pears and the damage done to different varieties of peaches is increasing, yet on account of the small acreage of these fruits the chief loss from a commercial standpoint is to the prune industry. Some idea of the destruction caused by the pear thrips during the previously mentioned bad years may be gained from the following figures, giving the approximate yield of prunes in pounds each year for the years 1900 to 1912, inclusive.

TABLE I.—*Yield of prunes for the Santa Clara Valley, 1900–1912, inclusive.*

Season.	Yield of dried fruit.	Season.	Yield of dried fruit.
	Pounds.		*Pounds.*
1900	120,000,000	1907	50,000,000
1901 [1]	35,000,000	1908	40,000,000
1902	120,000,000	1909	85,000,000
1903	90,000,000	1910	{ 35,000,000 40,000,000
1904	100,000,000		
1905	50,000,000	1911	100,000,000
1906	120,000,000	1912	65,000,000

[1] Severe frost.

In 1911 the pear thrips probably caused a heavy loss in spite of the fact that there were not more than one-half as many thrips present in this valley as in 1910. The good prune crop in the Santa Clara Valley in 1911 was due to light thrips injury and the very heavy rainfall. The amount of rainfall, which was about 8 inches more than the normal, not only placed the trees in excellent shape to bear a heavy crop, but, coupled with other climatic conditions during the early part of 1911 and latter part of 1910, lessened the work of the thrips very materially. Notwithstanding a favorable fruit year from a weather point of view, thrips in some places caused a great amount of damage. The thrips damage in the Santa Clara Valley for 1910 was caused principally by the adults, with very little larval work, while for 1911 it was just the reverse, the adults doing comparatively little injury because of less numbers and strong fruit buds as a result of the heavy winter rains. The scarcity of adult thrips in 1911 may have been due to several causes. Two heavy rains during the early part of April of the previous year knocked off many young larvæ before they were sufficiently mature for transformation. In addition the season for pupating, June to December, 1910, was abnormally dry, showing a deficiency in rainfall of 5.28 inches, while the emergence period in the spring of 1911 was unusually wet and cold. All of these conditions caused a higher mortality than would be the case under normal conditions. However, in orchards which showed comparatively few adults the larvæ were sufficiently abundant to riddle the foliage and cause much of the young fruit to drop. The heavy rains during the emergence period also checked to some extent the work of the adults.

In estimating the economic loss to the fruit industry of California caused by the pear thrips it is necessary to begin with the year 1904, when it was first known that the insect was doing commercial damage, and continue down to the present time. An attempt will be made to give a fair estimate of the amount of damage done yearly to the prune industry alone in the Santa Clara Valley for the years 1904 to 1911, inclusive.

The average size of prunes grown in the Santa Clara Valley is 60–70; that is, dried prunes requiring from 60 to 70 to make a pound. The price paid for prunes during the years from 1904 to 1911, inclusive, was variable, but would average close to a 3-cent basis; that is, 3 cents per pound for dried prunes running 80 prunes to the pound. In order to be conservative, the average size, 60–70, is disregarded, and the loss is figured on the regular 80-to-the-pound basis. In 1904 the loss was estimated at 500 tons, or 1,000,000 pounds (dried prunes), which, at 3 cents per pound, amounts to $30,000. For the year 1905 it was placed at 10,000,000 pounds and the damage at $300,000; in 1906 at 5,000,000 pounds, worth $150,000; in 1907, 15,000,000 pounds, worth $450,000; in 1908, 20,000,000 pounds, worth $600,000; in 1909, 30,000,000 pounds, worth $900,000; in 1910, 40,000,000 pounds, worth $1,200,000; and in 1911, 20,000,000 pounds, worth $600,000. The total of all of these years would be 141,000,000 pounds, valued at $4,230,000.[1] The estimates for some years probably have been close to the actual damage done, but more frequently the loss has undoubtedly been underestimated. In 1904 all the fruit of one orchard, comprising 100 acres of Imperial prunes, was totally destroyed, and this alone at an average crop of 5 tons of green prunes per acre, on a 3-cent basis for dried prunes, would have been valued at close to $30,000, because of the large size of this variety of prune, only from 30 to 40 of which make a pound.

In estimating this loss no account is taken of the great depreciation in value of the crop caused by scabbing. The entire yield each year has been counted as merchantable fruit, and estimates of damage made solely from orchards showing total loss or a marked reduction in tonnage produced.

To explain more fully the commercial quotation of a 3-cent basis, it is meant that 3 cents per pound will be paid for dried prunes averaging 80 prunes to the pound. For prunes which are larger and free from scab or defects the price is usually $1 per ton more for each point in size, and for smaller prunes the price decreases correspondingly.

As to the extent of the damage the pear thrips will cause in this county if left unchecked, it is difficult to estimate, but the fact that thrips were twice as numerous in 1910 as in 1909 shows their ability to double the damage performed in any preceding year. The cause for the notably light prune crop in 1910 is not attributed altogether to the work of the pear thrips, but partly to unfavorable weather conditions, which pervented many of the blossoms from setting fruit. However, all the large producing prune districts of the Santa Clara Valley were very seriously injured by the pear thrips, and hundreds

[1] These estimates are based on fuller and more complete reports than could be obtained in time for Circular 131 of the Bureau of Entomology, and these figures more nearly represent the actual loss.

of acres in these districts were prevented from blooming—a fact not attributable to unfavorable weather conditions but solely to ravages of the thrips. Other orchards, under same weather conditions but with little or no thrips injury, produced a full crop of blossoms.

During the year 1911 another type of injury that was different from previous years, which may be called cumulative injury, was noticeable in many orchards. Barring the three heavy frosts in April, the blooming and fruiting season in 1911 was exceedingly favorable in so far as climatic conditions were concerned. Nevertheless about the 1st of May the trees in many orchards turned a sickly yellow owing to the work of the thrips in 1911 and from devastations by this insect in previous years. Some orchards which were out of the frost belt and which were not severely injured by thrips in 1911 showed this condition noticeably. It is possible that much of this was due to neglect of the orchards by fruit growers who did not obtain crops of fruit during the preceding four years because of the injury of the thrips to the buds, blossoms, and young fruit.

As mentioned before, practically all of the Santa Clara Valley came into full bloom in 1911 and gave promise of a record crop, but larval injury was very heavy over the entire valley. This, with the result of injury in previous years, apparently greatly weakened the trees and caused much of the fruit to fall at the first unfavorable weather.

Injury to pears in the Santa Clara Valley has never risen to great proportions from a financial point of view, for the reason that most of the acreage of this kind of fruit is set out near Santa Clara and Alviso, sections of this valley where the thrips has not yet become dangerously numerous. However, during the season of 1911 a number of orchards in these localities became badly infested. The amount of damage done to cherries in this valley has not been determined on account of the scattered acreage planted to cherries in the infested area.

The distinctly severe years for thrips injury in Contra Costa County in pear orchards were 1908 and 1910, when the crops were practically annihilated. Also there was great loss the two previous years, 1906 and 1907. The prune orchards suffered in these years and in the year 1909, producing less than one-third of a normal crop any one year. The fruit crop has been seriously menaced each year since 1905, the area increasing yearly, and in 1911 it aggregated a total loss to the county of between $1,000,000 and $1,250,000.

Solano County has in some ways been more fortunate, as the thrips has been known to cause serious injury only since 1907, but even in that time the thrips has spread rapidly and caused great damage on large areas; the damage in 1911 was very extensive and the total loss to the county attributable to the work of the pear thrips amounted to at least $750,000.

The damage in Sacramento County was noticeable only in a comparatively limited area in 1909, increasing considerably both in area and destructiveness during 1910 and 1911, and the total loss to that county probably amounted to at least $250,000.

No accurate figures are available for the damage caused in Alameda County, but a considerable area has been infested for several years and many conservative estimates put the total loss to, but not including, 1912, as more than $150,000.

The pear thrips has more recently been found in slightly injurious numbers in Yolo and Napa Counties, in the eastern part of Sonoma County, in the northwestern part of San Joaquin County, and in some parts of San Benito County.

Including the infested areas in Santa Clara, Contra Costa, Solano, Sacramento, Alameda, Yolo, Napa, and Sonoma Counties, it is safe to say that the thrips, in absence of treatment, would cause an average yearly loss of over $2,000,000. With each additional year an additional loss of several hundred thousand dollars, due to the increase of the area infested and the increased losses in the areas previously infested, is to be expected. The total damage to the fruit industry of the State of California since the first appearance of the insect aggregates, it is believed, at least $6,630,000 up to but not including 1912.

FOOD PLANTS.

While the pear thrips is distinctly a deciduous-fruit insect and practically all of its damage is confined to this class of plants, it has been found upon a great variety of plants the list of which is increasing each year. The fact of its wide range of food plants makes extermination practically impossible, whereas control can be readily practiced. It has been taken upon the following plants and could probably subsist upon a number of them long enough to make it a constant menance to the fruit industry of California: Apricots, apples, almonds, cherries, figs, grapes, pears, plums, prunes, walnuts, madroña (*Arbutus menziesii*), wild California lilac (*Ceanothus thyrsiflorus*), poison oak (*Rhus diversiloba*), dogwood (*Cornus* sp.), acacia, willow (*Salix* sp.), laurel (*Umbellularia californica*), mustard (*Brassica nigra*), live oak (*Quercus wislizeni*), miner's lettuce (*Montia perfoliata*), and various grasses and weeds.

CHARACTER OF INJURY.

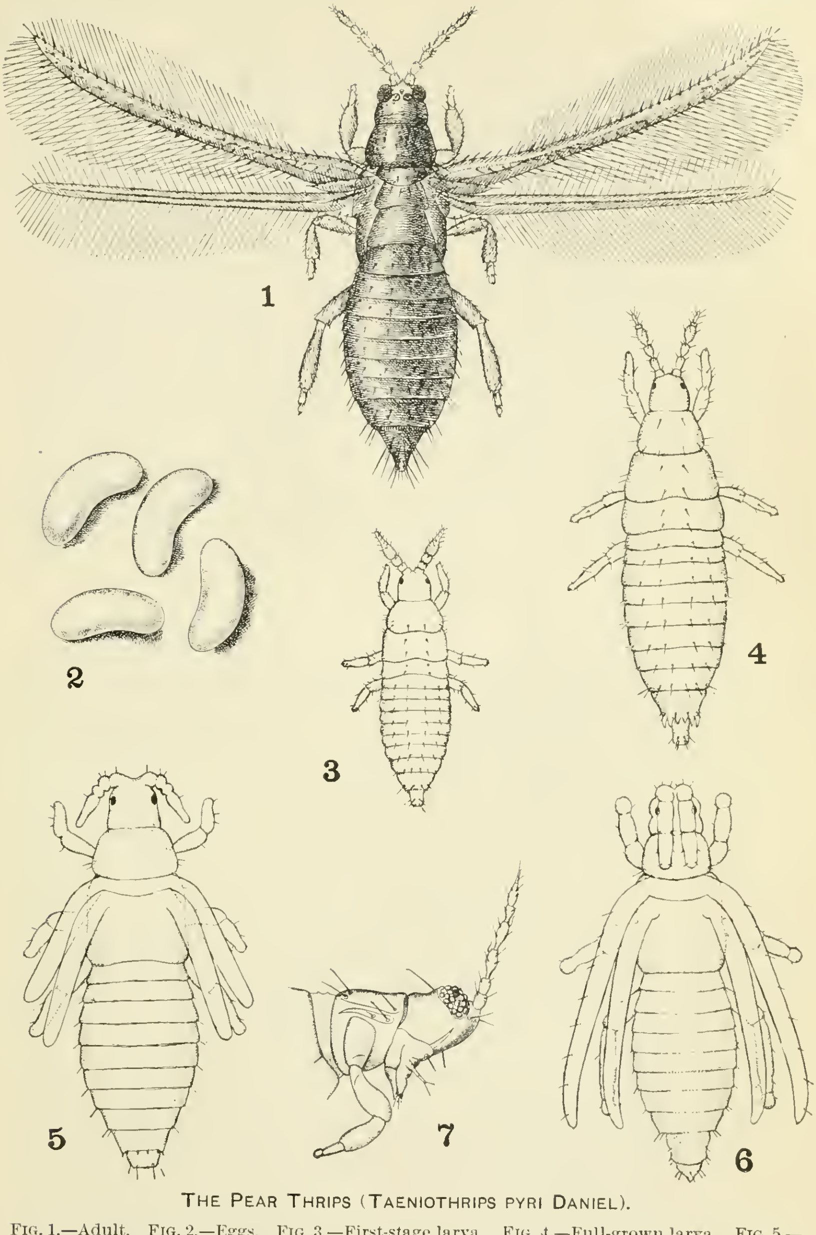
MANNER OF FEEDING AND TYPE OF MOUTHPARTS.

Injury to plants by the pear thrips is caused directly by the feeding of the adults and larvæ upon the various portions of the fruit, buds, flowers, and leaves, and also by the deposition of eggs in the leaf surfaces, fruit stems, and newly formed fruit.

The mouthparts of the Thysanoptera present many difficulties for study and are not thoroughly understood. They are so modified that various writers have disagreed regarding their homologies. They appear, however, to belong chiefly to the suctorial type, and they show many traces of a transition from the mandibulate type to the suctorial. (See Pl. I, fig. 7.) Viewed as a whole, the mouthparts appear as a broad and jointed cone attached to the posterior edge of the underside of the head and resting for a large part under the pronotum. The apex of the cone is quite sharp, but not so slender and drawn out as in the Hemiptera. The mouthparts as a whole are strikingly unsymmetrical. The most evident marks of this are the forms of the labrum and the left mandible. The first, which makes the front wall of the cone, is unsymmetrical in the whole order, but especially so in the Terebrantia. It is irregularly triangular in form and is attached by its broad base to the clypeus. It becomes narrower as it approaches the tip and is usually rounded in the Terebrantia but more variable in the Tubulifera, where it is pointed in some species and broadly rounded in others. The maxillæ are broad and flat and constitute the side walls of the mouth cone. They also taper toward their tips. The labium forms a hind wall of the mouth cone and is usually considerably broader at the tip than at the other parts. Within this hollow cone lie the piercing organs, which are three in number. First, there is a single large mandible lying on the left side of the mouth cavity, whereas the right side has no corresponding member.[1] The other two organs are the maxillary lobes. These are more slender and longer than the mandibles and are developed alike on each side. All of the mouthparts are strongly chitinized at the tip, being more so in the adults than in the larvæ although the mouthparts of the latter are otherwise closely similar to the former.

The members of this order are thought to use the mandibles for piercing the exterior portion of the plants, while the maxillary lobes, which are longer, are used to penetrate deeper into the tissues, and are moved with a rasping motion, causing the juices of the plant to flow, so that they may be sucked up into the alimentary canal. In feeding, as observed by aid of a hand lens, both adults and larvæ exhibit an up-and-down motion of the head combined with a forward motion which might be properly termed rooting. Most of the species under the writers' observation prefer to enlarge a wound into the plant tissues where the juices flow more readily rather than to select new areas for feeding. This continual macerating of the fruit by the pear thrips for a period of several days causes on deciduous fruits what is known as the characteristic pear-thrips scab, which

[1] The mandible in the Tubulifera is shorter and more bent than in the Terebrantia.



THE PEAR THRIPS (TAENIOTHRIPS PYRI DANIEL).

FIG. 1.—Adult. FIG. 2.—Eggs. FIG. 3.—First-stage larva. FIG. 4.—Full-grown larva. FIG. 5.—Pupa, first stage. FIG. 6.—Pupa, last stage. FIG. 7.—Side view of head showing mouth parts. All greatly enlarged. (Original.)

FIG. 1.—MATURE PEAR SHOWING INJURY RESULTING FROM FEEDING OF LARVÆ OF THE PEAR THRIPS. (ORIGINAL.)

FIG. 2.—TOMATO-SHAPED PEARS RESULTING FROM FEEDING BY ADULT PEAR THRIPS IN THE FRUIT BUDS BEFORE BLOOMING. (ORIGINAL.)

INJURY TO PEARS BY THE PEAR THRIPS.

is very noticeable when the fruit is picked in the fall. Although at this time the insects in question have been in the ground three or four months, the injury becomes more apparent with the maturity of the fruit, and the scabbing or scarring shows as the result of the early spring feeding by this species.

The most serious injury to deciduous fruits by the pear thrips is caused, first, by the feeding of the adults; secondly, by the feeding of the larvæ, and thirdly, by the deposition of eggs in the plant tissue by the adults. The effect of this last injury is more apparent upon the fruits of prunes and cherries than upon the other deciduous fruits. Numerous cases have been observed by the writers in both prune and cherry orchards where the trees blossomed heavily and there was promise of the setting of a good crop of fruit, but where practically all the fruit dropped, solely from the effect of having too many eggs deposited in the fruit stems, thus weakening the tissues, and because the larvæ, feeding directly on the fruit and foliage, so weakened the tree that it would not support a heavy crop of fruit. Perhaps the chief injury to cherries is caused by the deposition of eggs in the fruit stems. The long and tender stem of the cherry presents a most favorable place for the deposition of a great number of eggs.

Injury to the various fruits by adults and larvæ is different, but, classed in regard to bud structure, those fruits in which only a single blossom is produced in a fruit bud, such as the almond, apricot, and peach, seem to be less liable to severe injury than are the fruits which which form a cluster of blossoms amd later produce a cluster of fruits, such as pear, prune, cherry, and apple. If the thrips had their choice of food plants, pears would probably be attacked first in the spring and destroyed; also, other things being equal, a given number of thrips would do more injury no doubt in a pear orchard than in a cherry or prune orchard.

INJURY TO PEARS.

The greater injury to pears is caused by the feeding of the adults in the bud clusters before blooming. Coming out of the ground in great numbers in the spring as the fruit buds are swelling, the thrips soon work their way underneath the bud scales and there attack the individual buds. The feeding is not a biting and chewing process, but the thrips, by rasping the tender surfaces in the developing buds with their hardened or chitinous mouthparts, rupture the skin, and the exudation of sap begins. If only a few thrips are present this injury may be slight and the buds may develop and bloom, producing fruit of normal size, although sometimes short-stemmed, or scarred and misshapen. (See Pl. II, fig. 1.) Plate II, figure 2, shows two Bartlett pears which grew from a cluster that was badly injured but not entirely destroyed. Plate III, figure 1, shows a mature Bartlett pear the one-sided appearance of which was caused partly by adults and partly by larvæ. When thrips are more numerous a greater amount of the bud surface is injured, consequently there is a greater loss of sap. If this loss is sufficient to cause the cluster buds to "bleed" (sap to drop from the end), fermentation quickly sets in and the entire cluster is soon destroyed. (See fig. 3, in comparison with fig. 2, which shows the cluster buds developing normally.) In many cases blue molds gain a foothold in this fermenting sap and greatly accelerate the injury, causing complete destruction of all fruit buds. The dead clusters later dry up without opening. (See Pl. III, fig. 1, and compare it with Pl. III, fig. 2, which is from a photograph of the sprayed portion of the same orchard, taken on the same day.) These dead buds may remain on the trees for months unless washed off by rain or blown by winds. The writers have seen many orchards so severely injured that it was difficult to find a single healthy blossom, and the entire orchard from a distance presented at blossoming time a brownish color and dead appearance, due to these blasted buds.

FIG. 2.—Cluster buds of Bartlett pears developing normally. (Original.)

Weather conditions influence to a great extent the destruction following the injury caused by the thrips. For instance, the weather of 1909 in the interior valleys during late February and the first 20 days of March was open and comparatively dry, with more or less wind blowing, giving quick evaporation throughout the day. Many clusters of buds that were kept under observation throughout the season, with from 10 to 20 thrips in the cluster, developed many of their buds and produced fruit, a large percentage of which was first class. During this period for 1910 there was considerable rain and the atmosphere was warm and humid with very light evaporation. From many observations in Contra Costa and Solano Counties it was shown conclusively that in every case where as many as 10 to 15 thrips gained entrance into the bud cluster early in the season, and were left unmolested, the entire cluster was sufficiently injured to prevent the appearance of a single blossom. In 1909 there was greater evaporation, comparatively little of the characteristic bleeding showed at the tips of the buds, and far less of the blue molds appeared in any place. Also the thrips came out of the ground more slowly than in 1910. The latter year thrips were held back to a slight extent by cold wet weather, but once the emergence from the ground commenced, thrips came very rapidly. Then, too, they were more numerous throughout the entire section in 1910 than they were the previous year.

Fig. 3.—Work of the pear thrips on pear at San Jose, Cal. (Original.)

The serious nature of this insect can be understood when it is realized that in a badly infested pear orchard it is far more usual to find from 75 to 150 and often as high as 200 thrips to the cluster than only 10 to 15. Any spraying to be effective must be done before these thrips have remained long, in numbers, inside the bud clusters. A delay of four or five days in spraying the badly infested orchards in the spring of 1910 meant the loss of the entire crop, and in many cases a delay of two to three days for the first application meant a loss of more than half the crop.

In the ability completely to destroy the crop the adult is of more importance than the larva, and in many large orchards the destruction of the developing fruit buds by the adults has been so complete that by the time the trees would normally come into bloom there was left no possibility for a crop of fruit. The larva, together with the injury which has been caused by the deposition of the eggs by the adult, can lessen the prospects of a good crop of fruit after it has apparently set. To secure the best results it is always desirable first to apply efficient treatment against the adult in order to reduce the early injury to a minimum so that the trees may bloom, and later, to make additional treatment against the larvæ. This will usually result in increasing the value of the crop from 10 to 25 per cent for pears and 40 to 50 per cent for prunes. If remedial measures are not successfully used against the adult but only against the larvæ, it is not to be expected that 50 per cent of a crop will be saved; but the additional treatment against the larvæ after the adult treatments have been applied will cause from 10 per cent to 50 per cent more of the crop to remain on the trees. Without taking into account the after effects of migration, good results can be had in pear orchards by spraying against adults alone, if thorough work is done at the proper time.

INJURY TO PRUNES.

Next to the pear, thrips injure prunes most severely; and, as the larger fruit area in the Santa Clara Valley is devoted to this kind of fruit, and since the pear thrips has caused the failure over large areas of the prune crop for several years, growers in the Santa Clara Valley have commonly called this particular species the prune thrips. The large acreage of prunes and the general distribution of the pear thrips over the valley, together with the fact that the majority of the thrips are out before many of the buds of the French prunes have started to spread, make it very evident that these little insects, which are waiting on the outside of the twigs in enormous numbers, will at the first sign of life of the prune buds bury themselves into the very heart of the tenderest parts, and rapidly carry on their work of destruction. The numbers that will get inside of a prune cluster is really astonishing. Many times the writers have, from a single cluster, taken more than a hundred of these little insects feeding upon the tender blossom stems, the tips of the petals, and the stigma and style of the blossoms when they have opened. These parts mentioned seem to be the choice bits for the adults when feeding upon the prunes. The rapidity with which the thrips can destroy the whole year's crop is astonishing. Many a time orchardists have gone into their prune orchards at the time the buds were about ready to spread, and, with only casual observation, have failed to see these minute, dark-colored insects crawling around or at rest upon the twigs and buds. Upon inspecting the orchard four or five days later, expecting it to be in full bloom, they have been astounded to find practically all the buds destroyed, leaving no hope for a crop that year, the entire orchard presenting a brown, burnt appearance, with only a stray blossom now and then, a sight which is well known now to the majority of the prune growers of the Santa Clara Valley. Anyone who has ever seen one of these prune orchards with the burned, browned, and blasted appearance beside another of snowy whiteness will never forget the contrast. (See Pl. IV, comparing fig. 1 with fig. 2.) Again there may be a very severe larval injury on prunes, such as was the case in 1911. Very few adult thrips occurred in comparison with

FIG. 1.—UNTREATED PORTION OF PEAR ORCHARD, SHOWING LOSS OF PEAR BLOSSOMS RESULTING FROM ATTACK OF THE PEAR THRIPS. (ORIGINAL.)

FIG. 2.—SPRAYED PORTION OF SAME ORCHARD, SHOWING TREES IN BLOSSOM. (ORIGINAL.)

INJURY TO PEAR ORCHARDS BY THE PEAR THRIPS.

FIG. 1.—UNSPRAYED PORTION OF PRUNE ORCHARD IN WHICH BLOSSOMS ARE COMPLETELY DESTROYED BY THE PEAR THRIPS. (ORIGINAL.)

FIG. 2.—SPRAYED PORTION OF THE SAME ORCHARD, SHOWING TREES IN FULL BLOSSOM. (ORIGINAL.)

INJURY TO PRUNE ORCHARD BY THE PEAR THRIPS.

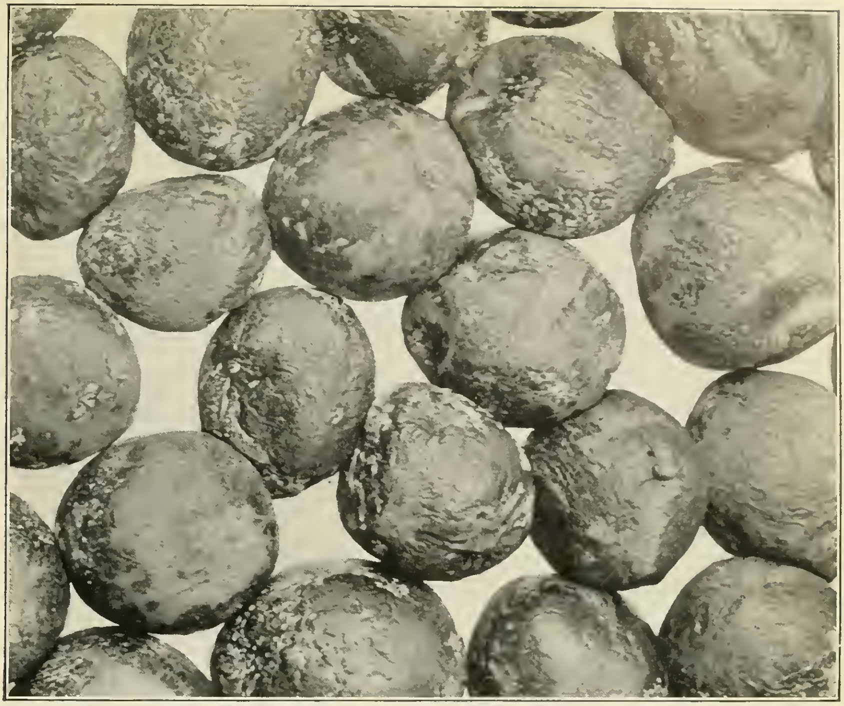


FIG. 1.—PRUNES SCABBED AS A RESULT OF FEEDING BY PEAR THRIPS LARVÆ. (ORIGINAL)

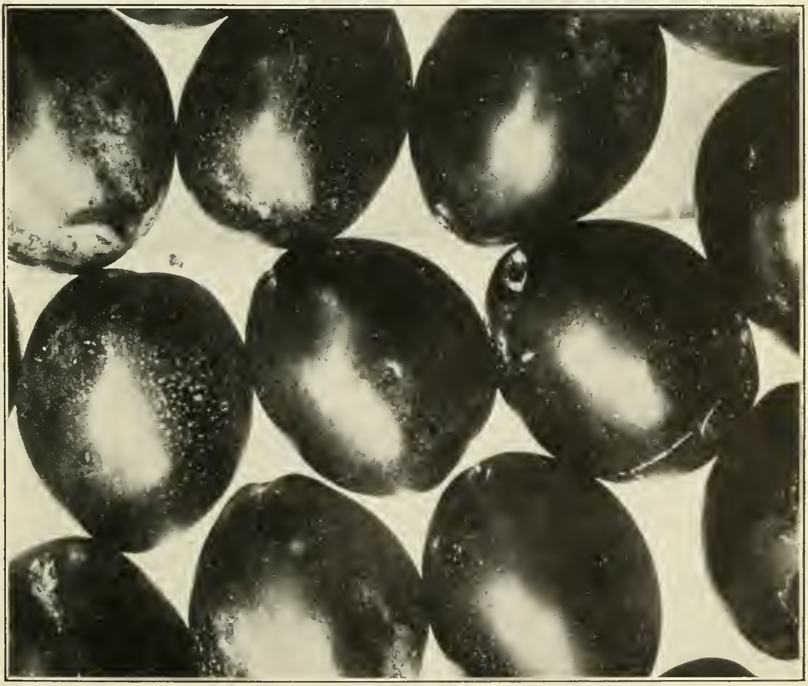


FIG. 2.—NORMAL FRUIT, UNINJURED BY THE PEAR THRIPS. (ORIGINAL.)

PRUNES INJURED AND UNINJURED BY PEAR THRIPS LARVÆ.

1910, and they did not accomplish much injury in the Santa Clara Valley, but larvæ were present in large numbers everywhere and riddled the foliage (fig. 4) and weakened the fruit stems, making the financial loss amount to about half as much as in 1910.

In regard to varieties, Imperial prunes seem to be attacked first and injured, on the whole, more severely than French prunes in the Santa Clara Valley. This may be explained in several ways: For one thing, the acreage of this variety in the Santa Clara Valley is much less than that of the French prunes and the blossoming period is usually about a week or more earlier; then, too, the small develop-

FIG. 4.—Prune foliage riddled by pear thrips larvæ. (Original.)

ing fruit stems of the Imperial prunes seem to be more tender and not so able to withstand the attacks of the thrips as are those of the French prunes. Sugar prunes, which blossom at a period intermediate between the blossoming periods of Imperial and French prunes, are, from a financial standpoint, not injured so greatly as are either of the other varieties. This is partly due to the fact that this variety sets an unusually large amount of fruit and is therefore able to withstand the loss of a considerable portion of it and still produce a fair crop. The scabbing of the prunes on this variety, however, is often so deep as to cause a large exudation of gum and to render a large portion of the fruit unmarketable. Plate V, figures 1 and 2, shows photographs of sprayed and unsprayed prunes, the prunes having been picked from trees when full grown. Robe de Sargent prunes blossom about the same time as French prunes, and are injured to the same extent as that variety.

INJURY TO CHERRIES.

Cherries, as a whole, are not injured so severely by the feeding of a given number of adults as would be the case for the same number of thrips upon pears and prunes, but certain varieties, especially the black cherries, suffer comparatively as much from a monetary standpoint as either pears or prunes. Probably the worst damage accomplished on cherries is by the deposition of eggs in the long fruit stems and in the leaves, and by the feeding of the larvæ upon the foliage. The deposition of eggs in the fruit stems has at times caused a large percentage of the cherry crop to drop, and it is a common sight to see the foliage entirely riddled by the larvæ, thus greatly weakening the trees. Many other instances are on record where the adults have injured the fruit buds to such an extent that only a few blossoms appeared. Late varieties of cherries, such as the Royal Anne, escape serious injury more than the earlier blooming black varieties. Fortunately the manner of bud growth and blossoming of cherries permits effective penetration of different spray solutions more advantageously than is the case with either pears or prunes.

INJURY TO APPLES.

While there are not many instances of great commercial injury to apples, yet individual cases have been known where the adult thrips have killed all of the buds in the cluster except the central one. This was especially noticeable in an orchard of the Newtown Pippin variety in the vicinity of San Jose in 1910. Some small orchards in Sacramento County were rather seriously injured during the same year.

INJURY TO PEACHES.

Following the apple, peaches come next in importance as regards possibility of dangerous injury, the early varieties suffering the greater loss. The more seriously injured varieties are the Muir, Nicol-cling, Crawford, Foster, and Lovel, in order of damage done, injury being more severe on the first two varieties mentioned. On account of the hairy pubescence on the young peach fruits, the thrips prefer to feed upon the nectary glands and the inside of the calyx cups; this prevents proper pollination, and the young fruits drop to the ground a few weeks after the blossoming period. Where the injury has been severe, peaches are sometimes prevented from blooming, and the larvæ feeding upon the tender leaves cause them to curl and become distorted somewhat in the same manner as does peach leaf-curl. Sometimes the larvæ feed on the young fruit, but rarely to the extent of causing any great loss.

INJURY TO APRICOTS.

Apricots have not, as a rule, been injured commercially except in cases where there are a few young trees around home grounds or near an infested pear or prune orchard. They are sometimes injured to about the same degree as peaches, and in some cases isolated trees have been observed which failed to bloom as a result of the work of the thrips. Larval injury to the young fruit is usually more extensive than is the case with peaches and may at times be serious. However, apricots are apparently not favorite breeding places for thrips.

INJURY TO ALMONDS.

Almonds are injured less by the thrips than any of the foregoing fruits. On account of the early blossoming of the trees and the relatively greater amount of exposed leaf surface at the time the thrips are out in numbers, together with the character of the blossom, which is similar to that of the peach, feeding by the thrips very rarely causes much commercial loss in almond orchards.

DESCRIPTION.

EGG.

The egg when first deposited is bean-shaped, translucent white, measuring on the average about 0.416 mm. in length and about 0.166 mm. at its widest part in the middle. (Pl. I, fig. 2.)

Just before hatching it decreases in length, appears swollen, has a slight brownish tint, and is faintly striated longitudinally where the antennæ and legs are folded together. The dark brown spots, the eyes of the young larva, are apparent at one end.

LARVA.

FIRST STAGE (LARVA 1 DAY OLD).

Length 0.646 mm.; width of head 0.166 mm.; width of mesothorax 0.183 mm.; width of abdomen 0.15 mm.; length of antennæ 0.2 mm.; length of antennal segments: I 20μ, II 40μ, III 45μ, IV 100μ. General color translucent white. General shape fusiform. Antennæ, head, and legs large in proportion to the rest of the body, and unwieldy. Antennæ distinctly four-segmented, first segment short, cylindrical; second segment about twice as long as first, oval cylindrical; third segment slightly longer than second, urn-shaped; fourth about as long as rest of joints together, acutely conical. A few very fine inconspicuous hairs present on all joints, more prominent on segment 4; Head subquadrate; eyes reddish brown. Thorax about as long as abdomen, slightly wider. Abdomen gradually tapering, 10-segmented, first eight segments subequal, IX and X longer and more abruptly tapering, with a fringe of long, white, nearly inconspicuous hairs. Legs stout; femora and tibiæ nearly equal in length; tarsi one-jointed, ending in a single black claw. (Pl. 1, fig. 3.)

SECOND STAGE (FULL-GROWN LARVA).

Total length 1.833 mm.; length of head 0.15 mm., width 0.1083 mm.; length of prothorax 0.1833 mm., width 0.2166 mm.; length of mesothorax 0.1833 mm., width 0.466 mm. Length of antennæ 0.2833 mm.; segment I 26μ, II 50μ, III 76μ, IV 66μ, V 14μ, VI 16μ, VII 33μ. Antennæ: Segment I short cylindrical; II obtuse spindle-shaped; III spindle-shaped, about as long as I and II together; IV nearly as long as III, broader than the rest, subconical; V short, narrow cylindrical; VI slightly narrower and longer than V; VII twice as long as VI, narrower and cylindrical. All joints transversely striated and with a few inconspicuous white hairs. General color faintly yellowish white, obtusely fusiform in shape. Body longitudinally and laterally faintly striated. Head quadrate; eyes prominent, dark reddish brown, situated a little in advance of the middle; mouth cone broadly rounded, nearly as long as the head, extending to the middle of the prosternum. Prothorax large, slightly wider than long, diverging posteriorly. Mesothorax and metathorax short and broad, twice as wide as long, subequal, in length about as long as prothorax. Abdomen broad, gently rounded, 10-segmented, broadest at segments V and VI; first eight segments subequal; segment IX distinctly longer, tapering to apex, the posterior edge armed with a circle of strong, short, thick wedge-shaped spines, the two mediodorsal and medioventral ones shorter and smaller; segment X slightly tapering, not quite as long as segment IX. Lateral edges of abdomen finely serrated, also with a few long inconspicuous white hairs which are more prominent on segment X. Legs strong; femora and tibiæ about equal; tarsi one-jointed, ending in a single black claw. (Pl. I, fig. 4.)

NUMBER OF MOLTS; DEVELOPMENT.

When first hatched the larvæ are active and start feeding immediately and soon become more robust. At the end of about seven to eight days they molt into second-stage larvæ, where (see description) they are still more robust and show also other differences. The total time required for the development of the larvæ is about three weeks, although this period is shorter during warm weather.

PUPA.

PREPUPA (FIRST STAGE).

Total length 1.333 mm.; length of head 0.1 mm., width 0.116 mm.; length of prothorax 0.183 mm., width 0.266 mm.; width of mesothorax 0.35 mm.; length of abdomen 0.666 mm., width 0.383 mm. Shape similar to adult; color translucent white, deeply tinted with brown. Head subquadrate, about as broad as long, eyes dark reddish brown. Mouth-cone broadly rounded, extending to about one-half length of the prosternum. Antennæ extending backward on each side of head, apparently four-jointed; first three segments nearly subequal in length, about as broad as long, thick and unwieldy; segment IV about as long as remaining joints, clublike, and tapering to an obtuse point. Antennæ with a few inconspicuous white hairs. Prothorax nearly twice as long as the head, broadly rounded posteriorly. Mesothorax broader; wing pads short, those of first pair of wings extending to distal edge of third abdominal segment. Abdomen 10-segmented, widest at III and IV, segments gradually tapering from there posteriorly. First eight segments subequal, IX and X longer, distal end of IX with broad spines somewhat similar to those of second-stage larvæ but shorter and smaller. Legs stout, similar to those of full-grown larva, whole body with sparse, light-colored, inconspicuous hairs. (Pl. I, fig. 5.)

PUPA (SECOND STAGE).

Total length 1.416 mm.; length of head 0.183 mm., width, 0.166 mm.; length of prothorax 0.166 mm., width 0.25 mm.; width of mesothorax 0.35 mm.; length of abdomen 0.783 mm., width 0.416 mm. Shape similar to adult, which is visible beneath the thin transparent shell. Apparently brownish in color, caused by adult within. Head broader than long; eyes large, dark brown; mouth-cone of adult within extending to posterior edge of prothorax. Antennæ large, cumbersome, laid back on the head and extending past middle of prothorax, four-jointed; I short; II elbowed, about twice as long as I; III short, cylindrical; IV longer than III, sides uneven as knotted club gently tapering to obtuse apex. Joint I of adult is in joint I of pupa, joint II of adult in joint II of pupa, and III of adult within III of pupa; remaining joints of adult within IV of pupa; 3 or 4 white, inconspicuous hairs projecting cephalad from elbow on joint II. Prothorax broader than long. Mesothorax about one and one-half times as broad as prothorax. Wing-pads extending to distal margin of eighth abdominal segment, fore pair not quite so far. Abdomen widest at third and fourth segments, tapering from there to obtuse apex. Posterior edge on ventral side of segment IX with four strong spines resembling a meat fork. This is apparently the cremaster. Legs stout. Entire body with numerous inconspicuous white hairs. (Pl. I, fig. 6.)

ADULT.

Length of head 0.13 mm., width 0.15 mm.; length of prothorax 0.13 mm., width 0.2 mm.; width of mesothorax 0.28 mm.; width of abdomen 0.31 mm.; total length 1.26 mm. Length of antennal segments: I 33μ, II 45μ, III 63μ, IV 54μ, V 33μ, VI 66μ, VII 9μ, VIII 12μ, total 0.31 mm. Color dark brown; tarsi light brown to yellow. Head slightly wider than long, cheeks arched, anterior margin angular, back of head transversely striate and bearing a few minute spines and a pair of very long prominent spines between posterior ocelli. Eyes prominent, oval in outline, black with light borders, coarsely faceted and pilose. Ocelli approximate, yellow, margined inwardly with orange-brown crescents, the posterior ones approximate to, but not contiguous with, light inner borders of eyes. Mouth-cone pointed, tipped with black; maxillary palpi three-segmented; labial palpi two-segmented, basal segment very short. Antennæ eight-segmented, about two and one-half times as long as head, uniform brown except segment III, which is light brown; spines pale; a forked sense-cone on dorsal side of segment III, with a similar one on ventral side of segment IV. Prothorax about as long but wider than head; a weak spine at each anterior and two large, strong ones on each posterior angle; other spines not conspicuous. Mesothorax with sides evenly convex, angles rounded; metanotal plate with four spines near front edge, inner pair largest. The mesonotal and metanotal plates are faintly striate. Legs moderately long, uniform brown except tibiæ and tarsi, which are yellow. Spines on tip of fore and middle tibiæ weak; several strong spines on hind tibiæ. Wings present, extending beyond tip of abdomen, about twelve times as long as wide, pointed at tips; costa of forewings thickly set with from 29 to 33 quite long spines; fore vein with 12 to 15 arranged in two groups of 3 and 6, respectively, on basal half of wing and a few scattering ones on distal part; hind vein with 15 or 16 regularly placed spines; costal fringe on fore wing about twice as long as costal spines. Abdomen subovate, tapering abruptly toward the tip from the eighth segment; longest spines on segments 9 and 10; abdomen uniform brown, connective tissue yellow. (Pl. I, fig. 1.)

SYSTEMATIC POSITION.

The pear thrips belongs to that suborder of the Thysanoptera called Terebrantia, which differs from the other suborder, the Tubulifera, in the possession by the female of a sawlike ovipositor; also, the terminal segments of the abdomen are conical and the wings are not equal in structure, the fore pair being the stronger. The membrane of the wings, also, has microscopic hairs. This species is placed in the family Thripidæ and is separated from the Æolothripidæ in that the antennæ usually have from 6 to 8 segments, the wings usually are narrow and pointed at the tips, and the ovipositor is downcurved. It is placed in the genus Tæniothrips of this family because the body is free from reticulation and the abdomen not closely pubescent; the head nearly or quite as long as wide, with a pair of long bristles between the anterior and posterior ocelli; the cheeks swollen, curving abruptly to the strongly protruding eyes; the antennæ eight-segmented, with the last two segments (the style) shorter than the sixth; the maxillary palpi three-segmented, the prothorax very slightly, if at all, shorter than the head, with two long bristles at each posterior angle; the fore tibiæ unarmed; the bristles on the veins of the forewings not equidistant, and the last abdominal segment of the female conical and without a pair of short, stout bristles on the dorsal surface.

Until recently this species was placed in the genus Euthrips Targioni-Tozzetti, which most American authors had used in the sense of Physothrips and Odontothrips, Tæniothrips and Frankliniella. Hood [1] has recently shown that the name Euthrips Targioni-Tozzetti (1881) was first used in a subgeneric sense as a substitute for the name Thrips, which had been used for a subgenus of Thrips Linné (1758), and that it is consequently a synonym of that genus. The pear thrips he places in the genus Tæniothrips Amyot and Serville, the orange thrips in Scirtothrips Shull, and, partly following Karny,[2] the various other species formerly assigned to Euthrips in the genera Physothrips, Odontothrips, and Frankliniella.

ANATOMY.[3]

OVIPOSITOR.

The ovipositor is attached to the ventral side of the eighth and ninth abdominal segments and is composed of four distinct plates, the under pair attached to the eighth segment and the upper or posterior pair to the ninth abdominal segment. The ovipositor in

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[1] Hood, J. Douglas. On the proper generic names for certain Thysanoptera of economic importance. *In* Proc. Ent. Soc. Wash., v. 14, no. 1, p. 34–44, 1914.

[2] Karny, H. Revision der von Serville aufgestellten Thysanoptera Genera. *In* Zoologische Annalen, Bd. 4, Heft 4, p. 322–344, 1912.

[3] For a description of the mouthparts see discussion under "Manner of feeding and type of mouthparts," p. 11–13.

the pear thrips is curved downward. The passageway between the plates is grooved so that the eggs can pass through readily. The upper edge (of the upper plates) is fitted with sharp sawlike teeth, while the lower plates have similar teeth for most of the way but also bear a number of broad cutting teeth. The end of the ovipositor is sharp and pointed. When this is inserted into the plant tissues, the slit or opening is enlarged by the action of the hard serrate edges of the ovipositor as it is worked up and down by the rather powerful muscles of the abdomen. The ovipositor when not in use is protected in a sheath along the ventral side of the last two segments of the abdomen.

WINGS.

The wings are long and slender, membranous, with a fringe of fine hair upon both the anterior and posterior margins, and are never folded. Both pairs of wings are quite similar and when at rest are laid back flat upon the abdomen, the pairs lying parallel in the Terebrantia. The wings of the family Thripidæ, to which the pear thrips belongs, are slender, and taper from the base to the tip, which is pointed; they bear a general resemblance to sabers. The veins in the family Thripidæ are not so prominent as in the family Æolothripidæ, and only one or two longitudinal veins are present, the cross-veins being very obscure.

FEET.

The legs and feet of thrips form one of the chief characteristics which separate this order from the various other orders of insects. They are composed of the usual parts of an insect leg, namely, coxa, trochanter, femur, tibia, and tarsus. There is nothing unusual in the formation of the first four parts, the femur and tibia usually being quite long and somewhat cylindrical. The tarsus is the most peculiar structure on the leg, and may be either simple or of two segments, and usually ends in one or two claws. In the family Thripidæ, they belong to the former type. The remarkable bladder-like structure, which for many years gave the name Physopoda to this order, is protrusile from the end of the last tarsal segment. It is present in both adults and larvæ. The end of the tarsus is cup-shaped, and into this cup the delicate membranous bladder is attached. When the foot is at rest the bladder is invisible and is withdrawn into the end segment. The bladder is protruded and brought into action when the adult is resting on some surface or walking around. The mechanism of the bladder has been partially worked out by Jordon and Uzel, but as it is somewhat intricate it will not be described here. If a swollen bladder is pricked or ruptured, the blood pours out and the bladder collapses quickly. The blood is probably what causes the protrusion of the bladder. Various agencies have been used in experiments to hinder the thrips in walking about on the surfaces of the plants they are attacking, with the view that if in some way the mechanism of the bladder was affected, either by causticity or by absorption, the bladder would not be able to perform its function, and the insects would fall from any surfaces that were so treated. This has not been successful from the writers' experience, as they have observed on numerous instances thrips crawling around on sticky surfaces, even on tanglefoot, which was to all appearances and to the touch very sticky. This bladderlike formation is probably so delicate that surfaces which appear smooth or sticky or caustic to the naked eye and human touch are rough and uneven to the thrips and are neither adhesive nor caustic. The writers have never seen thrips stuck to any surface by the ends of their tarsi, but only by their bodies, legs, or wings. It is apparent that they are able to walk on practically every kind of surface, especially after this treated surface has been exposed to the atmosphere for a few hours.

LIFE HISTORY AND HABITS.

ADULTS IN SPRING.

EMERGENCE FROM GROUND.

The first form of the pear thrips to be seen by the orchardists during the growing season is the adult (Pl. I, fig. 1), which emerges from the ground during the last winter months and the early spring. The period in which they first appear upon the trees in Santa Clara, Contra Costa, Solano, and Sacramento Counties is variable. Certain sections in each territory are earlier than others and some orchards are in advance of others in regard to blossoming conditions.

In the Santa Clara Valley during the year 1909 the first adult thrips were collected February 15. (See Table IV.) By February 18 they were quite numerous in one of the orchards under observation and were common in all orchards by February 25. Maximum emergence began about February 19 and lasted until March 18. They continued to emerge until the first three days in April. In Contra Costa County first thrips were out at the laboratory February 12 and in the field February 16, emerging in numbers by February 20. Maximum emergence was over by March 15 and all were out by March 27. During the season of 1910 the first thrips taken in the field in Santa Clara County were observed on February 7, while the first in emergence cages appeared on February 9. They were common in the field from February 15 on. Thrips appeared in maximum numbers from the cages (see fig. 5) beginning February 22 and ending March 10, with the last stragglers coming out as late as March 20. The emergence season for 1911 at first gave promise of being very early, as the first thrips were found in the field on January 29 and in the emergence cages February 1; but the heavy rains following in February and March caused it to be very backward, so that thrips were not common in the field until March 14, which was about the time of the true maximum emergence.

In Contra Costa County during the season of 1909 the maximum number of thrips emerged in cages, which were put in the ground in the yard at the laboratory, from February 23 to March 4. (See

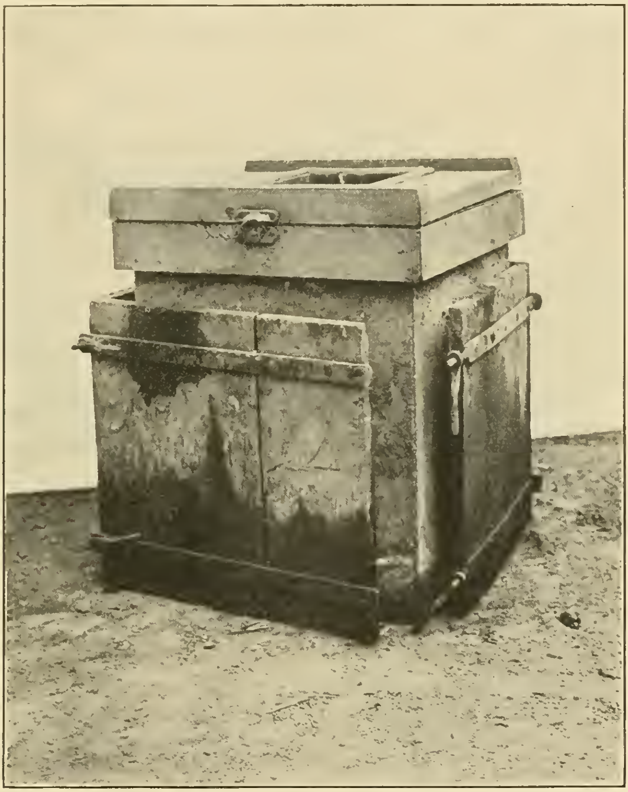

FIG. 5.—Type of soil cage used for soil samples in obtaining emergence records of the pear thrips at San Jose, Cal. (Original.)

Table VI and fig. 7.) In cages placed under trees (see fig. 6) in the field the thrips emerged in maximum numbers from February 26 to March 12 (see Table V and fig. 8). During the spring of 1910 the first thrips found to emerge in the cages at the laboratory were out on February 18 (see Table VI and fig. 9) and in the field cages on February 21, reaching a greater daily emergence by March 1, and continuing to emerge in considerable numbers until March 15, the maximum emergence being March 7 (see Table V and fig. 10). By comparing figures 7 and 8, which show the emergence records for

1909, with figures 9 and 10, showing the record for 1910, it will be seen that the time of emergence in any considerable numbers was much shorter in 1910 than was the case in 1909. No actual daily emergence records were kept in 1911, but no thrips were found in the field until February 18 and then only very few in one early almond orchard. On February 24 a few scattering specimens were found in two pear orchards. Not until March 12 were they appearing in any noticeable numbers, but the emergence was very rapid after this, reaching the maximum between March 15 and 20. The emergence of adults was mostly over by March 30.

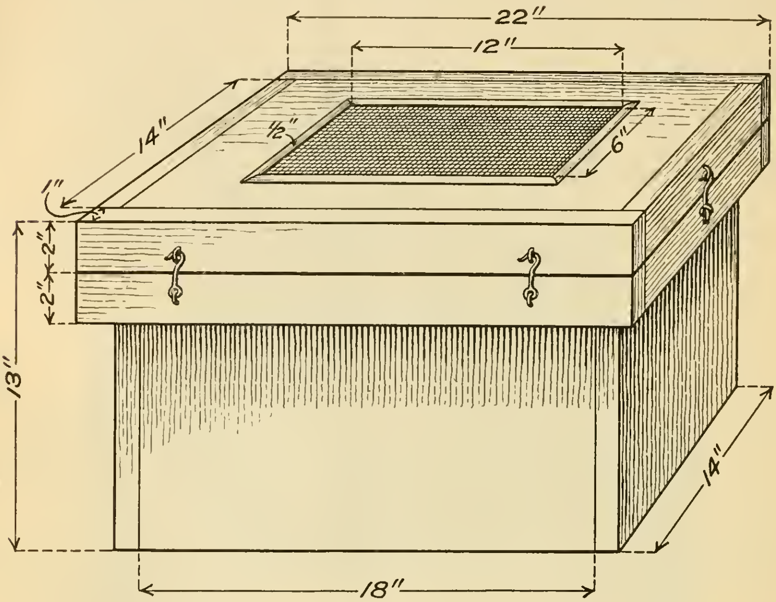

FIG. 6.—Type of wooden cage used for field emergence records of the pear thrips in orchards at Walnut Creek, Suisun, and Courtland, Cal., 1909–10. (Original.)

Emergence records and field observations in the Suisun Valley of Solano County (see Table VII and fig. 11) show that for the season of 1910 thrips came out of the ground in numbers on about the same dates as for Contra Costa County. They were out in numbers in the Courtland district of Sacramento County from two to four days earlier. Further observations in 1911 showed the emergence in these two sections to be about the same time as for Contra Costa County.

Records of the emergence for the years 1909, 1910, and 1911 are summarized in Table IV. From this table it will be seen that in Santa Clara County in 1909 most thrips appeared on March 3 while in 1910 March 4 yielded the highest number, with March 3 and 2 following close behind. The increase in emergence during the season 1909 (fig. 12) and the tapering off in the same year was more gradual

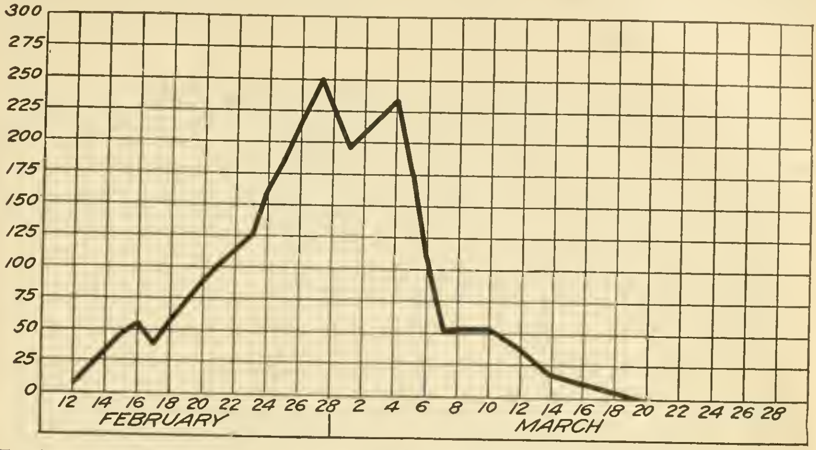

FIG. 7.—Curve illustrating emergence of adult pear thrips at laboratory, Walnut Creek, Cal., 1909. (Original.)

than during the season 1910 (fig. 13). This difference was most probably influenced during the latter season by the temperature.

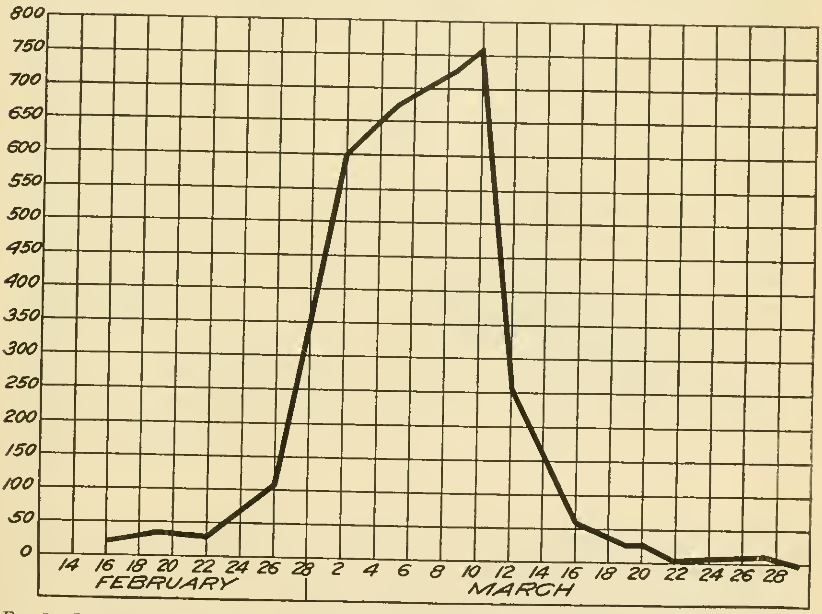

FIG. 8.—Curve showing emergence of pear thrips in cages under trees in field at Walnut Creek, Cal., 1909. (Original.)

RELATION OF EMERGENCE TO TEMPERATURE AND RAINFALL.

The average mean temperature for February and March, 1911, or the two months when practically all of the thrips emerged, was

50.7° F., or about the same as in 1909, and the emergence probably would have been very similar to the emergence for that year but for the abnormal precipitation in February and March, especially in the latter month.

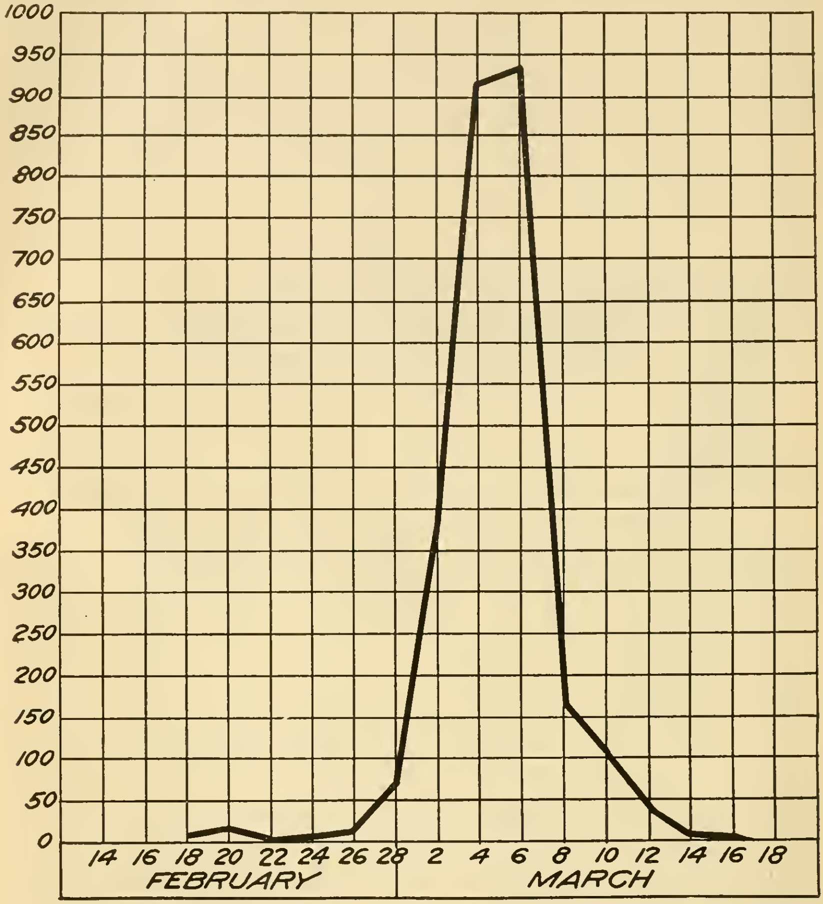

FIG. 9.—Curve showing emergence of adult thrips at laboratory, Walnut Creek, Cal., 1909. (Original.)

TABLE II.—*Mean temperatures for the months of February and March, 1909, 1910, and 1911.*

	°F.
Mean maximum temperature for month of February, 1909	59.2
Mean minimum temperature for month of February, 1909	42.2
Average mean temperature for month of February, 1909	51.0
Mean maximum temperature for month of March, 1909	60.0
Mean minimum temperature for month of March, 1909	40.0
Average mean temperature for month of March, 1909	50.0
Mean maximum temperature for month of February, 1910	58.8
Mean minimum temperature for month of February, 1910	38.5

	°F.
Average mean temperature for month of February, 1910	49.0
Mean maximum temperature for month of March, 1910	66.2
Mean minimum temperature for month of March, 1910	44.5
Average mean temperature for month of March, 1910	55.0
Mean maximum temperature for month of February, 1911	56.5
Mean minimum temperature for month of February, 1911	37.3
Average mean temperature for month of February, 1911	46.9
Mean maximum temperature for month of March, 1911	63.3
Mean minimum temperature for month of March, 1911	46.0
Average mean temperature for month of March, 1911	54.6

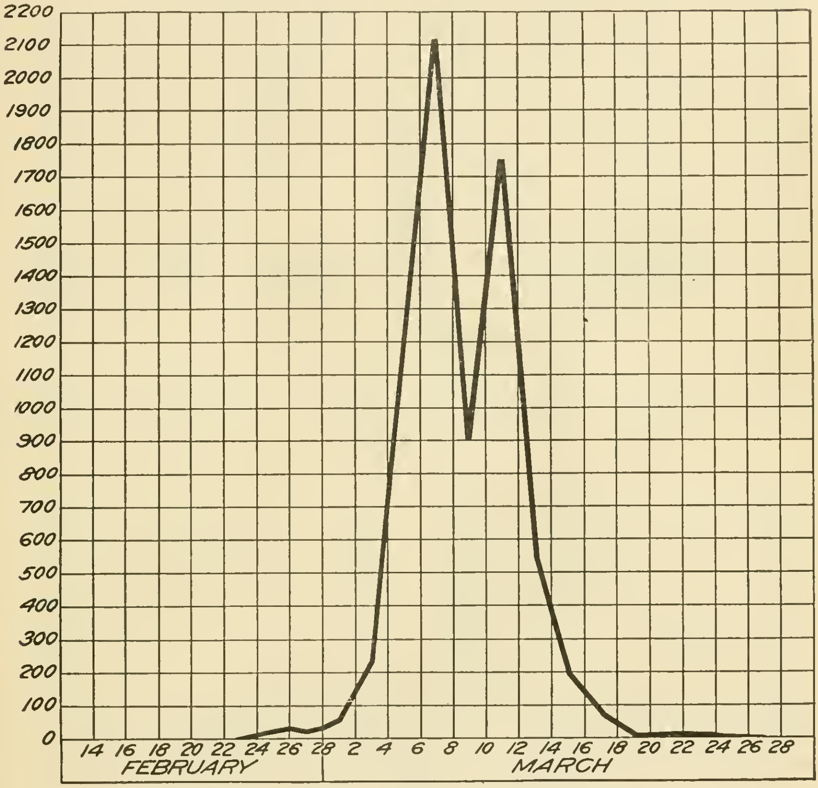

FIG. 10.—Curve showing emergence of adult pear thrips in cages under trees in field, at Walnut Creek, Cal., 1910. (Original.)

It will be seen from the temperature records (Table II) that while February, 1909, had 2 degrees higher average mean temperature than February of 1910, March of 1909 had 5 degrees less average mean temperature than March of 1910, making the average mean temperature for the months in which most of the adults emerged 50.5° F. in the year 1909 and 52° F. in the year 1910. Another factor which held back the emergence greatly the former year was the greater rainfall, the month of February, 1909, having 4.87 inches precipitation while February of 1910 had only 0.83 of an inch.

A comparison of the amount of precipitation for the three years 1909, 1910, and 1911 (see Table III) shows a large amount for 1909,

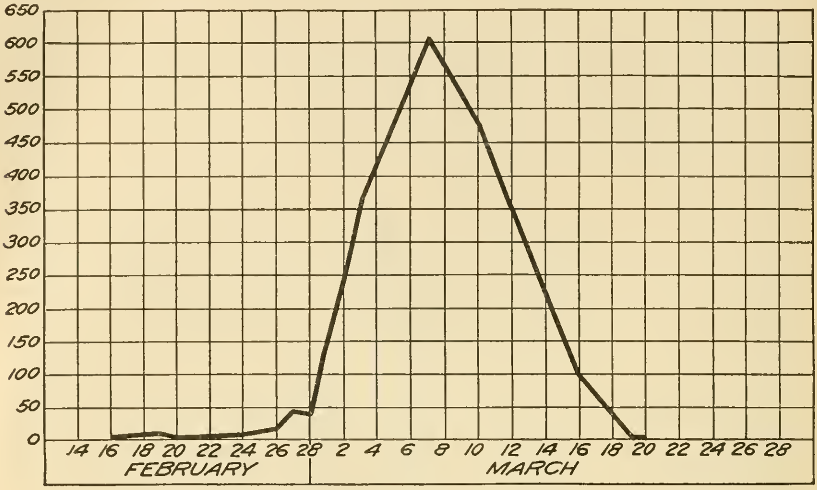

FIG. 11.—Curve showing emergence of pear thrips at Suisun, Cal., 1910. (Original.)

which with the low average mean temperature for the two emergence months caused the emergence to be drawn out. The season 1911 was very abnormal in the large amount of precipitation, especially

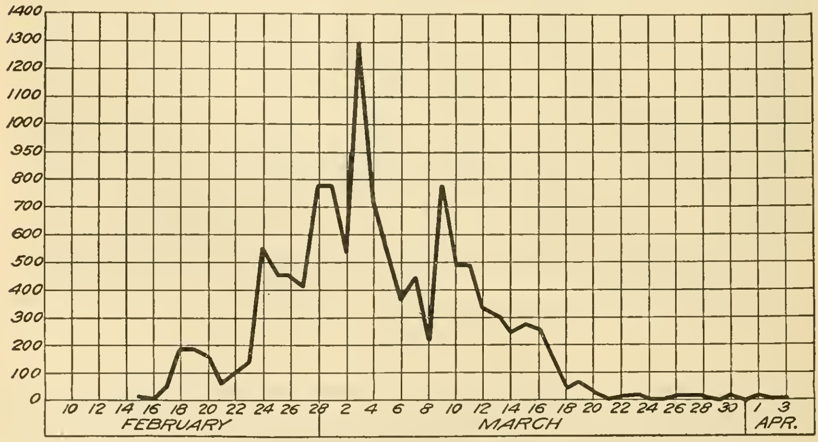

FIG. 12.—Curve showing emergence of pear thrips at San Jose, Cal., 1909. (Original.)

during the latter part of February and early March, causing a late blossoming season, and holding the thrips back to such an extent that comparatively little injury was caused by the adults.

TABLE III.—*Total precipitation for the years 1909, 1910, and 1911 at San Jose, Cal., laboratory.*

Month.	Precipitation in inches.		
	1909	1910	1911
February	4.87	0.83	2.03
March	2.77	2.84	6.26

One curious fact about the emergence for 1911 was the double maximum, one the latter part of February, from the 18th to the 26th, and another from the 8th to the 15th of March. (See Table IV and

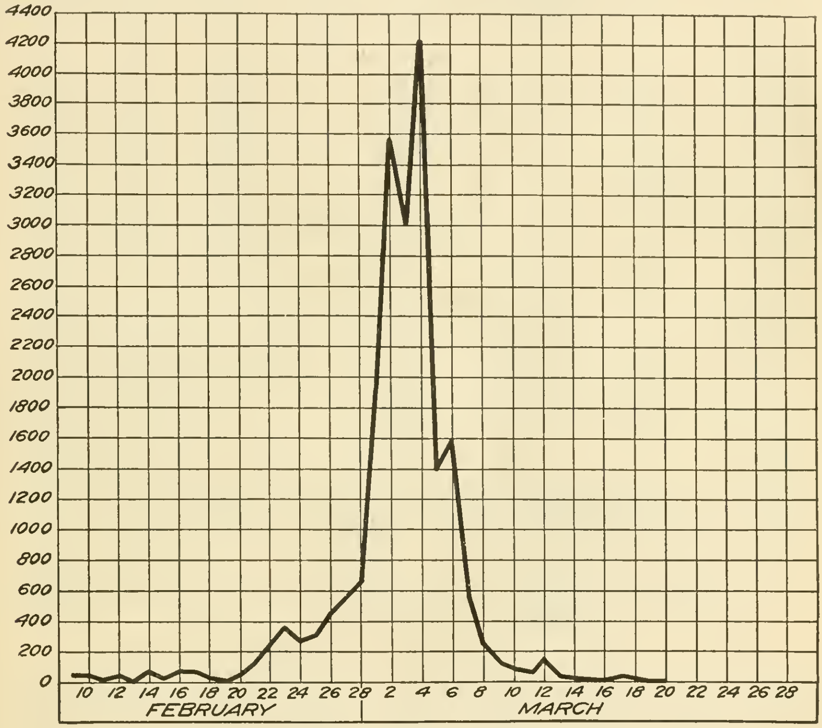

FIG. 13.—Curve showing emergence of pear thrips at San Jose, Cal., 1910. (Original.)

fig. 14.) From February 26 to March 11, inclusive, it rained every day from 0.02 of an inch to as much as 2.45 inches. Probably a number of the thrips which emerged in February were killed by the heavy rains in early March, or at least were not permitted to cause much injury. The pear thrips emerges from the ground during rainy weather, but not in such great numbers as during warm, sunshiny days, which was the case during the latter part of February and the early part of March of the year 1910. Whether the soil is clean or covered with weeds and grass at this time of year influences the time

of emergence by some two or three days. This was particularly noticeable in pear orchards used in cultivation experiments in Contra Costa and Solano Counties. In the plowed portions which were free from weeds, the surface dried out and warmed up more rapidly and thrips came out in numbers and into the trees three days earlier than on the unplowed part of the orchard, which was covered with a rank growth of vegetation. The shading of the soil by the vegetation seems to result in holding the thrips within the ground several days later, or else they spend some time on this succulent growth before going into the trees.

The following tables give the emergence records for the years 1909, 1910, 1911, and 1912 for Santa Clara County (San Jose, Table IV);

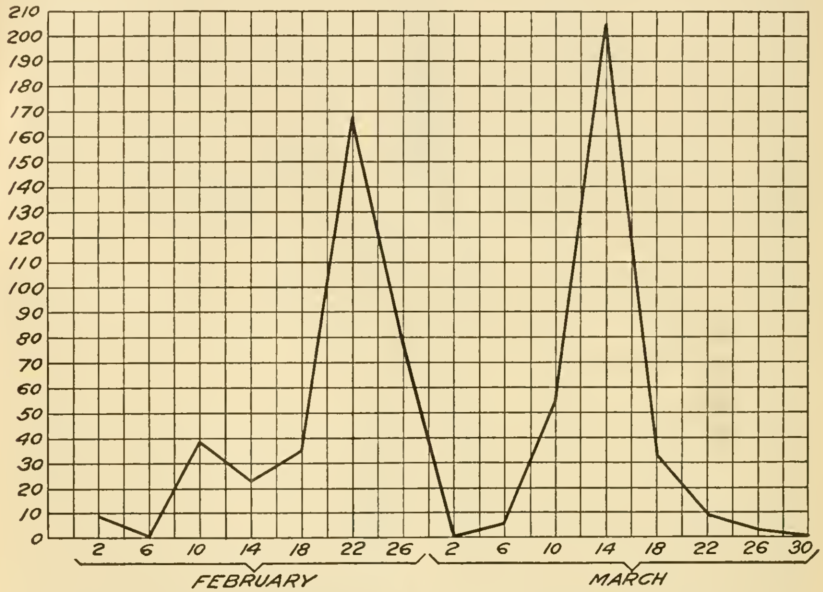

FIG. 14.—Curve showing emergence of pear thrips at San Jose, Cal., 1911. (Original.)

for 1909 and 1910 in Contra Costa County (Walnut Creek, Tables V and VI), and for 1910 in Solano County (Suisun, Table VII). These tables show the total number of thrips emerging on the given dates from soil in the cages. For the San Jose records, all the cages containing soil samples from infested prune orchards were placed in the ground at the laboratory. For the records in Contra Costa and Solano Counties, part of the cages were brought to the laboratory and buried in the ground and part were left in the ground under the trees in infested orchards. (See fig. 6 for type of cage used for the field emergence records in the northern counties.) It was not possible to take the emergence every day, but, so far as possible, counts were made at regular intervals.

TABLE IV.—*Total emergence of pear thrips from all the cages kept at the laboratory at San Jose, Santa Clara County, Cal., during 1909, 1910, 1911, and 1912.*

Date	Number of thrips emerging in 1909 from 18 cages.	Number of thrips emerging in 1910 from 18 cages.	Number of thrips emerging in 1911 from 4 cages.	Number of thrips emerging in 1912 from 4 cages.	Date.	Number of thrips emerging in 1909 from 18 cages.	Number of thrips emerging in 1910 from 18 cages.	Number of thrips emerging in 1911 from 4 cages.	Number of thrips emerging in 1912 from 4 cages.
Feb. 1	0	0	2	1	Mar. 9	776	144	1	366
2	0	0	7	1	10	497	100	32	442
3	0	0	0	0	11	498	73	54	81
4	0	0	0	0	12	338	179	71	83
5	0	0	0	1	13	313	45	56	161
6	0	0	1	5	14	248	20	22	313
7	0	0	28	3	15	279	7	17	433
8	0	0	5	6	16	259	4	9	239
9	0	25	1	9	17	152	20	2	158
10	0	18	4	9	18	42	7	4	596
11	0	16	1	9	19	61	2	0	209
12	0	16	22	21	20	28	2	0	144
13	0	4	0	15	21	2	0	3	106
14	0	88	0	33	22	6	0	6	114
15	18	22	11	37	23	13	0	1	103
16	0	27	5	65	24	3	0	1	68
17	52	34	2	104	25	2	0	0	52
18	192	33	17	242	26	3	0	1	39
19	192	14	62	490	27	7	0	1	38
20	169	23	41	384	28	7	0	0	61
21	75	62	32	325	29	0	0	0	17
22	119	129	33	440	30	2	0	0	14
23	135	375	25	422	31	0	0	0	14
24	552	272	26	515	Apr. 1	3	0	0	28
25	459	297	18	800	2	0	0	0	19
26	444	455	8	504	3	1	0	0	9
27	414	574	0	762	4	0	0	0	7
28	781	657	0	1,694	5	0	0	0	4
29	....	....	....	1,169	6	0	0	0	4
Mar. 1	781	1,975	0	1,721	7	0	0	0	26
2	535	3,592	0	276	8	0	0	0	5
3	1,299	3,011	2	284	9	0	0	0	3
4	711	4,217	4	399	10	0	0	0	1
5	508	1,402	0	400	11	0	0	0	1
6	362	1,595	0	585	12	0	0	0	0
7	438	539	1	1,227					
8	219	275	21	1,052	Total..	11,998	20,350	660	17,968

TABLE V.—*Emergence of pear thrips from cages placed in ground under trees in pear and prune orchards, Walnut Creek, Contra Costa County, Cal.*

Date.	Number of thrips emerging.	Date.	Number of thrips emerging.
1909.		1910.	
Feb. 13	0	Feb. 21	1
16	20	23	4
19	37	25	23
22	30	27	36
26	110	Mar. 1	56
Mar. 2	615	3	237
5	679	5	1,170
10	752	7	2,110
12	273	9	892
16	65	11	1,773
20	33	13	557
22	4	15	198
27	11	17	71
		19	3
		21	6
		27	5

TABLE VI.—*Emergence of pear thrips from soil samples taken from orchards in December and January and kept in cages at laboratory, Walnut Creek, Contra Costa County, Cal.*

Date.	Number of thrips emerging.	Date.	Number of thrips emerging.
1909.		1910.	
Feb. 12	3	Feb. 18	11
15	42	20	16
16	56	22	0
17	38	24	12
18	56	26	30
20	89	28	75
23	125	Mar. 2	377
25	185	4	918
27	246	6	937
Mar. 1	196	8	165
4	237	10	114
7	51	12	47
10	52	14	0
14	13	16	4
19	0		
22	0		

TABLE VII.—*Emergence records of pear thrips for Suisun, Solano County, Cal., 1910.*

Emergence of thrips from cages placed in ground under trees in orchards, Suisun, Cal.		Emergence of thrips from soil samples taken from orchards in December and January and kept in cages at laboratory, Suisun, Cal.	
Date.	Number of thrips emerging.	Date.	Number of thrips emerging.
Feb. 17	3	Feb. 16	1
19	0	17	3
21	0	18	2
23	0	19	6
25	1	20	1
27	20	21	1
Mar. 1	47	22	4
3	121	23	2
10	484	24	5
16	1	25	11
		26	11
		27	14
		28	41
		Mar. 1	105
		2	247
		3	243
		7	612
		12	357
		16	82
		19	8

The latest dates on which adult thrips were collected in the field were about the same for the years 1909 and 1910, the last ones being found from April 15 to April 25. In 1911 living adults were found as late as the middle of May. They were very scarce, however, after May. The number of living adults as a rule decreases rapidly after April 1.

The time adults will feed before they begin ovipositing varies. Those individuals which emerge early and which do not have a suitable place for ovipositing will feed from 15 to 20 days before placing any eggs, while individuals which emerge at a later date, as, for instance, from March 5 to 20, do not as a rule feed more than one or two days before depositing eggs. Individuals which were taken from emergence cages and placed in mica chimneys were observed ovipositing the day following their emergence. It is possible that in the field thrips begin depositing eggs more quickly on certain varieties of fruits than on others. This would be governed very largely by the presence or absence of available tissue suitable for oviposition. For this reason on the early blooming varieties of cherries thrips probably feed for a shorter time before oviposition commences than is the case with other fruits.

PERIOD OF EGG LAYING FOR INDIVIDUALS.

The egg-laying period for individuals does not usually last for more than three weeks. Individual thrips confined in mica chimneys on March 5, 1910, did not deposit any eggs after the latter part of March. The full period of egg laying for the entire brood throughout all the infested areas extends from about February 20 until near April 10, or a period of six to seven weeks.

LENGTH OF LIFE OF ADULTS.

Adult thrips confined in vials without food lived on an average three days, while those confined in vials with food lived about two weeks. Adult thrips confined on the trees within mica chimneys lived from three weeks to one month. The length of life of individuals in the field has not been observed accurately, but probably ranges in duration from three weeks to one month and a half.

RELATION OF EMERGENCE TO BLOSSOMING OF TREES.

The emergence period extends from early February to early April and is closely associated with the blossoming periods for the different varieties of fruits. Budding and blossoming of the different fruits is as follows: Almond buds begin to swell during the latter part of January and early February, and this variety of fruit is in full bloom between February 8 and 24. Apricots show first blossoms from February 12 to 23, and most varieties are in full bloom by from March 3 to 10. Peaches show first blossoms about February 23 and many varieties are in full bloom from March 8 to March 17. Black Tartarian cherries reach full bloom by March 15 to 20, while the Royal Anne variety has not at that time opened its buds. French prune buds are beginning to swell between March 8 and 11 and first blossoms appear by March 20. They are usually in full bloom between

March 26 and April 8. The Sugar and Imperial varieties precede the French by about one week. Bartlett pear buds begin to swell the last of February or the first of March, the first clusters usually spreading from March 10 to 15 and are in full bloom for quite an indefinite period between March 20 and April 10. Pears, prunes, and cherries, which are spreading their bud clusters just after the maximum numbers of thrips are coming from the ground, are the fruits most seriously injured by the pear thrips.

MIGRATORY HABITS.

Evidences of the migratory habits of the pear thrips have been noticed at times during the last three or four years. However, no definite observations concerning their migration had been made until the year 1910. Hitherto it had been noted that in some orchards the adults were very numerous early in the season and doing extensive damage. Later observations at an interval of four or five days showed very few adults present, and the entire orchard had the characteristic browned and burnt appearance. It was quite evident that after destroying all the fruit buds the thrips had migrated to other orchards in search of food.

It was possible to obtain more definite knowledge regarding migration in the year 1910 than had heretofore been known, for the reason that the thrips were unusually numerous throughout all the infested areas that year and weather conditions were such that practically the entire brood emerged from the ground in a few days. Also, following their emergence in great numbers, the weather was sufficiently warm that the destruction of the fruit buds in the various orchards was accomplished in much shorter time than is usually the case. Observations so far indicate that thrips migrate in swarms only on bright, warm days. Numerous instances of supposed migration were mentioned to the writers at various times during the season, the reports stating that the pear thrips were flying in swarms, but most of the cases reported lacked authentic evidence to bear them out, such as the saving of specimens. However, in the afternoon of March 28, 1910, the junior author drove out from San Jose toward Saratoga and had great difficulty in keeping both hands on the reins on account of the great numbers of thrips which, flying through the air, filled his eyes and covered his clothes. The prevailing direction of the wind on this day was not observed; no distinct migration or swarm was noted, however, although individuals were numerous flying across the road and could be readily seen when the observer looked toward the sun. They were more numerous on roads running north and south, and extended over a territory of 4 or 5 miles; they were the most numerous at the west end of Hamilton Avenue and along the San Tomas and Santa Clara and Los Gatos Roads.

On March 30, 1910, still more definite information was gained, and this is probably the most unique record of thrips migration which has yet been taken. The day was bright and rather warm and ended with the evening warm and a gentle breeze blowing from the south. Mr. E. L. Fellows, who was in Santa Clara on this day, started home about 5 o'clock in the afternoon. About 5.15 p. m., out on the Saratoga Road, he noticed a number of small, black insects which covered his face and hands, his hat and clothes, and got into his eyes. When he was one-fourth of a mile north of Meridian Corners he met the thickest part of the swarm, which appeared literally like a black, glistening, seething mass moving up and down like heat waves. From this place the insects became less numerous as he went toward home, which he reached about 6 p. m. He thought the swarm to be about 8 miles long and 4 miles wide, from 4 to 15 feet high, moving at the rate of about 10 miles per hour northward toward San Francisco Bay. As he was not sure concerning the identity of this insect, he gathered several hundred specimens in a paper bag and submitted them to the junior author for identification. They were found to be the pear thrips, *Tæniothrips pyri*. This same swarm was noticed by the junior author and by several fruit growers, but they did not have the opportunity to view the whole swarm as did Mr. Fellows.

Continued observations during the season of 1910 showed that the usual time for migration was from 3 to 6 p. m. on bright, warm days during the latter part of the period of maximum oviposition, which was also about the time many orchards have been so badly injured that the trees will not bloom.

This migratory habit is undoubtedly influenced chiefly by a desire for a new supply of food, better places for deposition of eggs, and suitable weather conditions, especially the temperature. The direction in which thrips will migrate depends upon the direction the wind is blowing, and the distance at which suitable feeding places are found.

No distinct migration of the whole brood has ever been observed, such as is the case with some species of Orthoptera. The migration from certain badly infested orchard localities has been influenced, without doubt, by the early destruction of the fruit buds in these orchards. Many instances are known where thrips are numerous and their injury severe in an orchard one year and not very numerous the succeeding year, but they are usually highly injurious again the third year. This phenomenon is more noticeable in pear than in prune orchards, due probably to the fact that a pear orchard in which all fruit buds have been destroyed is poor feeding ground for both adults and larvæ and reproduction is at the minimum under such conditions. This reappearance in damaging numbers the third year makes it evident that the orchardists should not allow their orchards to go untreated. It should be noted that the years 1907 and 1910 were the only seasons in which the pear thrips migrated to any great extent. No migration was known in the season of 1911, although it was watched for.

MANNER OF REACHING TREE TOPS FROM GROUND.

Most of the adults when emerging probably crawl around for a while on the ground until their wings get sufficiently dry and then fly up into the tree. Some, however, must undoubtedly crawl up the trunk, as a few have been caught by tanglefoot bands. This, however, can not be used as a method of control, since very few go up this way; moreover, the thrips would not be caught unless the bands were renewed every day or so, because the bands do not remain sufficiently sticky after a short exposure to the atmosphere.

REPRODUCTION.

According to Bagnall [1] an example of the male pear thrips was found by him among some specimens of this species taken from plum blossoms at Evesham, England, and submitted to him by Mr. Collinge, director of the Cooper Research Laboratory at Berkhamstead. His only description is that "It is much smaller than the female and the wings considerably overreach the tip of the abdomen." This is the first report of the existence of the male of this species, and in California very extensive observations by the writers and other workers have failed to show a single male, and the only type of reproduction known is by parthenogenesis. In all of the life-history experiments to secure data upon the length of the egg stage individual females were taken directly from the emergence cages and isolated. It is highly probable that practically all of the eggs which are deposited hatch, as no sterile eggs have ever been found.

OVIPOSITION.

Moulton [2] states that he has observed the adult in ovipositing to make first a hole in the epidermis of the plant tissue with the mouth before depositing the egg. Repeated observations by the writers of a large series of adults during oviposition have failed to

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[1] Bagnall, Richard S. A contribution to our knowledge of the British Thysanoptera (Terebrantia), with notes on injurious species. *In* Jour. Econ. Biol., v. 4, no. 2, p. 33-41, July 7, 1909. See p. 39.

[2] Moulton, Dudley. The Pear Thrips (*Euthrips pyri* Daniel). U. S. Dept. Agr., Bur. Ent., Bul. 68, pt. 1, rev., p. 7, Sept. 20, 1909.

show a single one going through this procedure. The usual method as shown by observations during the season of 1910 is as follows: The female starts the ovipositor into the tissue by working the abdomen up and down, gradually forcing the ovipositor its full length into the tissue. After this is done the thrips remains quiet for a short interval while the egg is passing out between the plates of the ovipositor. When finished, the female vibrates her antennae and jerks out the ovipositor. The prevailing posture during the whole period of oviposition is with the abdomen arched and the legs spread apart wider than when in walking. The average time required for the operation by a number of individuals observed during the season of 1910 ranged from three to five minutes. After depositing an egg the female usually resumes feeding for a short interval, but some individuals have been observed to deposit two and three eggs in succession without any feeding between times. The number of eggs that a female can deposit in a day is probably not over seven or eight, as the abdominal cavity is not large enough to hold more at one time.

EGGS.

PLACE OF DEPOSITION.

The eggs are always placed in the tenderest portions of the plant tissue, such as exposed blossoms, fruit stems, leaf stems, ribs of the leaves (preferably the midribs), and the leaf edges. Still others are placed in the young fruits. The pear thrips apparently prefers to oviposit upon cherries if a cherry tree is at hand, as the fruit and leaf stems, on account of their length and tenderness, offer excellent places for oviposition without making it necessary for the thrips to move over a large area. However, the small prunes and the stems, as also the stems and midribs of the young leaves of both prunes and pears, are well suited for oviposition by this species. The counts in Table VIII were taken upon leaf stems and fruit stems of French prunes and show the comparative percentage of eggs deposited in each; they also show the inability of the different spray mixtures to kill the eggs within the plant tissues, as these stems in question had been sprayed two days previously with a combination of tobacco extract and distillate emulsion.

TABLE VIII.—*Comparative percentage of eggs deposited in fruit stems and leaf stems of French prunes, San Jose, Cal., season of 1910.*

No. of observation.	Number of eggs in leaf stems.	Number of eggs in fruit stems.	No. of observation.	Number of eggs in leaf stems.	Number of eggs in fruit stems.
1	2	7	44	1	12
2	1	10	45	0	11
3	5	5	46	7	8
4	0	12	47	3	8
5	2	13	48	7	9
6	1	6	49	5	11
7	3	8	50	2	9
8	0	8	51	12	9
9	0	8	52	10	11
10	1	9	53	2	9
11	1	8	54	3	10
12	2	10	55	7	12
13	2	4	56	0	6
14	5	6	57	9	10
15	3	10	58	5	10
16	2	11	59	12	4
17	0	5	60	5	11
18	3	12	61	0	17
19	3	10	62	6	9
20	1	8	63	2	13
21	0	6	64	4	9
22	0	3	65	5	12
23	3	10	66	8	6
24	1	9	67	0	7
25	1	5	68	11	8
26	2	13	69	8	9
27	1	10	70	5	16
28	1	5	71	9	7
29	1	9	72	3	8
30	2	8	73	2	9
31	0	16	74	2	7
32	2	8	75	9	11
33	2	4	76	17	8
34	1	15	77	6	10
35	0	9	78	11	4
36	0	11	79	12	8
37	1	7	80	9	14
38	4	19	81	8	9
39	7	16	82	2	8
40	2	13	83	1	11
41	5	7	84	0	11
42	3	12			
43	3	9	Total...	299	786

It will be seen from this table that the average number of eggs placed within fruit stems of prunes is more than twice the number placed in the leaf stems. In pears a very large proportion of eggs is placed in ribs and veins of leaves and a comparatively smaller percentage in the fruit stems.

FIRST EGGS.

The first eggs that were noticed in the vicinity of San Jose and in Contra Costa County were placed about March 10 for the season of 1909, while most eggs were being placed about March 15 to 25, and the last eggs in early April. The first eggs were deposited in 1910 in the field about March 9, while maximum oviposition was from March 18 until about April 2. The last eggs were observed to be placed in the field toward the middle of April. In the interior counties, especially Sacramento and Solano Counties, eggs were being deposited in large numbers by March 15, and continued to be deposited in numbers until the latter part of March, a few being found in early April.

LENGTH OF EGG STAGE.

Moulton[1] records the length of the egg stage to be approximately four days, but detailed observations during the season of 1910 at San Jose show it to be considerably longer. The length of the egg stage was first ascertained by inclosing twigs with paper bags before thrips emerged so as to get no outside infestation. Later, when thrips were ovipositing in the field, a considerable number of adults were placed in mica chimneys which had been specially constructed to fit over the twigs in such a manner as to give them as nearly natural conditions as possible, and to permit the eggs to remain in living plant tissue because they usually dried out when the twigs were removed from the tree. These chimneys were made by sewing pieces of strong white cloth in the shape of tubes about 5 or 6 inches long and gluing one end of a cloth tube thus made to each end of the mica chimney. When placed upon the tree, ends of the cloth were tied securely around the twig so that no insects could get in from the outside. The thrips kept for oviposition remained in the cages over night and were removed the next day. To make sure that none would remain in to continue ovipositing, new cages were placed on the twigs in each case. Table IX shows the length of the egg stage.

TABLE IX.—*Length of egg stage of the pear thrips, San Jose, Cal., 1910.*

Cage No.	Date deposited.	Date hatched.	Number of eggs hatched.	Length of egg stage.	Average mean temperature.	Prevailing weather.
				Days.	° *F.*	
I	Mar. 10	Mar. 16	25	6	56	Cloudy.
		17	6	7	57	Do.
		18	9	8	58	Do.
		19	8	9	57	Do.
		20	3	10	57	Do.
		22	10	12	52	Do.
		23	3	13	52	Do.
		24	1	14	52	Do.
II	Mar. 10	Mar. 16	13	6	56	Cloudy.
		17	27	7	57	Do.
		18	30	8	58	Do.
		19	35	9	57	Do.
		20	8	10	57	Do.
III	Mar. 10	Mar. 16	27	6	56	Cloudy.
		17	4	7	57	Do.
		18	9	8	58	Do.
		19	14	9	57	Do.
		20	10	10	57	Do.
		22	4	12	52	Do.
		23	1	13	52	Do.
		24	1	14	52	Do.
IV	Apr. 7	Apr. 14	3	7	55	Clear.
V	Mar. 29	Apr. 5	1	7	56	Clear.
		8	1	10	56	Do.
		10	1	12	56	Do.
VI	Mar. 29	Apr. 7	2	9	56	Clear.
		9	4	11	56	Do.
		10	1	12	56	Do.
		12	1	14	55	Do.

[1] Op. cit., p. 8.

TABLE IX.—*Length of egg stage of the pear thrips, San Jose, Cal., 1910*—Continued.

Cage No.	Date deposited.	Date hatched.	Number of eggs hatched.	Length of egg stage.	Average mean temperature.	Prevailing weather.
				Days.	° *F.*	
VII	Mar. 29	Apr. 3	1	5	56	Clear.
		8	1	10	56	Do.
VIII	Mar. 29	Apr. 7	1	9	56	Clear.
		8	7	10	56	Do.
		9	3	11	56	Do.
		10	4	12	56	Do.
IX	Mar. 29	Apr. 2	1	4	57	Clear.
		6	1	8	56	Do.
		7	1	9	56	Do.
		8	4	10	56	Do.
		10	4	12	56	Do.
		14	1	16	55	Do.
X	Apr. 6	Apr. 12	1	6	54	Cloudy.
XI	Apr. 6	Apr. 13	1	7	54	Cloudy.
XII	Apr. 6	Apr. 13	2	7	54	Cloudy.

SUMMARY.

Number eggs deposited.	Time required for incubation.	Number eggs deposited.	Time required for incubation.
	Days.		*Days.*
1	4	34	10
1	5	7	11
66	6	24	12
44	7	4	13
49	8	4	14
61	9	1	16

For the 296 eggs under observation, the maximum length of the egg stage was 16 days, and the minimum 4 days, making 8.3 days the average time required for incubation.

The eggs of the pear thrips are undoubtedly affected by temperature conditions, but rainy weather as compared with clear weather seems to make no difference when the mean temperature is the same, as all eggs are embedded in the moist plant tissue and do not require additional moisture from the atmosphere.

It is evident that all of the eggs are not in the same stage of development at the time they leave the abdomen of the female, since eggs deposited upon the same day ranged from 4 to 16 days in the length of the egg stage. An examination of the average mean temperature for the various cages shows usually several degrees less mean temperature for a long egg stage in comparison with a short egg stage.

The maximum and minimum temperatures influencing the different lots of eggs are given in Table X.

TABLE X.—*Maximum and minimum temperatures during period of incubation for eggs of the pear thrips, San Jose, Cal., 1910.*

Date.	Maximum temperature.	Minimum temperature.	Date.	Maximum temperature.	Minimum temperature.
	° F.	° F.		° F.	° F.
Mar. 10	73	44	Mar. 28	64	40
11	72	48	29	69	40
12	57	48	30	76	41
13	71	44	31	78	43
14	68	49	Apr. 1	70	45
15	70	44	2	63	43
16	70	53	3	66	46
17	69	54	4	75	41
18	62	50	5	67	46
19	61	48	6	65	46
20	60	51	7	64	40
21	57	47	8	66	45
22	61	46	9	66	47
23	57	39	10	61	51
24	60	37	11	56	47
25	59	44	12	66	46
26	57	44	13	72	41
27	51	42	14	74	41

NUMBER OF EGGS DEPOSITED BY A SINGLE FEMALE.

Up to the season of 1910 only conjectures had been made as to the number of eggs a single female would deposit, but by taking individuals as soon as they emerged and placing them separately upon twigs in the mica cages described under the heading "Length of egg stage," the total progeny of a single female was ascertained—approximately, therefore, the total number of eggs possible for one individual to deposit. Each individual was allowed to remain undisturbed on the twigs inside the cage. After the eggs hatched the larvæ were removed and counted, yielding the following total number: Cage 1, 155 larvæ; cage 2, 146 larvæ; cage 3, 142 larvæ; cage 4, 99 larvæ; cage 5, 117 larvæ. The maximum number of eggs laid is 155, the minimum 99, and the average 131.8. This is probably close to the average number of eggs that would be deposited by a single female out in the field, although some few long-lived individuals would perhaps exceed 200 eggs.

DEPTH EGGS ARE DEPOSITED IN TISSUE.

The eggs are deposited within the plant tissue immediately underneath the outer epidermis and are inclosed by the tissue. The places where they have been deposited can readily be found with the aid of a hand lens because of the little swellings on the stems and by the scars left where the ovipositor had been inserted into the plant.

LARVÆ.

FIRST APPEARANCE.

The very first larvæ appear on almonds, apricots, and the early plums, usually about the 1st of March. Larvæ begin to hatch on prunes and pears the middle of March and usually are in maximum numbers in the interior valleys of Contra Costa, Sacramento, and Solano Counties the last of March and the first 10 days of April, while the maximum number in Santa Clara County appear the first 15 days of April and the last ones in all the infested regions are found some time in early May.

TIME SPENT IN FEEDING.

The time spent in feeding, or the period required for the larvæ to obtain their growth, is from two to three weeks, for individuals. For the whole brood—that is, from the time the first larvæ are found on any variety of fruit to the time the last ones are found in the trees—a period of about two months and a half is spent, from the latter part of February to the early part of May.

MOLTS.

After the larvæ have hatched and fed for some seven or eight days they shed their skins, becoming more robust, and ovoid in shape, and in this form they continue until they molt again into the prepupal stage while in the ground. After the larvæ have molted the first time they remain upon the tree from ten days to two weeks before becoming full grown and dropping to the ground. The total time spent upon the tree is from two to three weeks.

LEAVING TREES AND ENTERING GROUND.

On leaving the trees the larvæ do not crawl down but either fall or are knocked off by rains or shaken off by winds. A large number fall with the dropping calyces. Numerous instances were recorded in the year 1910 in which heavy rains knocked off large numbers of larvæ, some of which reached their full growth by feeding upon miner's lettuce, which was at the time the only vegetation growing in this orchard; but many of these immature larvæ were quite small and failed to reach full growth, which is partly responsible for the smaller number of adults in some sections the following year, 1911. The young and only partially grown larvæ that fall off the trees and do not come in contact with any weed or grass in the orchard mostly perish. Only the full-grown larvæ that fall to the ground in cultivated orchards work their way into soil Larvæ that fall off normally do not ascend the trees again, but in some cases in cherry orchards where foliage was near the ground on the trunks of the trees many of the larvæ were noted to crawl back to lower foliage. This would not be likely to occur on pears or prunes, where there is little or no foliage near the ground.

HABITS OF LARVÆ IN THE GROUND.

After the larvæ have pentrated the soil to a sufficient depth they hollow out for themselves a small oblong cell, the inner surface of which is a hard, smooth wall, the cell proper being about one-half inch long. These cells are made for safe places in which the larvæ may pupate or transform to adults. It is here they spend most of the year.

DEPTH TO WHICH LARVÆ GO IN THE GROUND.

The depth that larvæ will penetrate the ground depends largely upon the type of soil. Practically all of the larvæ go below the 3 or 4 inches of a loose topsoil mulch and establish themselves at various depths in the harder soil below. The depths at which larvæ are found in soils vary from 1 to 26 inches. Both of these are extremes and very rarely contain many thrips. In Contra Costa, Solano, and Santa Clara Counties from 50 to 95 per cent of the thrips do not go below 9 to 10 inches, the gravelly soil having the highest percentage of the larvæ nearest the surface. Some of the sedimentary soils along the Sacramento River are very open and porous—a recent alluvial containing a great deal of decaying vegetable matter. The larvæ in such soil may go much deeper, and in many cases they were found in numbers 24 to 26 inches below the surface when none could be found above this depth. In other cases where these light soils have a good heavy sod, thrips have been found in large numbers from 1 to 3 inches below the surface in the cells constructed among the grass roots.

DEPTH TO WHICH LARVÆ GO IN DIFFERENT SOILS.

An absolutely definite statement as to how deep larvæ will go in the various soils, such as gravelly, sandy, sandy loam, sediment loam, and adobe, can not be made, and only comparisons can be given from samples taken from these various soils. On account of the local character of thrips infestation it is important, when one is trying to ascertain the depth of most of the larvæ in an orchard, that several samples be taken, to insure accuracy. The samples should come not only from different parts of the orchard but also from various distances and locations in the vicinity of the same trees. Soil samples for determining the number of thrips per square foot and the depth to which the larvæ go in the soil should be taken at about 2 to 4 feet from the base of the tree.

The samples from which the records given in Table XI were made were taken by sinking galvanized-iron cages into the soil and removing them to the laboratory. The cages had a sliding fourth side which could be be removed so that each layer could be examined by cutting off the desired thickness and sifting the dirt upon a piece of black paper. The average depth to which larvæ will penetrate in gravelly and sandy loam soils is usually less than in heavy sedimentary loam. In those soils which incline toward the adobe type and in the distinctly adobe soil the larvæ usually go deeper. On account of the cracking of this latter type of soil as it dries out in the spring, and the texture, which is such as to prevent the making of a perfect soil mulch, suitable places for making the cell are not found so near the surface. In soils which can be worked readily except in cases of silt deposits or an abnormal amount of vegetable matter below the surface, very few larvæ, as a rule, penetrate to an unusual depth below the surface; for this reason practically all the soils in the Santa Clara Valley that are badly infested by thrips are such as render possible the obtaining of practicable results from early fall plowing. Table XI shows the comparative depth of larvæ in a number of samples of soil taken from 10 orchards in Santa Clara County. While no sandy soil is present, these samples represent fairly well the different types of soil of the Santa Clara Valley.

TABLE XI.—*Comparative depth of larvæ of the pear thrips in various soil samples, Santa Clara County, Cal.*

Number of layer.	Depth.	Richmond orchard.		Hume orchard.		Landon orchard.		Johnson orchard.		Harkins orchard.		Curry orchard.		Bogen orchard.		Arthur orchard.		Sorosis orchard.		F. Cottle orchard.	
		Heavy clay loam.		Gravelly loam.		Sedimentary loam.		Heavy clay loam near adobe.		Heavy clay loam near adobe.		Heavy sandy loam.		Heavy clay loam.		Heavy clay loam.		Sandy loam.		Sedimentary loam.	
		4 samples.		4 samples.		10 samples.		2 samples.		8 samples.		4 samples.		6 samples.		4 samples.		4 samples.		4 samples.	
		Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.
	Inches.																				
4....	3–4	0	0	171	9.92	0	0	1	0.50	6	50.81	0	0	......	......	3	1.02	......	......	17	2.51
5....	4–5	4	3.33	295	27.01	249	8.41	16	8.64	32	5.15	2	1.50	3	0.80	7	3.41	1	0.79	89	15.65
6....	5–6	17	17.50	393	49.21	518	25.92	79	49.45	54	12.47	23	18.79	29	8.62	7	5.80	14	11.90	134	35.34
7....	6–7	39	50.00	240	63.13	829	53.94	81	89.40	136	30.89	7	24.06	39	19.14	34	17.40	55	55.55	148	57.19
8....	7–8	29	74.17	261	78.26	501	70.87	5	91.91	168	53.68	39	54.13	45	31.27	91	48.46	25	75.39	101	72.13
9....	8–9	21	91.66	235	92.46	305	81.18	10	96.96	103	67.62	11	61.66	71	50.40	85	77.47	6	80.16	132	91.72
10....	9–10	7	97.50	58	95.82	168	86.85	3	98.98	74	77.64	48	97.76	58	66.04	42	91.84	8	86.50	45	98.26
11....	10–11	3	100.00	47	98.55	172	92.67	2	99.49	67	86.70	3	100.00	41	77.09	17	97.61	9	93.65	7	99.29
12....	11–12	......	......	17	99.54	87	95.27	0	99.49	40	92.14	......	......	26	84.09	4	98.98	6	98.41	2	99.59
13....	12–13	......	......	8	100.00	21	96.59	0	99.49	30	96.20	......	......	25	90.84	3	100.00	1	99.20	1	99.89
14....	13–14	......	......	......	......	76	98.88	0	99.49	15	98.24	......	......	17	95.40	......	......	0	99.20	1	100.00
15....	14–15	......	......	......	......	33	100.00	1	100.00	13	100.00	......	......	12	98.65	......	......	1	100.00	......	......
16....	15–16	......	......	......	......	......	......	......	......	......	......	......	......	4	100.00	......	......	......	......	......	......
Total number of larvæ....		120	......	1,725	......	2,959	......	198	......	738	......	133	......	370	......	293	......	126	......	677	......
Average number of larvæ per square foot........		120	......	1,725	......	1,183	......	396	......	369	......	133	......	247	......	293	......	126	......	677	......

In Contra Costa County the greater portion of the orchard area is on the distinctively adobe soil. It is a noticeable fact that the larvæ penetrate this soil to a greater depth than they do the hard gravelly soils, probably owing to the greater prevalence of cracks. An examination of Table XII, which is the record of the results of soil examinations from five pear orchards and one prune orchard during the winter of 1908–09, shows that all of the larvæ in the hard gravelly soils were within 8 inches of the surface, while in the adobe soil only 79 per cent were found at this depth, the other 21 per cent being between 8 and 13 inches below the surface.

TABLE XII.—*Comparative depth of larvæ of the pear thrips in various soils near Walnut Creek, Contra Costa County, Cal.*

Pear and prune orchards.					
Anderson, F. A. Bancroft, and Whitman (pear), and Jones (prune) orchards. Heavy loam to adobe.				Wescott and H. H. Bancroft (pear) orchards. Hard, sandy, gravelly soil.	
Number of layer.	Depth.	24 samples.		12 samples.	
		Number of thrips.	Per cent above.	Number of thrips.	Per cent above.
	Inches.				
2	1–2	0		3	3.33
3	2–3	0		3	6.66
4	3–4	0		9	14.44
5	4–5	76	10.33	18	36.66
6	5–6	276	47.83	33	73.33
7	6–7	152	68.70	18	93.33
8	7–8	82	79.98	6	100.00
9	8–9	48	86.23	0	
10	9–10	32	90.57	0	
11	10–11	42	96.28	0	
12	11–12	24	99.55	0	
13	12–13	4	100.00	0	
Total number of larvæ		736		90	
Average number of larvæ per square foot		123		30	

AREA AROUND DIFFERENT TREES IN WHICH THRIPS ARE MOST NUMEROUS.

The area around trees in which thrips are most numerous would usually be within a radius of 6 to 8 feet of the base in prune orchards where the trees are from 22 to 24 feet apart. Under prune trees which are from 18 to 20 feet apart, and where the branches overlap, the area infested will be more uniform, and more thrips will be present midway between the rows than nearer the base, as such trees, growing close together, usually do not have so many smaller limbs in the center of the tree as nearer the end of the branches. Pear trees are more upright and compact in growth; hence the greater percentage of the larvæ are near the trunk of the tree, and in the average Bartlett pear orchard most of the larvæ in the ground are within a radius of 2 to 3 feet of the base of the tree.

TIME SPENT AS LARVÆ IN GROUND.

The time spent by larvæ in the ground before pupating varies. The minimum time is about 2 months, with a maximum of about 8 months, while most of the larvæ will spend about 5 to 6 months within the soil before pupating. Of many examinations of soil samples in Contra Costa and Solano Counties no larvæ were found after November 29; all had pupated prior to this time.

PUPÆ.

STAGES.

As soon as the white larva gets ready for transformation it sheds its skin and develops into what is called the prepupa, which is also white and resembles somewhat the full-grown larva, although also having some features of the adult. In this stage the legs resemble slightly the legs of the adult and the short wing pads extend to about the end of the third or fourth abdominal segment. The antennæ in this stage do not project over the back, as in the case of the pupa or second stage, but project latero-caudad. The exact length of time spent in this prepupal stage has not been ascertained, but from observations made upon other Thysanoptera by the writers this stage is usually very short and in the pear thrips probably does not last more than a week or 10 days before the prepupal skin is shed and the insect passes into the second pupal stage or real pupa.

TIME OF FIRST, MAXIMUM, AND LAST PUPATION.

The earliest pupæ are found during the month of May, and these are very rare. It is possible that these will form late-emerging adults, but more than likely they are premature larvæ that are sickly or infected with some fungous organism which causes them to develop prematurely. All of these early pupæ probably die and fail to reach the adult form. A few pupæ can be found the latter part of July, and there is a gradual increase in numbers through August and September. During the month of October, however, pupation reaches its maximum and may continue through November and into December, by which time it has practically ceased.

Samples taken from orchards in July and August show some pupæ, while sometimes large numbers of samples taken from the same orchards in September fail to show the presence of any. Table XIII shows the relative number of early pupæ and of larvæ found in the Santa Clara Valley during the summer of 1909. Two samples of soil were taken from each orchard for each examination.

TABLE XIII.—*Comparative number of pupæ and larvæ of the pear thrips found in the soil during July and August, 1909, San Jose, Cal.*

Landon and Cottle prune orchards.					
Sample Nos.	Date examined.	Larvæ.		Pupæ.	
		Number.	Per cent.	Number.	Per cent.
	1909.				
30–33...	July 15	556	99	66	1
34–37...	20	127	100	....	....
38–41...	28	67	86	11	14
42–45...	Aug. 3	44	94	4	6
46–49...	17	22	100	....	....
50–53...	17	165	87	22	13
54–57...	23	65	80	13	20
58–61...	23	93	82	18	19

The time of pupation varies considerably with different orchards; for instance, in orchards where irrigation is practiced in the early fall, pupation probably starts at an earlier date than in orchards where this custom is not followed. Furthermore, from a number of examinations made the past two years it seems evident that pupation begins earlier in those orchards having a heavy sedimentary soil than in orchards which have a light, gravelly soil. Fall plowing would necessarily be more effective upon orchards which have a gravelly soil on account of this habit of late pupation, which would enable the owners to wait until the fall rains have started before plowing, and also because a larger number of thrips are near the surface.

EFFECT OF WEATHER CONDITIONS UPON PUPATION.

It is hardly probable that temperature conditions affect the length of the pupal stage of the pear thrips very greatly, since the ground does not freeze in the winter, except in the Eastern States, and the mean temperature at 6 to 9 inches below the surface for the year around is probably more even than it is above the ground. An early, wet fall would probably cause the thrips to pupate earlier than would be the case in a dry season.

The time spent in the pupal stage varies from one to four months, while the normal time for most of the pupæ is about two months.

ADULTS IN WINTER.

The first adults appear in the ground in late October, the number increasing gradually until December to early January, by which time practically all pupæ have transformed to adults. The time spent in the ground as adults before emerging and appearing on the trees varies from a minimum of one month to a possible maximum of five months, averaging, however, about three months.

SEASONAL HISTORY.

Adult thrips first appear in early February upon the fruit buds and continue to emerge until in the early part of April, appearing in maximum numbers from February 22 to March 10, thus covering the entire period of swelling of buds and blossoming of trees. By the time the fruit buds have swollen sufficiently to separate slightly the bud scales at the tip the adults force their way within, feeding upon the tenderest parts of the buds. Egg laying usually begins when the first leaf surface or fruit stems are exposed, depending somewhat upon the variety of fruit attacked. First oviposition usually occurs the latter part of February and the last toward the middle of April, while maximum oviposition occurs from about March 10 to April 1. The majority of eggs are deposited in the fruit stems, young fruit, and leaf stems, and require from 4 to 16 days to hatch, averaging about 8 days.

By the time Bartlett pear and French prune trees are breaking into full bloom the adult thrips have done practically all of the injury they are able to accomplish. Injury by adult thrips is distinctly associated with the fruit buds before blossoming.

Larvæ first appear in numbers toward the latter part of March and can be found upon the trees up to the middle of May. They appear in maximum numbers from April 1 to April 15.

The larvæ feed upon the foliage and young fruit, causing on the latter the well-known thrips scab, and individuals remain on the trees for two to three weeks in attaining their growth, the entire brood of larvæ requiring 8 to 10 weeks from the first-appearing to the last-disappearing individuals.

All of the larvæ have dropped from the trees by the middle of May and penetrated the soil to a depth of from 1 to 26 inches, depending upon the type and condition of same, in most cases the majority being within 8 to 9 inches of the surface.

Sometimes in July a few larvæ transform into the tender pupæ, and by October the pupæ are in maximum numbers, the last larvæ pupating in November. The pupal stage lasts from one to four months, the usual time being about two months.

Early in February adults, which, in some instances, have remained as such for several months in the ground, appear upon the trees and wait for the first opening of buds, when they begin the work of destruction.

NATURAL ENEMIES.

Probably no single order of insects of such great economic importance has so few effective natural enemies as the Thysanoptera. This is partly due to the small size of the insects belonging to this order, their manner of working, their great activity, their unique life history, and the fact that not more than six or seven species in the order have ever accomplished any great economic damage. Practically all the attempts to control the thrips by artificial means have been within the United States. Of the few natural enemies of Thysanoptera that do exist, the most important seems to be *Triphleps insidiosus* Say, which feeds upon thrips by impaling them upon its beak and sucking out the juices. *Megilla maculata* De G., chrysopid larvæ, and syrphid larvæ have also been found feeding upon thrips. Uzel [1] has found *Triphleps minutus* L. preying on thrips and credits Heeger with the finding of *Scymnus ater* Kug., *Gyrophaena manca* Er., and some fly larvæ feeding in the same manner. Hinds [2] mentions having found some small scarlet acarid attached to the membranous area of the body of *Anaphothrips striatus* Osborn. Uzel [1] and Quaintance [3] have both found eggs of nematode worms within the bodies of adult thrips. J. C. Crawford [4] in December, 1911, gives a short account of *Thripoctenus russelli* Crawford, a new internal parasite of Thysanoptera and later Russell [5] publishes a more complete account of the life history and habits of this parasite. The first recorded host of *T. russelli* was *Heliothrips fasciatus* Pergande, but it has been reared from *Thrips tabaci* Lind. and *Frankliniella tritici* Fitch. Its oviposition has been observed in *Heliothrips femoralis* Reuter and *H. haemorrhoidalis* Bouché. Great hopes were entertained by Mr. Russell for its colonization among related injurious Thysanoptera.

Of plant parasites, Thaxter [6] has taken an Empusa fungus destroying a species of thrips in the larval, adult, and pupal stages, and Petit [7] and Hinds [8] have found a fungus which they thought was causing some of the species of thrips to die.

No effective natural enemy has been found preying upon the pear thrips. Moulton [9] mentions some raphidians feeding upon the younger forms of this species and has also found a species of ant killing individuals. He mentions [10] a fungus which he regarded as parasitic during the season of 1905 and 1906, but the last three or four years have failed to show that any appreciable amount of benefit has been derived from it. Very little of the fungus has been observed during the years 1908, 1909, and 1910.

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[1] Uzel, Heinrich. Monographie der Ordnung Thysanoptera. Königgrätz, 1895, 472 p. 10 pl. See p. 362.

[2] Hinds, W. E. Contribution to a Monograph of the Insects of the Order Thysanoptera Inhabiting North America. *In* Proc. U. S. N. Mus., vol. 26, p. 119, 1902.

[3] Quaintance, A. L. The Strawberry Thrips and the Onion Thrips. Fla. Agr. Exp. Sta., Bul. 46, p. 79–114, 12 figs. July, 1898.

[4] Crawford, J. C. Two new Hymenoptera. *In* Proc. Ent. Soc. Wash., v. 13, no. 4, p. 233–234, 1911.

[5] Russell, H. M. An Internal Parasite of Thysanoptera [*Thripoctenus russelli*]. U. S. Dept. Agr., Bur. Ent., Tech. Ser. no. 23, pt. 2, p. 25–52, figs. 11, Apr. 27, 1912.

[6] Thaxter, Roland. The Entomophthoreae of the United States. *In* Mem. Boston Soc. Nat. Hist., v. 4, no. 6, p. 134–201, pls. 14–21, Apr., 1888. See p. 151, 172, 174, pl. xvii, figs. 200–219.

[7] Pettit, Rufus H. Some Insects of the Year 1898. Mich. State Agr. Coll. Exp. Sta., Bul. 175, p. 341–373, 20 figs, July, 1899. See p. 343–345, figs. 1, 2.

[8] Loc. cit.

[9] Moulton, Dudley. The Pear Thrips (*Euthrips pyri* Daniel). U. S. Dept. Agr., Bur. Ent., Bul. 68, pt. 1, rev., p. 14, Sept. 20, 1909.

[10] Op. cit., p. 15.

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 184

Contribution from the Bureau of Entomology, L. O. Howard, Chief,
April 8, 1915.

(PROFESSIONAL PAPER.)

THE HUISACHE GIRDLER.[1]

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INTRODUCTORY.

The huisache tree is one of a variety of trees and shrubs horticulturally called "wattles" and is probably a native of Texas, although it occurs in Asia, Australia, and to a certain extent in Africa. The flowers furnish the perfume known as frangipanni and the plant is cultivated in southern Europe for the manufacture of perfume. The pods are valuable in tanning and dyeing and the plant is used as an ornamental for the formation of hedges and for shade throughout the Tropics. The bright yellow flowers which are produced in abundance and are large in comparison with those of other acacias render it one of the most beautiful of flowering shrubs of this type. The tree reaches a maximum height of about 35 feet, with a trunk diameter of about 1 foot when properly trained. The trunk is short, the branches somewhat drooping and widespreading, forming a beautiful roundheaded tree with light-green feathery foliage.

The huisache tree (*Acacia farnesiana*) of the Southwest has a number of insect enemies, but none is so injurious as a girdler which often damages young trees in such a way as to eradicate them for a time, completely severing them a few inches above ground.

During the summer of 1910, while the writer was engaged, under the direction of Dr. F. H. Chittenden, in the investigation of insects that attack the pecan, this insect, which may be called the huisache girdler, first came under observation. It seemed advisable to keep the species under surveillance in its attacks on the huisache, since it was not known but that pecan trees in the vicinity might become a center of attack at any time, for the reason that two near relatives, *Oncideres cingulata* Say and *Oncideres texana* Horn,

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[1] *Oncideres putator* Thom., a beetle of the family Cerambycidæ.

Note.—This bulletin contains a technical description of an insect infesting the huisache tree of the Southwest. The form of injury is discussed and methods of control are given.

75718°—15

were known to injure the pecan. In any case, the huisache was of sufficient value to warrant a thorough investigation of the girdler, as it holds front rank as a shade tree in the newly developed country in the lower Rio Grande Valley. When the girdlers were first found and observed at work they were exceedingly abundant, and there was no difficulty in collecting a large number in a very short time. A shipment was immediately made to Washington, where Dr. Chittenden identified the insect as *Oncideres putator*, and later Mr. E. A. Schwarz confirmed this determination. Since the girdler was first observed, its work has become more conspicuous each successive season. In 1913, over the infested area as a whole, the beetles appeared in lesser numbers, but in places they were more abundant and the damage was greater than at any time during the four years previous. This would indicate that climatic conditions were not altogether responsible for the decrease, as some of the infested areas were near and in close proximity to one another. It is believed that natural enemies were responsible in part, if not wholly, for the lack of uniformity in distribution in 1913.

The beetles (Pl. I) possess powerful mandibles and saw with ease branches 1¾ inches in diameter, completely severing them from the main body of the tree. The eggs, as with other twig girdlers, are deposited in the severed portion of the branch, and never below where it is girdled. The writer has observed as many as 63 girdled branches from one tree, some of which measured 40 millimeters in diameter, the average ranging from 22 to 35 millimeters. (See Pl. II.) No other girdler has been observed to prune branches of this diameter, and all near relatives with which we are acquainted prune or girdle much smaller branches. *Oncideres putator*, unlike some girdlers, does not work so much in pairs, but is often found in colonies as well. The girdling is usually begun a few inches from the base of the branch selected for oviposition or just above where it joins the body of the tree or larger branch, though cases have been observed where the attack was directed to the middle of the branch. At times after the sawing has been begun by one female beetle others will begin depositing eggs before the girdling is very far advanced, apparently with little fear that the branch will not be completely girdled in due time. Young trees are often girdled only a few inches above ground, but where large trees are adjacent the beetles seem to prefer attacking the branches instead. (Pls. III, IV.)

In view of the fact that in the lower Rio Grande Valley and other parts of the Southwest where much development in farm lands is in progress, and where the huisache is oftentimes the only shade tree found upon a farmer's premises, it is thought advisable to present here for publication the life history, food plants, and habits of this girdler, with suggestions for control.

DESCRIPTION.

The beetle belongs to the family Cerambycidæ, subfamily Lamiinæ, tribe Onciderini. One of the chief characteristics of the tribe is that the front coxal cavities are angulated on the outer side and closed behind; the antennæ of the male are much longer than the body, and those of the female are as long as the body.

THE BEETLE.

With this species the antennæ of both sexes are longer than the body, and there is little difference in the antennal length in each sex. The beetles (Pl. I) are brownish gray in color, and measure in length from 18 to 24 millimeters, the average length being 22 to 23 millimeters. The mesothorax is wider than in some other species of this genus and measures on an average from 7 to 9 millimeters. In a short time after emerging from the pupal case the beetles lose more or less of their brownish-gray appearance, as the hairs covering their blackish elytra or wing covers are rubbed off, causing them to appear darker in color. This species, like its near relatives, has about one-third of its wing covers more grayish than the remaining two-thirds. The posterior margin of this densely clothed grayish band extends slightly behind the meson. The head and thorax are clothed with brownish hairs a little more densely than the wing-covers when the beetle first emerges, but it gradually loses this brownish tinge for a darker one. Ordinarily there seems to be little difference in size between the males and females. While the writer has found specimens of each sex at times smaller than those of the other, it is evident that the size depends upon the nourishment afforded the larva during its growth, as this in all probability has a bearing on the size of the adult beetle.

After making a large number of measurements it was found that about 60 per cent of the females were from 1 to 1½ millimeters longer than the males, so we may say that the body of the female is slightly larger than that of the male, although this will not be noticed by the collector without the use of a lens. On the other hand, the collector may differentiate the sexes by observing the distal joint or segment of the antennæ; in the males this segment is about twice as long as that of the female. The length of this segment in the males runs from 4 to 6½ millimeters, while in the females the average will be from 2 to 3 millimeters. This method of distinguishing the sexes does not require the use of a lens, but one should be careful to see that the distal joint has not been broken off, in the male particularly, for then the specimen will not be very different to the unaided eye from the female. The antennæ of both sexes are quite easily broken, and during the latter part of the mating season it is difficult to find a perfect specimen.

THE EGG.

The egg is of a cream-white color when first deposited and from 2.5 to 3 millimeters long, with a diameter about one-third the length. It is elliptical ovate in shape, with one end slightly more pointed than the other. Just before hatching the color changes to yellowish white, when, with the aid of a lens, the embryonic larva is visible.

THE LARVA.

The newly hatched larva, after consuming enough of the eggshell to liberate itself therefrom, measures about 2.8 millimeters in length and is of a pale white color, with the exception of the head, which is light brown, with the mandibles darker.

THE PUPA.

The pupa is white and ranges from 18 to 22 millimeters in length. Later the color changes to light brown, and just before transformation takes place to chocolate brown. When observing the pupa with a lens the dark-colored spines on each segment are very pronounced, particularly on the dorsum.

DISTRIBUTION AND HISTORY.

Oncideres putator has been recorded from the States of Arizona, New Mexico, and Texas, and from Mexico. The species is probably more injurious in Mexico than in this country, as it appears very susceptible to cold, and since breeding takes place during the fall and winter months it apparently could never become a serious pest in localities were the temperature drops much below freezing.

The following note was published in 1912[1] at the meeting of the American Entomological Society, October 24, 1912:

> Dr. Skinner exhibited specimens of *Oncideres putator* and said that the species was probably rare in collections. If there is a single brood, this might be accounted for by their late appearance. The specimens were taken by Rehn and Hebard in Sycamore Canyon, Baboquivari Mountains, Pima County, Ariz., October 6, 9, 1910; Palo Alto ranch, Altar Valley, Pima County, Ariz., October 6, 10, 1910; Tucson, Ariz., October 3, 4, 1910; and Snyders Hill, Pima County, Ariz., October 11, 1910.

Exact localities have also been recorded by Bates:[2] Orizaba and Jalapa, Mexico; Belize, Honduras; San Juan, Guatemala; Bugaba, Panama. Mr. Schwarz records the species from Arizona, New Mexico, and western Texas, and the writer has taken it in southern Texas and at Matamoras, Mexico. The species is native to Central America and has come into the United States from Mexico. There are very few data to be found on *Oncideres putator*, while a considerable amount

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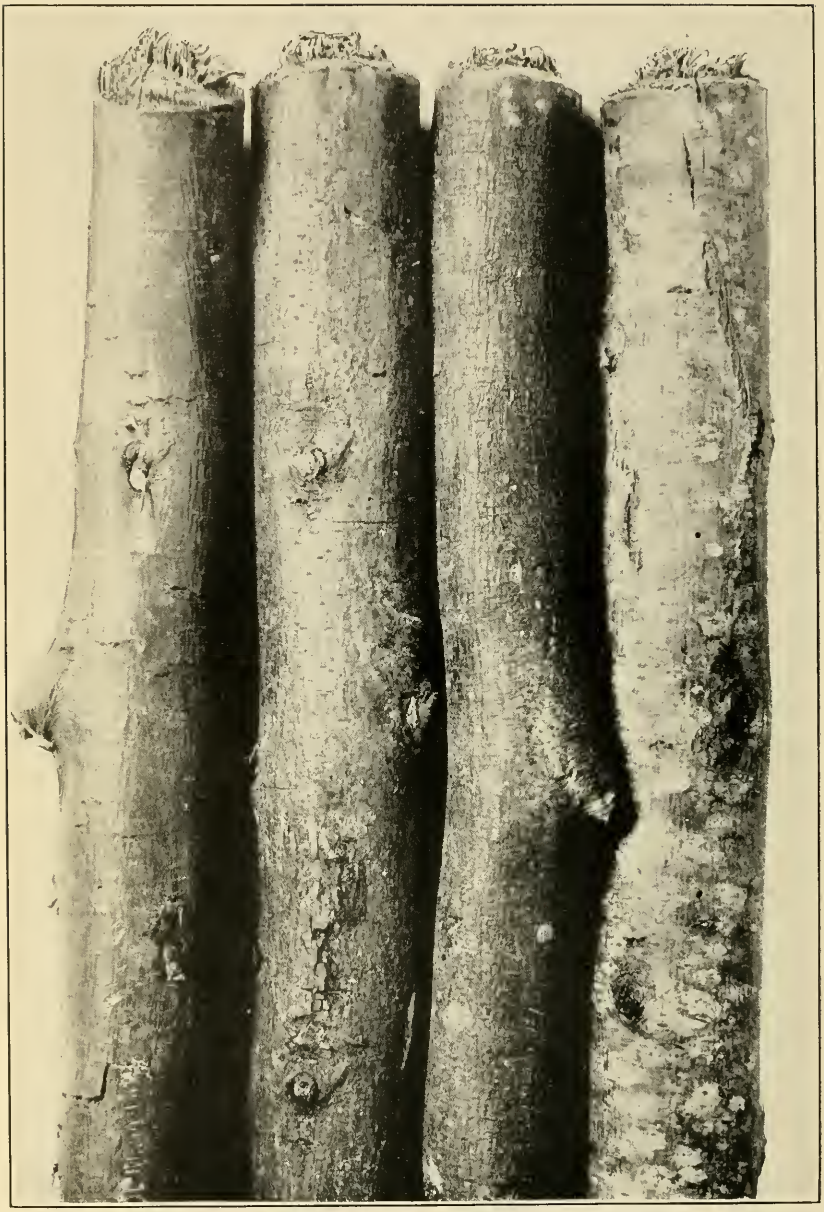
[1] Ent. News, v. 23, no. 10, p. 484, Dec., 1912.

[2] Bates, H. W. Longicornia. *In* Biol. Cent. Amer. Insecta, Coleoptera, v. 5, p. 125, Aug., 1880, and Supplement, p. 367, July, 1885.

THE HUISACHE GIRDLER (ONCIDERES PUTATOR). (ORIGINAL.)



WORK OF THE HUISACHE GIRDLER.

Portions of Huisache branches showing method of cutting off by the girdler (*Oncideres putator*) at top; also showing places where skin has been ruptured. Small holes made by secondary borers. Reduced. (Original.)

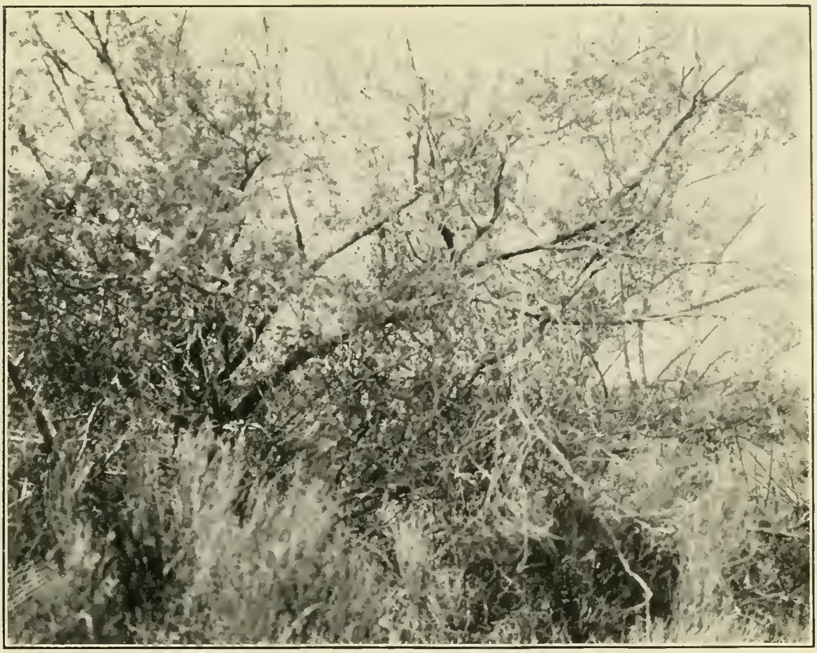


FIG. 1.—WORK OF THE HUISACHE GIRDLER EARLY IN THE SEASON. TWENTY BEETLES COUNTED ON THIS TREE. (ORIGINAL.)

FIG. 2.—TREES WHICH HAVE NOT BEEN SERIOUSLY INJURED BY THE GIRDLER, BUT NO DEAD BRANCHES ALLOWED TO REMAIN ON OR NEAR TREES. (ORIGINAL.)

WORK OF THE HUISACHE GIRDLER.

FIG. 1.—ROW OF HUISACHE TREES ONLY SLIGHTLY DAMAGED BY THE HUISACHE GIRDLER. (ORIGINAL.)

FIG. 2.—STREET SCENE IN WHICH HUISACHE TREES HAVE BEEN DAMAGED BY THE HUISACHE GIRDLER. (ORIGINAL.)

WORK OF THE HUISACHE GIRDLER.

of information has been placed on record of *Oncideres cingulata* Say. It appears that some of the early writers on the Onciderini mentioned only the genus Oncideres in writing of the depredations of the insects concerned.

The first information received by the Bureau of Entomology in regard to the injurious appearance of *Oncideres putator* in this country was in 1899 at Calabasas, Ariz. The report came from Mr. Morgan R. Wise, who sent specimens of mesquite (*Prosopis juliflora*) which had been girdled by the beetle, together with the statement that this tree was much injured by the girdler. The previous year the beetles had accomplished much damage, so that this year the girdled dead twigs snapped off. It was the opinion of the correspondent that, if this condition was continued, ultimately the mesquite tree would be exterminated by being so badly crippled as to preclude the possibility of its bearing fruit. Mr. Schwarz says that the beetles damage mesquite in western Texas and New Mexico, as well as in Arizona.

The genus Oncideres has been discussed by a number of authors, but the writer has been unable to find, in literature on this group, any memoranda on the biology of the species in question. Dr. W. Muller[1] discusses the habits of Oncideres in South America, but mentions no specific characteristics, nor does he mention the occurrence of *Oncideres putator*. He states, however, that the species which occur in Brazil frequently sever branches of a diameter of 2 inches or more.

Leng and Hamilton[2] state that *Oncideres putator* is probably synonymous with *O. cingulata* Say.

The species was originally described by Thomas,[3] but no biological notes are included in the description.

FOOD PLANTS.

So far as the writer has been able to observe, the species has in southern Texas five food plants, but the huisache appears to be preferred and the other trees have never been found to be injured in any way comparable with the huisache. The following is a list of the plants or trees on which the species has been found feeding, as well as depositing:

Huisache (*Acacia farnesiana*), mesquite (*Prosopis glandulosa*), huajilla (*Acacia berlandieri*), ratama (*Parkinsonia aculeata*), and *Mimosa lindheimeri*. The host plants are here given in the order of preference by the insect, and no great amount of injury has been

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[1] Müller, W. Über die gewohnheiten einiger *Oncideres*-Arten. *In* Kosmos, Zeitschrift für die gesamte Entwicklugslehre, v. 19, p. 36–38, 1886. Stuttgart.

[2] Leng, C. W., and Hamilton, John. The Lamiinæ of North America. *In* Trans. Amer. Ent. Soc., v. 23, p. 101–178, March, 1896. Oncideres, p. 140–141.

[3] Thomson, James. Physis, v. 2, no. 5, Paris, Aug., 1868. Revision des groupes des Oncidérites, p. 41–92. *Oncideres putator*, p. 81.

observed to the last three when there was sufficient huisache in close proximity to the emerging beetles. In fact, the greatest amount of damage to "huajilla" and "ratama" was noticed when collections of huisache branches containing larvæ were left near ratama and huajilla trees.

LIFE HISTORY.

The beetles begin to appear early in September and continue to emerge from their pupal cavities until the latter part of November, though most of the brood issues during the month of October. In the laboratory most of the material encaged developed adult beetles by October 12. The adults remain for several days in their pupal cells after they have emerged from the pupal cases before attempting to cut their way out of the pupal cavities through the bark of the branch. Just as soon as they have partaken of a little food, which consists of bark from the branch, and the wing covers are sufficiently hardened, copulation begins. Of specimens observed in the laboratory none began copulating or showed activity before two days after their emergence in the adult stage. This species of Oncideres, unlike its near relatives, *Oncideres cingulata* and *O. texana*, does not so frequently work in pairs. The writer has found the beetles working in pairs, but during midseason they occur to a greater or less extent in colonies. The writer has observed as many as 24 on one small tree, and two-thirds of them at times would be females. The males go from one female to another, and do not seem to possess the monogamous instinct.

While making observations on the species during October, 1910, it was decided to see how long a period was required for one unassisted female to prepare the egg cavity and deposit an egg. The first one tried deposited in 1 minute and 35 seconds, another in 4 minutes and 50 seconds, and the next in 4 minutes and 40 seconds. Observations made later show that from 1 to 5 minutes is ordinarily required for the female beetle to deposit. This, however, does not include preparing the cavity to receive the egg, for it generally requires about 10 minutes to prepare the cavity. The beetle begins this cavity by inserting both mandibles as deeply as possible into the bark of the branch that is to be girdled. After forcing the mandibles deep into the bark the beetle draws them together as nearly as she can. Then one is removed and the other worked deeply into the puncture. It is then removed and the other mandible is inserted in the same manner. Later both mandibles are inserted and a tiny chip removed. Then the work begins again with one mandible at a time, until the cavity is prepared to receive the egg. The beetle then reverses its position and forces the ovipositor into the cavity as deeply as possible. Shortly the egg can be seen leaving the body of the beetle. After the egg is inserted the beetle frees herself by withdrawing the ovipositor, one side at a time, and then she searches for another suitable location. The eggs are ordinarily placed between the layers of bark, and it may here be stated that this species does not deposit particularly about buds or at the base of smaller branches, but may lay her eggs anywhere along the branch girdled. It also might be added that, unlike some, this species of Oncideres does not make transverse incisions in the bark, presumably to prevent the growth of the branch from crushing the egg.

There is, in addition, a difference from *Oncideres cingulata* and *O. texana* in the way this species leaves the egg after deposition, in that only a very slight gluey excretion is made in sealing the opening to the egg cavity, and at times there is none at all. This waxy secretion is very conspicuous with the work of the two smaller species.

The larva feeds along gradually, leaving in its burrow behind excrement and castings well packed, which may prevent attack of an enemy from the rear. It has been observed that when a branch not completely severed remained in the top of the tree the young larvæ would often perish, presumably for lack of moisture. On the other hand, the writer has noticed branches that remained several feet above ground all season and which developed beetles during October. It thus appears that it will depend upon the amount of rainfall and climatic conditions generally as to whether the mortality of the larvæ is high in the suspended branches—well up in the tops of the trees. If there should be a moderate rainfall during the winter and spring months, it is thought that the mortality in these suspended branches would be very low, but on the other hand if it should be dry, the mortality would be high. While the larva will stand a very dry atmosphere for several months, its growth will not be as rapid as where there is sufficient moisture to permit constant feeding. Larvæ that have been checked in growth from lack of moisture develop very rapidly when placed in more humid surroundings and appear to obtain their growth just as soon as when left under normal conditions. They could not well do otherwise and thrive in the climate where they have been found most numerous. There is a limit, however, to the amount of moisture the larvæ can stand, for in one instance in the laboratory the mortality was about 70 per cent, and it could be attributed to no other cause than an excess of water. The duration of the larval period is approximately 42 weeks under ordinary conditions, though under the most favorable conditions they may develop in 39 or 40 weeks. Before transforming to pupa the larva prepares a pupal cavity or cell by drawing about it all castings and thus surrounding itself with more or less of a wall that would be difficult for any insect enemy to penetrate. The larva then cuts a hole into the bark and transforms to the pupa. During the growth of the larvæ in the branch they produce a grinding noise that can be heard several feet away, and when the branch is disturbed this noise is more pronounced. The pupæ in turn make a somewhat similar noise when disturbed, and for this reason one must raise the bark covering in order to know just when transformation takes place.

Before the pupal stage of this species could be had the writer was transferred to Indiana, and the material was taken there in order to obtain the pupæ. The branches were examined frequently during the months of June and July, but no pupæ were observed until August, and the first adult beetle emerged September 15. The duration of the pupal stage is approximately four weeks, with an average mean temperature of 72.5° F.

There is only one generation of this beetle each year, approximately 12 months being required for the life cycle from egg to adult.

LONGEVITY.

The beetles that emerged in the laboratory were kept in confinement without fresh food and lived from 4 to 12 days, while those that were captured, confined in the insectary, and furnished proper food lived from 10 to 21 days, the males dying from 1 to 5 days in advance of the females.

NATURAL ENEMIES.

There are several species of parasites that attack the eggs and larvæ of *Oncideres putator*, one species in particular attacking both egg and larva. The following were reared February 3, 1915, at Brownsville, Tex.: *Chryseida inopinota* Br., *Eurytoma* sp. (Chttn. No. 1921), *Caenophanes* sp. (Chttn. No. 1922), a pteromalid (Chttn. No. 1923), and *Meteorus* sp. (Chttn. No. 1924). It is thought that the larvæ have one or more predaceous enemies, but none has been observed to this writing. It is believed that the southern downy woodpecker (*Dryobates pubescens*) and probably also the Texas woodpecker (*Dryobates scalaris bairdi*) attack the larvæ. While neither of these birds has been found with larvæ, they have been observed at work on branches that contained numerous larvæ of this insect and have left empty chambers behind.

Table I shows something of the mortality early in the season.

TABLE I.—*Mortality of the huisache girdler, based on examinations made January 8, 1913.*

Number of branch.	Diameter of branch (millimeters).	Number of eggs.	Number of live larvæ.	Number of dead larvæ.
I	26	11	0	0
II	30	0	58	3
III	35	19	153	2
IV	28	0	197	14
V	32	0	173	17
VI	37	7	52	0

On January 13, 1913, four prunings of huisache were stripped of bark, and the following table made:

TABLE II.—*Infestation of the huisache girdler by parasites, based on examinations made January 13, 1913.*

Number of branch.	Diameter of branch (millimeters).	Number of eggs.	Number of living larvæ.	Number of larvæ parasitized.
I	36	0	363	11
II	30	0	104	5
III	25	0	79	6
IV	38	59	135	0

These tables give the degree of infestation to a single branch and the mortality of the larvæ at a very early date. The parasites of the larvæ are more numerous a little later in the season, although the egg parasite appears even as early as December 1. This parasite is more effective against the larvæ before they approach a size more than two-fifths of an inch in length; although it attacks the larvæ throughout the season it does not appear in as large number then as it does early in the season.

METHOD OF CONTROL.

Since this insect spends at least 10 months in the severed branch during the egg, larval, and pupal stages, its control is only a matter of collecting the pruned branches and destroying them by burning. This would not be a laborious task, as the girdled branches are so large that it is not difficult to locate them, and as the species does not appear to migrate very rapidly to new territory, this method would nearly eradicate the species in isolated localities, at least, in one or two seasons' time, taking it for granted that a few branches might go unnoticed. (See Pl. III, fig. 2.) The work of burning the branches could best be done from the first week of January to the first of August, as the writer has not observed the laying of any eggs as late as January 1. As the huisache wood burns readily, it should be comparatively easy to collect and destroy pruned branches from a large number of trees in a comparatively short time. In addition to this measure, the beetles might be collected by hand where one has only a small number of trees to guard against this girdler, and in this way the trees could be protected before any damage had been done.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 186

Contribution from the Bureau of Entomology, L. O. Howard, Chief, and the Bureau of Plant Industry, Wm. A. Taylor, Chief.
February 27, 1915.

A METHOD OF FUMIGATING SEED.[1]

By E. R. Sasscer, *Chief Inspector, Federal Horticultural Board*, and Lon A. Hawkins, *Plant Physiologist, Plant Physiological and Fermentation Investigations.*

INTRODUCTION.

A perfectly reliable method of destroying insects present in seeds imported into this country, without injury to the seed, is much needed. The exclusion of insects by a careful selection of apparently uninfested seeds at the port of export is impracticable, because many injurious insects pass their larval and pupal stages and a portion of the adult stage inclosed within the seed and on this account might easily escape notice when the seeds were inspected. Furthermore, seeds are frequently received from localities where injurious insects are not well recognized, and, also, insects which are only slightly injurious in their native habitats occasionally become destructive pests when established in this country.

The ordinary methods of destroying insects in stored seeds, such as subjecting them to heat (with or without moisture), carbon bisulphid, and hydrocyanic acid in the presence of air, have been tried and found unsatisfactory for this purpose.

It occurred to the writers to create a partial vacuum in the container in which the seeds had been placed and fill the chamber with some gaseous insecticide, such as carbon bisulphid or hydrocyanic acid, in the belief that a much larger amount of gas might thus be forced into the crevices of the seeds and into the insect galleries than would be possible if the entrance of the gas were dependent upon diffusion under normal atmospheric pressure. This method was successfully used with a number of different kinds of seeds and insects, and a convenient chamber, described later, was devised for fumigation under reduced pressure.

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[1] This work was carried on in cooperation between the Federal Horticultural Board and the Office of Plant Physiological and Fermentation Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

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FUMIGATION CHAMBER.

The fumigation chamber (fig. 1 and fig. 2, *b*) is of iron tubing, 36 inches long by 12 inches in diameter. One end of this cylinder is permanently closed with a heavy iron cap (fig. 1, *a*). The other end is fitted with a flange and can be closed with a brass plate (fig. 1, *b*), which is held in place by clamps. One face of the plate is ground to fit the flange, which is also ground. A wide rubber gasket is placed between the two faces when the plate is clamped in position. The chamber is designed to lie with its longest axis in a horizontal position. On the side of the chamber intended to lie uppermost three openings are made, one being in the center and one at each end. The opening

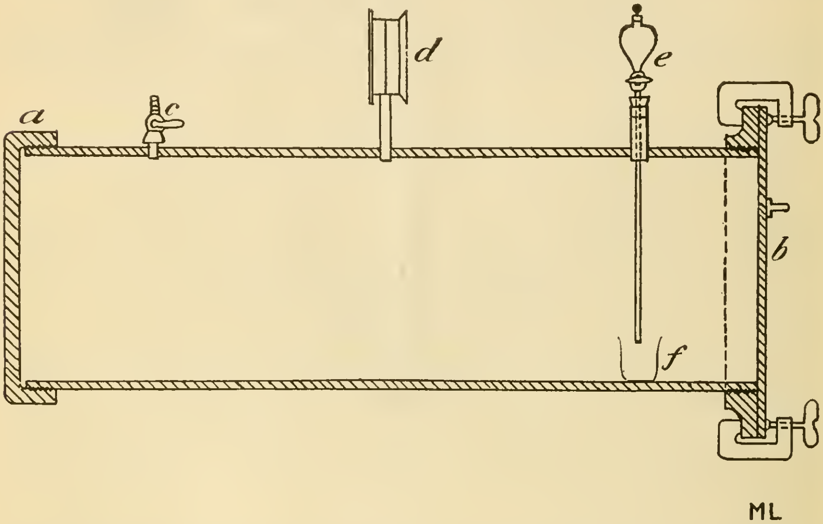

FIG. 1.—Diagram of fumigation chamber: *a*, Iron cap; *b*, brass plate clamped on end of chamber; *c*, gas cock for attaching suction hose; *d*, vacuum gauge; *e*, dropping funnel, by means of which the sulphuric acid is introduced into the chamber; *f*, beaker to contain cyanid.

near the capped end is fitted with a gas cock (fig. 1, *c*), so that the suction hose of a vacuum pump can be readily attached. A vacuum gauge, registering the decrease in pressure in units equivalent to inches of mercury, is placed in the center opening (fig. 1, *d*), while a tubulature is placed in the opening near the flange. The tubulature is closed with a perforated rubber stopper bearing a dropping funnel (fig. 1, *e*) so arranged that the bulb and stopcock are outside the chamber, while the tube extends down inside the chamber nearly to the bottom. The rubber stopper and dropping funnel can be readily removed when seeds or other material to be fumigated are placed in the chamber. An air pump, driven by a motor and capable of reducing the air pressure to the equivalent of about 0.05 of a millimeter of mercury, is used to secure an almost complete vacuum (fig. 2, *a*).

When this apparatus is used for fumigation, the seeds, contained in either a cloth bag or an open vessel, are placed in the chamber, and the requisite amount of sodium or potassium cyanid in a small beaker is so arranged that the neck of the dropping funnel extends down into the beaker (fig. 1, *f*). The cover is then clamped on and the chamber exhausted. In extracting the air from the chamber, the suction is continued until the gauge registers 30 inches or more—that is, the air in the chamber is exhausted until the pressure is the equivalent of some fraction of an inch of mercury. The suction is then cut off by means of the gas cock, and the required quantity of diluted acid, which has been previously placed in the bulb of the

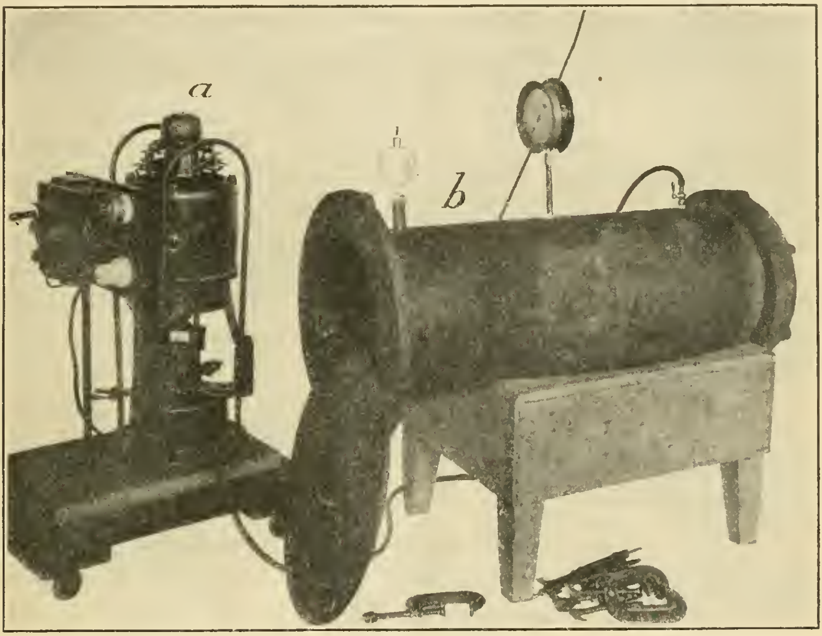

FIG. 2.—Air pump (*a*) and fumigation chamber (*b*) used in the experiments described in this bulletin.

dropping funnel, is allowed to flow slowly upon the cyanid in the beaker within the chamber. The hydrocyanic acid is thus prepared in the chamber and no trace can get out. After the seeds are exposed to the gas for the required time, the stopcock of the dropping funnel is opened to let the air into the chamber. As the discharge pipe of the air pump extends outside the building, the mixture of hydrocyanic acid and air can not escape into the room. As soon as convenient, the stopper and funnel are removed and, by means of the air pump, air is sucked through the chamber, thus washing the hydrocyanic acid out of the chamber before the cover is taken off and the seeds removed. In the experiments described here the seeds were examined carefully at several different times to see whether all insects were killed. The viability of the seeds was then tested.

Part of the germination tests recorded in this paper were made by Mr. W. R. Lucas, of the Office of Foreign Seed and Plant Introduction, but in most cases tests with treated and untreated seeds were carried out by Mr. W. L. Goss, of the Seed Laboratory of the Bureau of Plant Industry.

In these experiments the duration of the exposure and the concentration of hydrocyanic acid were varied in order to determine the minimum exposure and concentration of hydrocyanic acid which would insure the death of all the infesting insects. It was also considered of interest to determine whether the seeds would be uninjured if exposed longer and with a higher concentration of the hydrocyanic acid than that necessary to kill the insects. The duration of the exposure and the amounts of sodium or potassium cyanid are given in the description of the experiments. The 1–1–2 formula was used for potassium cyanid and the 1–1½–2 formula for sodium cyanid.

The iron fumigation chamber already described was used in most of the experiments. In some of the preliminary work, however, desiccators or bell jars were used instead. The essentials of the method were the same in either case, and no description of these pieces of apparatus seems necessary.

EXPERIMENTS.

The summarized results of these experiments are here given in tabular form for comparison (Table I).

TABLE I.—*Summary of experiments in fumigating against insects.*

Material.	Infested with—	Kind of cyanid and amount used.	Time of exposure.	Result.	Germination test.
Avocado:			*Hrs.*		
26 seeds.	One adult avocado weevil (*Heilipus lauri*).	Sodium cyanid, ½ gm., in desiccator.	1	Insect dead	22 out of 26 seeds germinated.
29 seeds.		...do	½		20 out of 29 seeds germinated; 21 out of 25 germinated in control test.
5 seeds.	Larvæ of avocado weevil (inclosed in a cotton-plugged vial) and broad-nosed grain weevil (*Caulophilus latinasus*).	...do	½	All stages dead	Seed cut up to determine mortality of insects and not planted.
20 seeds.		...do	6	...do	No germination.
Do.		...do	12	...do	Do.
6 seeds.	Larvæ of Conotrachelus sp. and broad-nosed grain weevil, all stages.	Sodium cyanid, 4 gms.	½	...do	All seeds germinated.
10 seeds.	...do	...do	¼	No insects alive out of 50 examined of all stages.	Do.

TABLE I.—*Summary of experiments in fumigating against insects*—Continued.

Material.	Infested with—	Kind of cyanid and amount used.	Time of exposure.	Result.	Germination test.
Avocado:			*Hrs.*		
7 seeds.	Larvæ of Conotrachelus sp. and broad-nosed grain weevil, all stages.	Sodium cyanid, 2 gms.	¼	1 grain-weevil larva alive.	Not planted.
6 seeds.	4 with all stages of broad-nosed grain weevil; 2 uninfested.	do	½	All stages dead	3 seeds planted and all germinated.
10 seeds.	Scolytid	do	½	Out of several hundred specimens 1 live adult was found.	Not planted.
Do	do	Sodium cyanid, 4 gms.	½	All stages dead	Do.
Sorghum seed.	Bruchus sp.	Sodium cyanid, 2 gms.	¼	Insects alive	75.5 per cent germination; seed badly infested.
Do	Bruchus sp. and rice weevil (*Calandra oryza*).	Sodium cyanid, 4 gms.	½	All stages dead	71 per cent germination; seed badly eaten.
Do	do	do	1	do	83 per cent germination.
Do	Rice weevil and cadelle (*Tenebroides mauritanicus*).	Sodium cyanid, ½ gm., in desiccator.	½	do	Of four grades fumigated, the percentage of germination was as follows: 78.5; 86.5; 88; 83.
Do	do	do	1	do	Germination of fumigated seed superior to that of untreated seed.
Do	Rice weevil	Potassium cyanid, 2 gms.	30	do	Seed thoroughly infested with insects previous to fumigating and only 15 per cent germinated.
Bulbs	Bulb mite (*Rhizoglyphus hyacinthi*).	Sodium cyanid, ½ gm., in desiccator.	1	All mites dead	Bulbs thoroughly infested and unfit for planting.
Cotton seed.	Adults of the red grain beetle (*Cathartus gemellatus*).	Sodium cyanid, 1½ gms.	1	All insects dead	Not planted.
Gleditsia sinensis in seed pods.	Bruchus sp. (adults)	Sodium cyanid, 2 gms.	½	All insects dead, both in and out of seed pods.	Percentage of germination approximately the same with both fumigated and untreated seed.
Do	do	Sodium cyanid, 4 gms.	½	do	Do.
Phaseolus vulgaris.	Bruchus sp	Sodium cyanid, ½ gm., in desiccator.	1	All insects dead	Germination of fumigated seed superior to that of untreated seed.
Pineapples	Pseudococcus sp	do	½	do	Not planted.
Tussock moth (*Hemerocampa leucostigma*):					
500 egg masses.		Sodium cyanid, 2 gms.	½	Some larvæ hatched several days after exposure.	
250 egg masses.		Sodium cyanid, 4 gms.	½	No hatching	

The results given in Table I indicate that the fumigation of seeds by the introduction of hydrocyanic acid into an air-tight chamber, from which the air has been practically exhausted, is effective, provided the exposure is not less than half an hour. An exposure of one-fourth hour is effective with the apparatus employed in these experiments if four or more grams of cyanid are used.

SUMMARY.

Fumigation by the method described in this bulletin was found to kill insects without injury to the seed and with a considerably shorter exposure than is necessary in the usual method of seed fumigation. Further experiments will be conducted with special reference to the use of carbon bisulphid, which is not considered in this paper.

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INSECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 189

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ April 12, 1915

STUDIES OF THE CODLING MOTH IN THE CENTRAL APPALACHIAN REGION

By

F. E. BROOKS and E. B. BLAKESLEE, Entomological Assistants
Deciduous Fruit Insect Investigations

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 189

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
April 12, 1915.

STUDIES OF THE CODLING MOTH IN THE CENTRAL APPALACHIAN REGION.

By F. E. Brooks and E. B. Blakeslee,
Entomological Assistants, Deciduous Fruit Insect Investigations, Bureau of Entomology.

CONTENTS.

INTRODUCTION.

In many localities throughout the central Appalachian region the recent rapid development of the apple-growing industry has made the control of the codling moth (*Carpocapsa pomonella* L.) a subject of special and increasing interest. The hilly or mountainous nature of the land has led to the location of orchards at elevations ranging from a few hundred feet to more than 4,000 feet above the level of the sea. The great diversity of temperature that occurs between the lower and the more elevated orchards has a marked effect on the time of transformation of the different stages of the codling moth, and consequently has direct bearing on the relative number and the destructiveness of second-brood larvæ.

In the spring of 1911 the Bureau of Entomology began a study of the codling moth in the region just mentioned, as a part of its investigations of this insect throughout the United States, giving particular attention to time of appearance of the different broods at various altitudes and latitudes. The work was conducted by or under the immediate direction of the authors of this paper and was continued for three consecutive years at several points located in Virginia, West Virginia, and Maryland.

The writers are greatly indebted to the large number of fruit growers in the various localities where the investigations were carried on for the free use of orchards in which to obtain banding records, for buildings to shelter rearing jars, and for other courtesies. During the progress of the work many essential suggestions were made by Prof. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, under whose direction the studies were made.

LOCALITIES IN WHICH INVESTIGATIONS WERE MADE.

The studies described herein were conducted at Charlottesville, Fishersville, Greenwood, and Winchester, Va.; Keyser, French Creek, and Pickens, W. Va.; and Hagerstown, Smithsburg, and Hancock, Md. The senior author had charge of the investigations in West Virginia and the junior author had charge in Virginia and Maryland. At several of the points mentioned only partial or incomplete records were obtained. The similarity of conditions at Smithsburg and Hancock, Md., and Keyser, W. Va., to other localities where records were being kept, together with a shortage of the fruit crop and the difficulty of visiting so many places at sufficiently frequent intervals, led to the discontinuance of operations at these points after the first year.

NATURE AND EXTENT OF THE INVESTIGATIONS.

The work was conducted by selecting, for banding, from 10 to 15 unsprayed bearing apple trees of late ripening varieties in each locality. Wherever it was possible medium-sized trees with smooth bark were chosen. In some cases such trees could not be found and old trees with rough bark were used. The rough scales of bark were scraped from the trunks and from the bases of the larger branches of these old trees, but even then they were much less desirable for the purpose than the younger, smooth-barked trees.

In the spring, before the first-brood codling-moth larvæ had commenced to leave the fruit, burlap bands were tied around the trunks of the trees 2 or 3 feet above the ground, and in some cases additional bands of the same material were placed around the bases of the larger branches. The trees were all tagged and an individual account kept as to the number of larvæ going under the bands to "spin up." The bands were removed and examined at frequent intervals and the larvæ taken from them were counted and placed in rearing jars. In 1911 the larvæ were collected and the rearing jars examined every 10 or 12 days, and in 1912 and 1913 the examinations were made every 3 or 4 days. During the course of the work more than 20,000 larvæ were collected and placed in the jars for rearing.

The jars containing the larvæ were supplied with small devices made of thin pieces of wood bound together, with openings between into which the larvæ entered to "spin up." It was found that strips cut from sheets of transparent celluloid could be used under the wood to advantage, as this permitted the wood covering to be removed for the purpose of examining the larvæ or pupæ without tearing or disarranging the cocoon. The jars were covered with cheesecloth and were placed under shelter, usually in open sheds, where they had out-of-door temperature. These sheds were always located near the orchard in which the larvæ had been collected. The jars were examined on the same dates as the bands, and the moths that had issued at each examination were counted and destroyed. Larvæ that wintered were preserved and records were made of the date they issued as moths the spring following. So far as possible the band records were checked and supplemented by observations on the condition of the insect in the orchard.

EXPLANATION OF THE USE OF TERMS.

The terminology of this paper is made to conform as nearly as possible with that of previous papers on the codling moth issued by the bureau. The term "generation" applies to the moth in all its stages from the egg to the adult, regardless of whether the life cycle is completed in one season or whether the insect winters during its development, in which case the life cycle would occupy parts of two seasons. The term "brood" is used to designate the insect in any of its four stages. Broods of eggs, larvæ, pupæ, and imagos occur normally, with more or less seasonal regularity, in the orchards of any given locality, and the term "brood" usually refers to the individuals in the aggregate of any particular stage of a given generation.

In the Appalachian section a first brood and a partial, or practically full, second brood of larvæ occur annually. In some southern localities a small third brood is possible. Some of the larvæ of the first brood and practically all those of the second brood winter in the cocoon. These are all spoken of as "wintering larvæ." In the spring these wintering larvæ transform to "spring pupæ," which in turn develop into "spring moths." The spring-brood moths produce "first-brood eggs," from which hatch "first-brood larvæ." The individuals of this generation that complete their transformation during the first season are known in their successive stages as "first-brood pupæ" and "first-brood moths." These moths in turn produce "second-brood eggs" and "second-brood larvæ." Where "second-brood pupæ" and "second-brood moths" occur they may produce "third-brood eggs" and "third-brood larvæ."

INVESTIGATIONS AT CHARLOTTESVILLE, VA.

DESCRIPTION OF LOCALITY.

Charlottesville is situated at the foot of the eastern slope of the Blue Ridge Mountains, at an elevation of 400 to 500 feet above sea level. In the immediate vicinity of the city there are several large and profitable bearing apple orchards, as well as a considerable acreage of young orchards planted within the last four or five years. Its own interests, therefore, as well as its proximity to the large orchards of the Blue Ridge section, make Charlottesville of considerable importance as a commercial apple-growing center. Investigations of the seasonal life history of the codling moth were carried on in this section in 1911, 1912, and 1913. Only the work of the last two years, however, was considered of sufficient value to be included in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

A large proportion of the larvæ collected in the orchard in the fall of 1911 succumbed to cold or disease the following winter, and the rearing material available for moth emergence was consequently rather limited. On account of the small number of insects reared and some irregularity in the observations the records are not included in detail. Moths were first observed in the rearing cages at Charlottesville on May 7, and at Greenwood, where conditions are not far from those at Charlottesville, adults began appearing about May 8. Also the summer brood of moths emerged in the rearing cages at Charlottesville 45 days later (June 20), which is about the interval that must elapse between the two broods of adults in that latitude. Therefore we may safely assume that in 1912 the emergence of spring-brood moths began in the orchards at Charlottesville soon after May 1.

FIRST-BROOD MOTHS.

Table I gives the time of emergence of 247 moths that issued from band-collected material at Charlottesville in 1912. Beginning on June 20, emergence continued through the rest of June, the whole of July, and about half of August. One moth emerged as late as September 2.

TABLE I.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1912.* (See fig. 1.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 20	1	Aug. 1	5
24	5	5	10
28	32	9	30
July 2	1	13	20
5	42	17	7
10	6	21	3
13	22	25	0
17	15	29	0
21	23	Sept. 2	1
25	12		
29	12	Total	247

BAND COLLECTIONS.

It would be difficult to find a more satisfactory orchard in which to conduct band-record experiments than the one used at Charlottesville in the summer of 1912. The trees used were part of an orchard

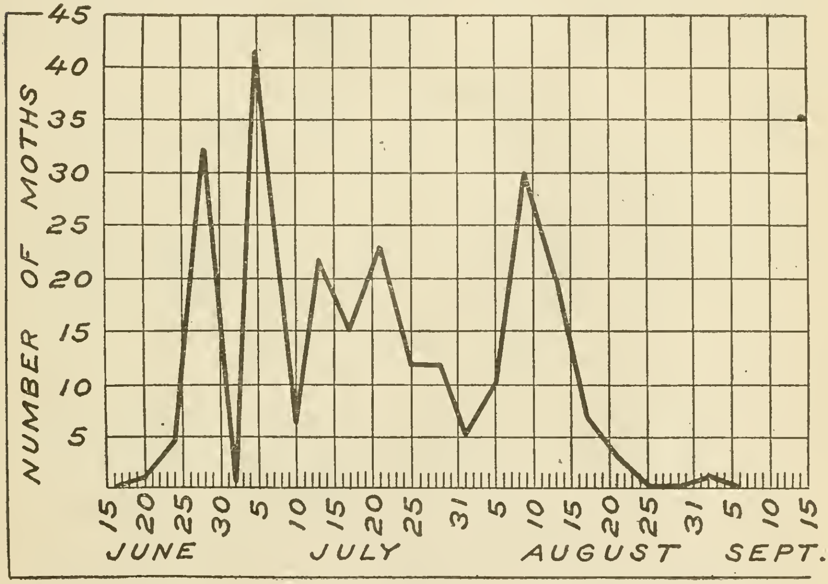

FIG. 1.—Diagram to illustrate emergence of first-brood moths of the codling moth (*Carpocapsa pomonella*) at Charlottesville, Va., in 1912.

that had not been sprayed for a number of years. Those banded were of the Winesap variety, about 18 years old, and carried a heavy crop of fruit throughout the season. In Table II are given the collections of the season and the summarized results of the rearing experiments.

TABLE II.—*Number of larvæ of the codling moth taken from the bands and reared at Charlottesville, Va., in the summer of 1912 and the spring of 1913.* (See fig. 2.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1912.	Number over-wintering.	Number winter-killed.	Number of moths emerging, 1913.
June 12	12		12			
17	48	14	34			
22	49	11	38			
26	26	8	18			
July 1	34	11	21	2	2	
5	33	10	23			
9	26	9	17			
13	20	2	17	1		1
17	20	1	19			
21	34	12	22			
25	27	11	15	1		1
Aug. 1	12		4	8	2	6
5	20		5	15		15
10	23	1	1	21	2	19
13	26	3		23	3	20
17	27			27		27
21	37	10	1	26	16	10
25	30			30	15	15
29	45	10		35	15	20
Sept. 2	61	7		54	28	26
5	60	6		54	13	41
10	52	9		43		43
14	80	20		60	5	55
18	53	2		51	19	32
25	32	3		29	13	16
29	14	4		10	4	6
Oct. 2	2			2		2
5	2			2	2	
Total	905	164	247	494	139	335
Per cent	100	18.12	27.29	54.59	15.36	39.23

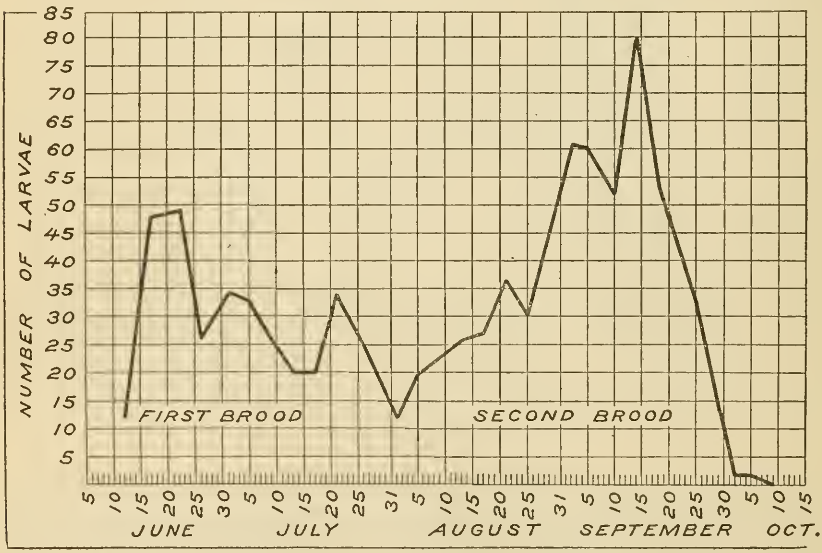

FIG. 2.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1912.

Unfortunately examinations were not begun until June 12, while larvæ were doubtless leaving the fruit as early as June 5–6. Codling-moth larvæ appeared under the bands in considerable number throughout June and July, most of those collected previous to August 1 transforming to adults the same season. After August 1 the number of larvæ collected again increased considerably, the greater part of those taken after this date spinning up and wintering. Since summer-brood moths appeared June 20, it is reasonable to suppose that second-brood larvæ were beginning to enter the apples about July 1. If we allow a slightly longer time than has been found by other observers to be the minimum feeding period of the second brood, we might expect second-brood larvæ to be leaving the fruit by the last of July to the first of August. The fruit was picked shortly after October 5 and the records discontinued, although a few of the second brood had not finished feeding by that time.

Table II gives the results of the rearing experiments carried on with the 905 larvæ taken in the orchard in the summer of 1912. Due to handling, cannibalism, disease, etc., 18.12 per cent were lost in the rearing jars; 27.29 per cent emerged as moths that season; 54.59 per cent wintered; 15.36 per cent were winter-killed; and 39.23 per cent passed the winter and emerged as moths in the spring of 1913.

SUMMARY FOR SEASON OF 1912.

At Charlottesville in 1912 the spring-brood moths began emerging in the early part of May. First-brood larvæ began leaving the fruit the early part of June. First-brood moths began emerging June 20, allowing 10 days for egg-laying and incubation; second-brood larvæ began feeding by July 1. After August 1 most of the larvæ taken under the bands belonged to the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The emergence records of 355 moths of the spring brood at Charlottesville in 1913 are given in Table III.

TABLE III.—*Emergence of spring-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
Apr. 18	2	May 21	21
21	2	24	21
24	2	27	11
27	7	30	10
30	18	June 2	8
May 3	78	5	8
6	27	8	1
9	42	11	1
12	17		
15	55	Total	355
18	24		

It will be remembered that the work of 1912 did not include a detailed account of the appearance of the spring brood. There was, however, very good evidence that spring-brood emergence began that season shortly after May 1. On the whole the seasonal conditions of the spring of 1913 were slightly in advance of those of 1912, and spring-brood moth emergence seems to have occurred about 10 days earlier in the former year. Moths began appearing in numbers on April 27–30, and maximum emergence was reached on May 3. Moths continued to issue in jars through May and part of June, emergence ceasing June 11. It is probable that first-brood larvæ began feeding by May 1, or 12 days after the first moth appeared in the rearing cages.

FIRST-BROOD MOTHS.

In 1913 the first of the first brood or summer brood of moths issued on June 14, from material taken under the bands in the orchard on June 5. However, emergence occurred in numbers on June 23 and reached its maximum on July 8. On the whole the graph in figure 3 probably represents fairly well the time of appearance in the orchard of the two broods of moths at Charlottesville in 1913. An occasional second-brood larva may have begun feeding by June 25, but it is probable that the insects were not entering the fruit in numbers before July 1.

Table IV.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 14	1	July 23	7
17	3	26	7
20	5	29	16
23	18	Aug. 1	7
26	11	4	2
30	24	7	2
July 2	26	10	0
5	26	13	3
8	40	16	1
11	21	19	0
14	28	22	1
17	10		
20	11	Total	270

BAND COLLECTIONS.

At Charlottesville, as in the other parts of the central Appalachian section, the short crop of fruit during the season of 1913 seriously interfered with the work. After the dropping, which normally follows the feeding of the first brood, not enough fruit remained to furnish food for the second-brood larvæ, and the unusually small numbers of larvæ that appeared under the bands in the latter part of the summer throw out of line completely the proportions of transforming and wintering insects. The relatively small number of overwintering larvæ given in Table V must be considered as unusual and not as evidence of what occurs under normal conditions.

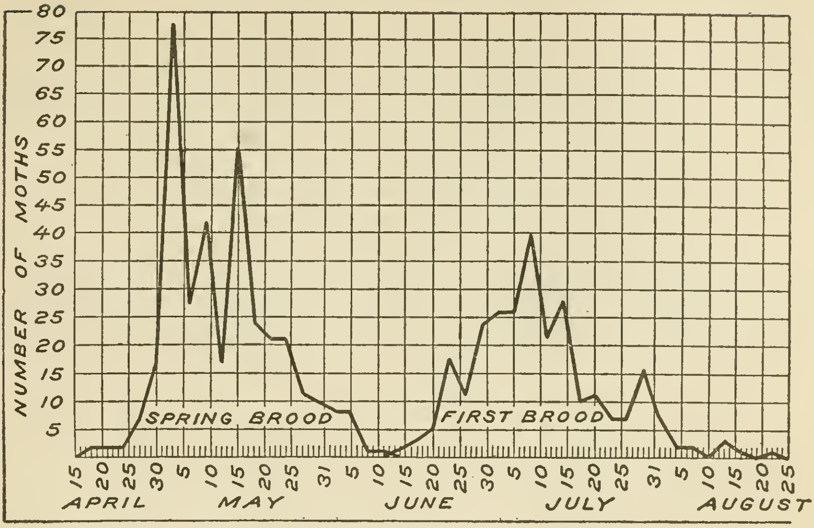

FIG. 3.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Charlottesville, Va., in 1913.

TABLE V.—*Number of larvæ of the codling moth taken from bands and reared at Charlottesville, Va., in 1913.* (See fig. 4.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number of larvæ overwintering.
June 5	6	2	4	.....
8	20	7	13	.....
11	33	11	22	.....
14	18	5	13	.....
17	35	19	16	.....
20	90	32	57	1
23	37	10	27	.....
26	54	27	25	2
30	85	52	31	2
July 2	19	8	9	2
5	23	3	20	.....
8	15	7	8	.....
11	10	4	5	1
14	8	3	4	1
17	10	3	7	.....
20	3	2	1	.....
23	1	.....	1	.....
26	5	.....	5	.....
29	1	.....	1	.....
Aug. 1	2	1	.....	1
4	13	10	.....	3
7	3	.....	.....	3
10	1	1	.....	.....
13	8	3	1	4
16	3	1	.....	2
19	6	1	.....	5
22	3	1	.....	2
25	2	.....	.....	2
28	9	5	.....	4
Sept. 1	1	.....	.....	1
3	1	.....	.....	1
6	5	1	.....	4
9	2	.....	.....	2
12	.....	.....	.....	.....
15	10	4	.....	6
Total	542	223	270	49
Per cent	100	41.14	49.82	9.04

First-brood larvæ were taken from the bands on June 5, and continued to appear in increasing numbers through the remainder of June and most of July, the largest collection of the season occurring on June 20. Since moths of the summer or first brood appeared in the rearing cages on June 14 and in numbers by June 20, second-brood larvæ were probably entering the fruit in the field June 25–30, and, allowing a normal feeding period, must have begun to appear under the bands in the last of July to the first of August. A few larvæ were collected up to September 15, when the remaining fruit was picked and the records discontinued. Figure 4 represents graphically the numbers and time of collection of the larvæ taken from the bands during the season. In all, 542 larvæ were taken from the bands, 223,

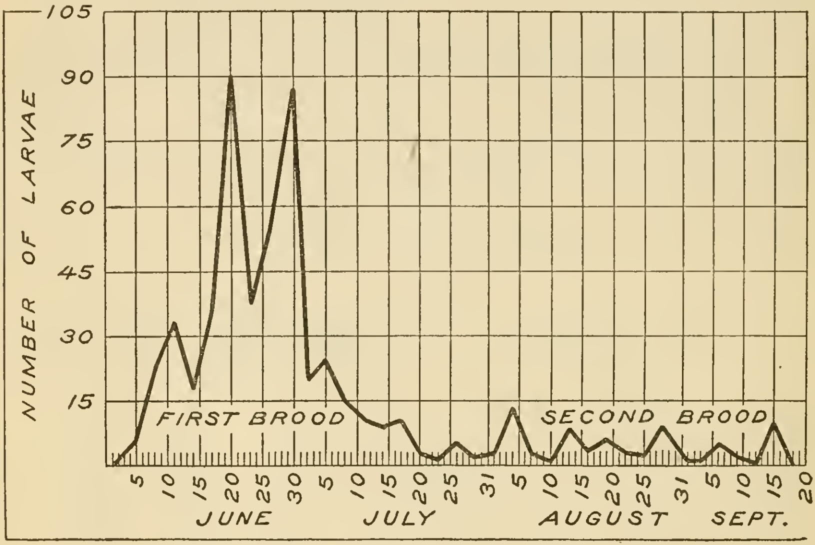

FIG. 4.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1913.

or 41.14 per cent, of which perished in the rearing cages; 49.82 per cent emerged as moths the same season, while 9.14 per cent spun up and wintered. As has already been explained, the comparative numbers of wintering and transforming larvæ given in Table V must not be considered usual. At Charlottesville in an ordinary season a large proportion of the first brood transforms, giving rise to a relatively large second brood, and with a fair crop of fruit the larvæ of the second brood taken under the bands should far exceed the first in numbers.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began emerging at Charlottesville on April 18. First-brood larvæ might be expected to have entered the fruit by April 28–30, though not in any number until several days later.

First-brood larvæ were taken under the bands June 5, and by August 1 probably most of them had left the fruit. First-brood moths appeared in the rearing cages on June 14, and in numbers June 23. Second-brood larvæ must have been entering fruit June 25–30, and were leaving by the last of July to the first of August.

INVESTIGATIONS AT GREENWOOD, VA.

DESCRIPTION OF LOCALITY.

Greenwood is situated about 18 miles west of Charlottesville, in a section of the Blue Ridge Mountains where commercial apple growing has been well established for years. In a mountain orchard section, such as this, there is considerable variation in the elevation of orchard sites. The orchard in which band-record experiments were conducted was at an altitude of about 900 feet above sea level. The work in this section for the season of 1912 is given in part only, the moth emergence of that summer being considered of sufficient importance to find a place in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

Table VI contains the emergence records of 180 moths as they occurred in the rearing cages at Greenwood in 1912. The first visit of the season to Greenwood was made on May 8, and the table shows that three moths were found in the jar of wintering larvæ at that time; while these may have emerged two or three days previously, from the number appearing two days later (May 10) it can be assumed that moth emergence was just beginning on May 8.

TABLE VI.—*Emergence of spring-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 8	3	May 30	34
10	11	June 3	15
14	18	7	5
18	28		
22	20	Total	180
26	46		

Some time was spent in the orchard in an unsuccessful search for eggs and young larvæ, and their absence indicates that moths had at least not been appearing in the field in numbers up to that time. Maximum emergence did not occur until May 26, although moths were appearing in some numbers during all of the period from May 10 to June 3. None emerged in the rearing cages after June 7, although, had more insects been under observation, an occasional adult would probably have appeared later.

FIRST-BROOD MOTHS.

The first collection of larvæ in 1912 was delayed until June 12, though as none of those taken under the bands at the time had pupated, the beginning of first-brood moth emergence was not seriously affected thereby. In all 639 moths appeared in the rearing cages between June 23 and August 28. (See Table VII.)

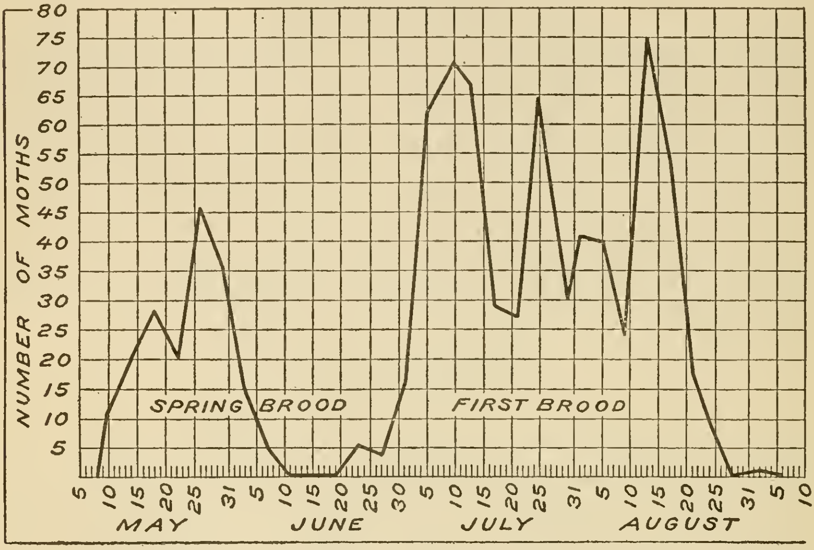

FIG. 5.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Greenwood, Va., in 1912.

TABLE VII.—*Emergence of first-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 23	6	Aug. 1	41
27	4	5	40
July 1	17	9	24
5	62	13	75
10	71	17	53
13	67	21	18
17	29	24	9
21	27	28	0
25	65		
29	30	Total	639

The seasonal appearance of the two broods of moths is given in figure 5.

Work at Greenwood was discontinued in 1913, the transformations of the codling moth being apparently so nearly the same as at Charlottesville that almost daily observation would be necessary to distinguish any variation at all, and according to the plan of work followed it was impossible to take records oftener than every three or four days.

INVESTIGATIONS AT HAGERSTOWN, MD.

DESCRIPTION OF LOCALITY.

Hagerstown, Md., is situated on a comparatively level portion of the lower Cumberland Valley. The country is more or less rolling, but the relative differences in altitude are not great, the actual elevation above sea level of most of this section being from 500 to 600 feet. There are a few large orchards in the vicinity, but fruit growing in a commercial way has not received much attention until recently. However, Hagerstown is not far from some very important fruit-growing districts on the east, the west, the north, and the south. Band-record experiments were carried on in this section for 1911, 1912, and 1913.

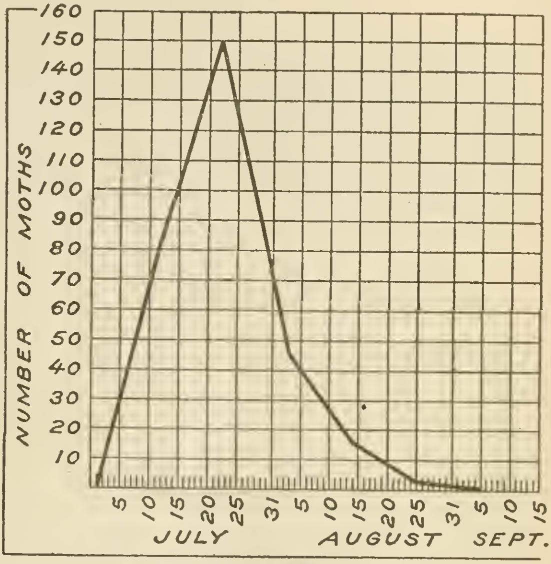

Fig. 6.—Diagram to illustrate emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.

INVESTIGATIONS IN 1911.

FIRST-BROOD MOTHS.

The long intervals between observations in 1911 (10 to 12 days) make the records of that year of rather doubtful value, and while they are included for Hagerstown and Pickens, it must not be understood that they are comparable in any but a general way to the data obtained in the two following years' work in these sections.

Table VIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.* (See fig. 6.)

Date of observation.	Number of moths emerging.
July 12	82
22	151
Aug. 3	46
14	16
Aug. 25	3
Total	298

The collection of larvæ from the bands, and the summer-brood moth emergence given in Table VIII, can be better appreciated by reference to figures 6 and 7, and it is doubtful if much could be added by a detailed discussion of the season's work.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

It will be noted that the records for spring-brood moth emergence given in Table IX were obtained at Smithsburg, Md., and therefore do not represent accurately what took place at Hagerstown. The Smithsburg section is 9 miles east of Hagerstown, at the foot of the Blue Ridge Mountains, and at a considerably higher elevation, and

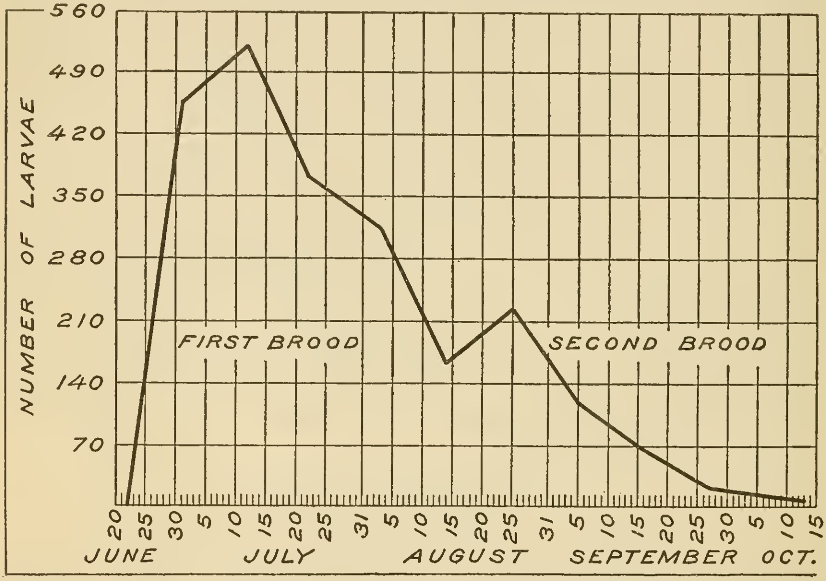

FIG. 7.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1911.

the seasonal conditions at Hagerstown are somewhat in advance of those at Smithsburg. However, no satisfactory record of moth emergence was obtained at Hagerstown in the spring of 1912, and as this was practically the only record of any value secured at Smithsburg, it is included in the report of the work in the former section.

TABLE IX.—*Emergence of spring-brood moths of the codling moth at Smithsburg, Md., in 1912.* (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 30	2	June 19	10
June 3	9	23	4
7	17		
11	23	Total	85
15	20		

It will be seen from figure 8 that emergence began on May 30, and reached its maximum on June 11, after which time the moths decreased in numbers, ceasing to appear altogether after June 23. It would probably be safe to say that the first-brood larvæ were entering fruit by June 1, or very soon thereafter.

FIRST-BROOD MOTHS.

The emergence records of 148 moths given in Table X were obtained from the material collected in the orchard at Hagerstown and represent fairly well the occurrence of the summer or first brood of moths in the field. The 148 moths accounted for in this table comprise all that transformed during that season of the 1,706 larvæ reared, a fact

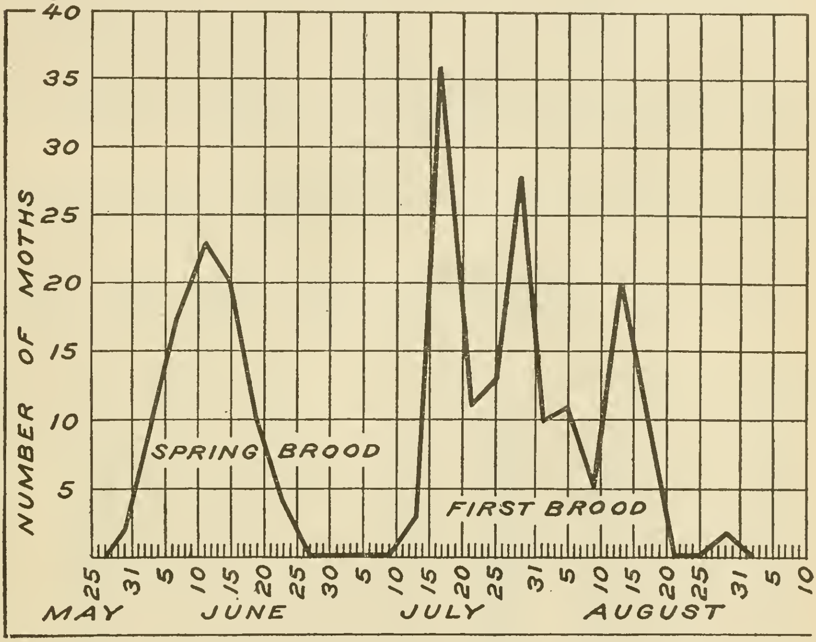

FIG. 8.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Smithsburg, Md., and first-brood moths at Hagerstown, Md., in 1912.

which probably accounts for the relatively small number of second-brood larvæ that appeared under the bands later in the summer (see fig. 9).

TABLE X.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1912.* (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 13	3	Aug. 13	20
17	36	17	9
21	11	21	....
25	13	25	....
29	28	29	2
Aug. 1	10		
5	11	Total	148
9	5		

First-brood moths began to emerge on July 13, and emergence continued throughout the remainder of July and the fore part of August. Two adults appeared as late as August 29, though emergence had practically ceased August 17. The codling moth is very sensitive to weather conditions, its development being especially retarded by cold, and the irregularity in the emergence curve of first-brood moths in figure 8 is due, in part at least, to extreme temperature variations of the season.

Second-brood larvæ probably began entering fruit at Hagerstown in 1912, about July 23 to 27.

BAND COLLECTIONS.

Altogether 1,706 larvæ were taken from the bands at Hagerstown in 1912. (See Table XI.) The trees used were of the York Imperial variety, about 15 years old, smooth bodied and loaded with fruit. Bands were placed in the fore part of June and examinations made every three or four days, beginning June 15.

Table XI.—*Number of larvæ of the codling moth taken from the bands and reared at Hagerstown, Md., during the summer of 1912 and the spring of 1913.* (See fig. 9.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number emerged, 1912.	Number overwintering.	Number winter-killed.	Number emerged, 1913.
June 29	11	4	7			
July 1						
5	58		42	16	7	9
9	55	24	28	3	3	
13	144	27	42	75	24	51
17	240	53	15	172	109	63
21	183	44	2	137	137	
25	207	61	10	136	100	36
29	228	75	2	151	112	39
Aug. 1	117	22		95	40	55
5	97	18		79	25	54
9	59	12		47	36	11
13	35	5		30	23	7
17	30	2		28	11	17
21	15	10		5		5
25	60	31		29	19	10
30	30	8		22	2	20
Sept. 2	48	22		26	19	7
6	16	9		7	7	
10	21	7		14	7	7
14	16	4		12	8	4
18	28	8		20	13	7
22	8	2		6	4	2
Total	1,706	448	148	1,110	706	404
Per cent	100	26.26	8.68	65.06	41.38	23.68

From figure 9 it will be seen that the first larvæ appeared under the bands on June 29, the numbers gradually increasing through July. From August 1 to 21 the collections decreased, increasing again slightly after the latter date, and it is probable that second-brood larvæ were beginning to leave the apples about this time. Only 8.68 per cent of the first-brood larvæ transformed to moths, which explains the relatively small second brood of larvæ shown in figure 9.

Comparison of figures 7 and 9 would suggest that, in the relative numbers of the two broods of larvæ appearing under the bands, the seasons of 1911 and 1912 were very similar.

As has already been said, only 8.68 per cent of the 1,706 larvæ taken under the bands at Hagerstown in 1912 transformed to moths that summer. The percentage of 26.26 that died in the rearing cages from handling, cannibalism, disease, immaturity, and other causes compares closely with that observed at other points, and the rearing work was evidently done with as much care and under as favorable conditions as in the localities where a much larger proportion of the first brood transformed; 65.06 per cent wintered, 41.38 per cent were winter-killed, and 23.68 per cent emerged as moths

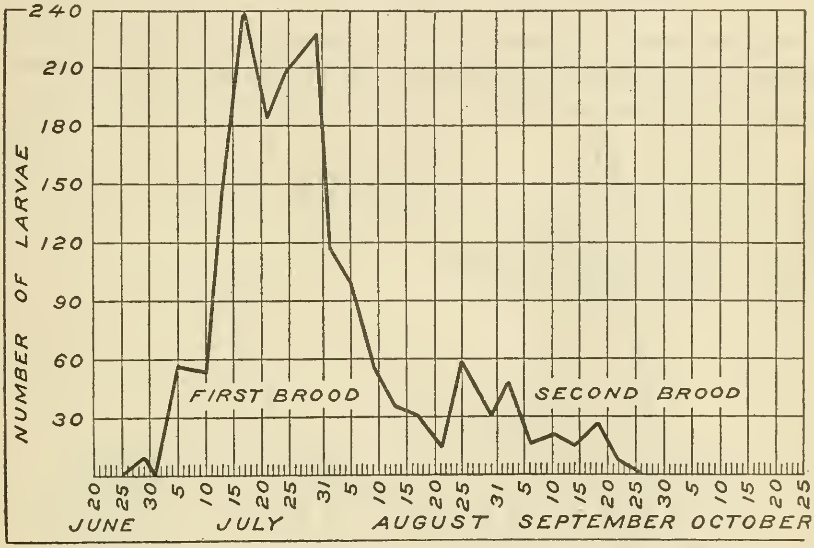

FIG. 9.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1912.

in the spring of 1913. The percentage of winter-killed larvæ at Hagerstown was much larger than in other localities that year.

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in rearing cages at Smithsburg, Md., on May 30 (probably several days later than at Hagerstown). First-brood larvæ were probably entering fruit 10 to 12 days later (soon after June 1, at Hagerstown). First-brood larvæ were leaving apples in the field from June 25 to 29 to August 17 to 21.

First-brood moths began emerging from field-collected material on July 13. Second-brood larvæ probably began feeding soon after July 23, and were leaving the fruit in numbers soon after August 21.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Table XII gives the emergence of moths of the spring brood at Hagerstown in 1913.

TABLE XII.—*Emergence of spring-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 15	2	June 5	45
18	6	8	22
21	12	11	25
24	9	27	81
27	38		
30	77	Total	404
June 2	87		

The first moths appeared in the rearing cages on May 15, but maximum emergence did not occur until May 30 to June 2. Careful

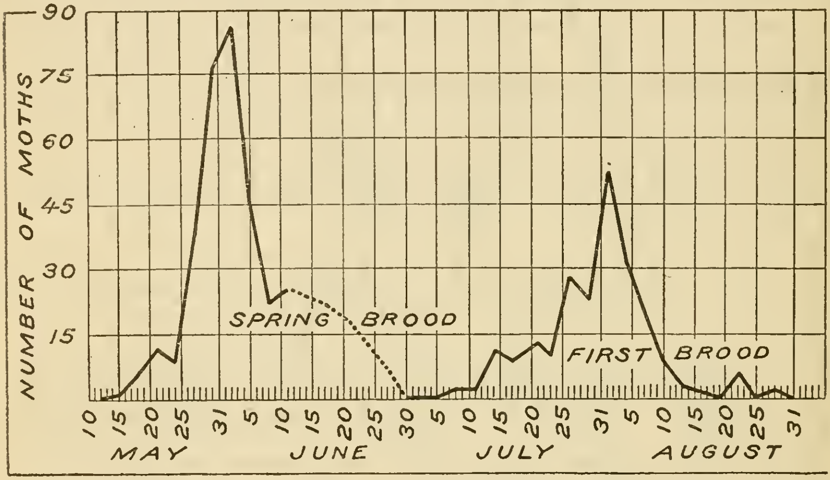

FIG. 10.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Hagerstown, Md., in 1913.

records were taken every three days up to and including June 11, but from June 11 to June 27 observations were discontinued, as indicated by the dotted line in figure 10. However, of 404 moths accounted for in Table XII, all but 81 had emerged by June 11, and the break from then until June 27 does not seriously affect the value of the records. Allowing 10 to 12 days for egg laying and incubation, first-brood larvæ were evidently beginning to feed by May 25 to 27.

FIRST-BROOD MOTHS.

The relation of the two broods of moths emerging at Hagerstown in 1913 is clearly illustrated in figure 10. Adults appeared in the rearing jars with more or less regularity from July 8 to August 10. Emergence ceased altogether on August 28. (See also Table XIII.)

TABLE XIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 8	2	Aug. 7	20
11	2	10	8
14	11	13	3
17	8	16	1
21	13	19	0
23	10	22	6
26	29	25	0
29	23	28	2
Aug. 1	53		
4	31	Total	222

Probably a few second-brood larvæ were entering fruit in the field by July 20 to 25.

BAND COLLECTIONS.

In Table XIV are given the records of the collections and rearings of 2,756 larvæ taken under the bands at Hagerstown in the summer of 1913.

TABLE XIV.—*Number of larvæ of the codling moth taken from bands and reared at Hagerstown, Md., during the summer of 1913.* (See fig. 11.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number overwintering.
June 27	3	1	2	
30	12	4	8	
July 2	38	12	17	9
5	30	6	18	6
8	78	19	24	35
11	86	31	34	21
14	136	38	41	57
17	95	22	24	49
21	181	53	28	100
23	116	22	14	80
26	150	77	7	66
29	108	44	4	60
Aug. 1	105	40		65
4	73	11	1	61
7	109	36	3	70
10	108	27	1	80
13	101	11		90
16	148	49	1	98
19	121	41		80
22	110	28		82
25	26	6		20
28	128	[1] 104		24
31	92	16		76
Sept. 3	203	48		155
6	111	34		77
9	127	61		66
12	42	8		34
15	32	12		20
18	14	4		10
21	18	8		10
25	9	5		4
27	17	1		16
30	9	3		6
Oct. 3	5			5
6	5	1		4
9	6			6
12	2			2
15	1			1
18	1			1
Total	2,756	883	227	1,646
Per cent	100	32.04	8.24	59.72

[1] Eaten by mice.

Larvæ began to appear on June 27, and were taken under the bands in numbers through the remainder of June, all of July, and part of August. It will be noticed that on August 25 (fig. 11) there was a sharp decrease in the number of insects collected. Considering the time first-brood moths began appearing in the rearing cages at Hagerstown, and correlating with what was taking place at Winchester and elsewhere, second-brood larvæ very likely began appear-

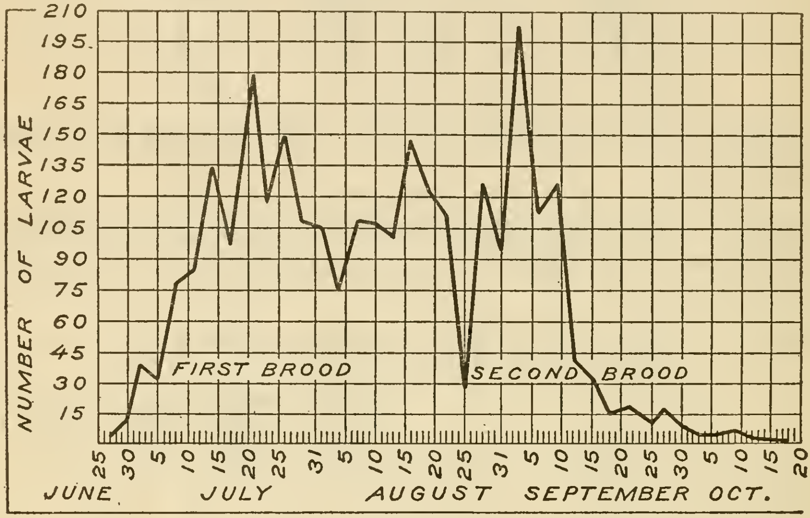

FIG. 11.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1913.

ing under the bands soon after August 25, though an unusual overlapping of the two broods of larvæ is apparent in the collections. Records were discontinued about October 25, though no larvæ appeared under the bands later than October 18.

The 8.24 per cent of transforming larvæ taken under the bands at Hagerstown in 1913 compares closely with the 8.68 per cent that transformed in 1912. The 32.04 per cent of larvæ that died from handling, cannibalism, etc., in 1913 is much higher than has usually been observed, due in part to the fact that one jar of larvæ was devoured by mice, and discarding consideration of this cage the loss is brought down to 29.37 per cent. The 59.72 per cent of wintering larvæ is only slightly less than the 65.06 per cent obtained in 1912.

SUMMARY FOR SEASON OF 1913.

Spring-brood moth emergence began May 15 and closed June 27. Allowing 10 to 12 days from emergence to hatching of first eggs, we might expect that first-brood larvæ began entering the apples May 25 to 27. First-brood larvæ appeared under the bands on June 27. First-brood moths began to emerge in the rearing cages on July 8, though not in numbers until July 11 to 14. Second-brood larvæ were probably beginning to enter the fruit about July 20 to 25 and were leaving in numbers after August 25.

INVESTIGATIONS AT WINCHESTER, VA.

DESCRIPTION OF LOCALITY.

Winchester, the county seat of Frederick County, Va., is one of the principal shipping points for a large and well-developed apple-producing territory in the northern part of the Shenandoah Valley. The altitude of most of the country immediately surrounding Winchester varies from 650 to 800 feet above sea level; thus the relative variations in elevation are not great and the seasonal conditions are fairly uniform for the whole section. The life-history studies of the codling moth in this section for the seasons of 1912 and 1913 follow.

In Table XV are included the emergence records of 94 moths that issued at Winchester in the spring of 1912.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

TABLE XV.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 22	2	June 11	8
26	4	15	4
30	19	19	1
June 3	26	23	3
7	26	27	1
		Total	94

The first moth appeared in the laboratory rearing cages between May 18 and 22, though observations indicate that moths emerged several days earlier in the field. On the 24th of May eggs were rather common in the orchard, and two newly hatched larvæ were found just entering apples. Certainly moths were emerging in the field, in 1912, not later than May 15. By May 30 first-brood larvæ were observed entering fruit in the orchard in considerable numbers. The last spring-brood moth emerged June 27.

The fruit was unusually large when attacked by the codling moth in 1912, and it is of some interest to note that curculio cuts and rough spots on the apples were more frequently used by the first-brood larvæ as points of entrance than was the calyx end of the fruit.

The first of the 1912 summer or first-brood moths emerged on July 9. Eggs were laid by moths in confinement on July 13, by moths emerging during the period from July 9 to 13, but since one moth issued

July 9 it is possible oviposition began two or three days earlier in the field. Moths emerged in the rearing cages until August 21. (See Table XVI.)

FIRST-BROOD MOTHS.

TABLE XVI.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 9	1	Aug. 2	25
13	20	6	8
17	25	10	23
20	27	14	18
25	27	18	13
29	33	21	8
		Total	228

The relation of the two broods of moths can be better understood by reference to figure 12, where their seasonal appearance is represented graphically.

BAND COLLECTIONS.

An old unsprayed orchard located about a mile south of Winchester was used for the band-record experiments of 1912. The trees

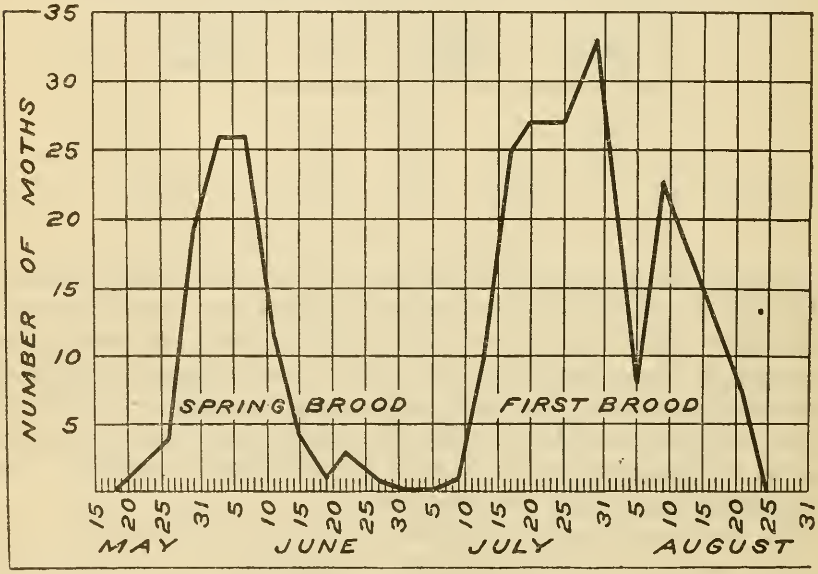

FIG. 12.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1912.

were of late fall and winter varieties well laden with fruit, and the infestation was very extensive, practically every apple being attacked by one or more codling-moth larvæ at some time during the season.

One larva was taken under the bands on June 19. The number collected increased throughout the remainder of June and the first half of July. By referring to figure 13 it will be noticed that during the fore part of August there occurred a series of very small collections, and about this time evidently most of the first-brood larvæ had left the fruit, while those of the second brood were still feeding. On July 15 newly hatched larvæ were observed entering fruit in the field in sufficient numbers to exclude the probability of their belonging to the first brood, especially since the last of the spring-brood moths appeared on June 27. The second-brood larvæ did not hatch in the laboratory until July 19, but this was probably three or four days behind field conditions. Allowing for a normal feeding

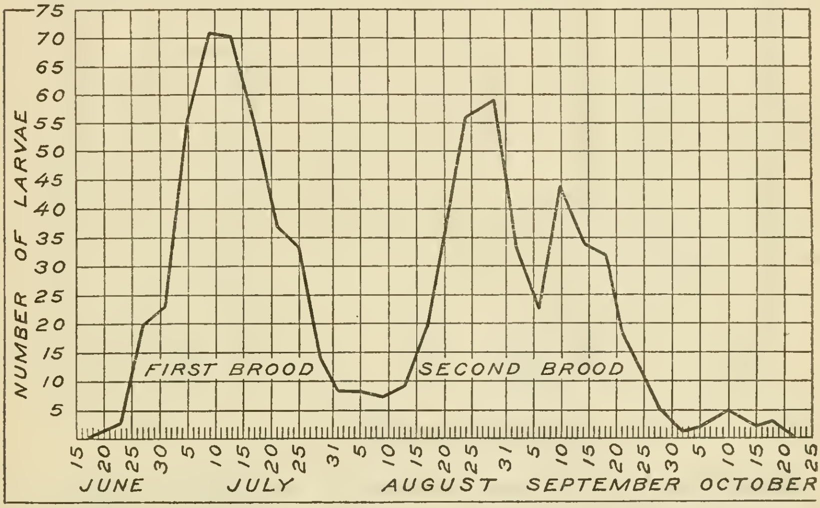

Fig. 13.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1912.

period, some of the second-brood larvæ should have been leaving the apples about August 9 to 13. The collections increased through the latter part of August and the first half of September. No larvæ appeared under the bands after October 18.

During the season of 1912 at Winchester 798 larvæ were taken from the bands and reared. Of these 27.19 per cent were killed in handling or were devoured by their fellows after being placed in the rearing cages; 28.57 per cent emerged as moths of the first brood; 1.38 per cent were parasitized; 42.86 per cent of the larvæ collected wintered, and 15.04 per cent were winter killed; 27.44 per cent passed the winter successfully and emerged the following season, while 0.38 per cent represents the proportion of parasites that issued in the spring of 1913. (See Table XVII.)

TABLE XVII.—*Number of larvæ of the codling moth taken from the bands and reared at Winchester, Va., during the summer of 1912 and the spring of 1913.* (See fig. 13.)

Date of collection, 1912.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emerged, 1912.		Number of larvæ overwintering.	Number of larvæ winter-killed.	Emerged, 1913.	
			Moths.	Parasites.			Moths.	Parasites.
June 19	1		1					
23	3		3					
27	20	5	14		1	1		
July 1	23		23					
5	56	16	36	3	1	1		
9	71	24	42	4	1		1	
13	70	31	37	1	1		1	
17	56	16	31	3	6	2	4	
21	37	11	19		7	1	6	
25	33	17	11		5	1	4	
29	14	2	6		6		6	
Aug. 1	8	1	4		3		3	
5	8		1		7		7	
9	7	1			6	2	4	
13	9	1			8		8	
17	19	5			14	4	10	
21	37	7			30	8	21	1
24	56	4			52	19	33	
29	59	3			56	29	27	
Sept. 2	32	14			18	6	10	2
6	22	6			16	7	9	
10	44	17			27	15	12	
14	34	3			31	14	17	
18	32	6			26	10	16	
21	18	10			8		8	
25	11	6			5		5	
28	5	2			3		3	
Oct. 2	1				1		1	
5	2	1			1		1	
10	5	4			1		1	
15	2	1			1		1	
18	3	3						
Total	798	217	228	11	342	120	219	3
Per cent	100	27.19	28.57	1.38	42.86	15.04	27.44	0.38

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 to 22, and probably two or three days earlier in the field. First-brood larvæ began entering the fruit in the field May 24. First-brood larvæ began leaving the apples June 19. First-brood moths began emerging July 9; second-brood larvæ were observed entering fruit in the field on July 15, and a few had finished feeding by August 9 to 13.

INVESTIGATIONS IN 1913.

SPRING-BROOD AND FIRST-BROOD MOTHS.

The seasonal conditions of the spring of 1913 were considerably in advance of those of 1912, and the appearance of the spring-brood moths was correspondingly earlier. Moths appeared in numbers on May 6 and maximum emergence occurred three days later.

TABLE XVIII.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1913.* (See fig. 14.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6	18	June 2	14
9	38	5	10
12	6	8	6
15	16	11	3
18	30	14	7
21	29	17	3
24	8	20	1
27	16		
30	14	Total	219

Moths continued to issue in the rearing cages until June 20. The irregularity of the emergence curve in figure 14 is due in most cases

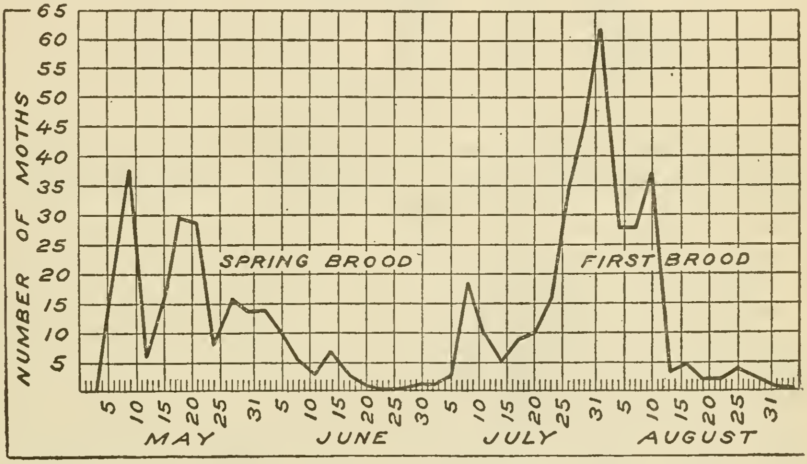

FIG. 14.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1913.

to fluctuations in temperature. The first moth emergence in confinement occurred 16 days earlier in 1913 than in 1912, but since adults were probably appearing in the field in 1912 not later than May 15, we may assume that spring-brood emergence began in the field only 10 to 12 days earlier in 1913.

The seasonal appearance of the two broods of moths can perhaps be best appreciated by referring to figure 14. The emergence of 326 moths of the first brood are given in Table XIX. The first adults of this brood appeared in the laboratory in 1913 on June 30, nine days earlier than in 1912. However, not until July 5 to 8 did adults appear in any numbers, and in reality the difference in the time of appearance of summer, or first-brood, moths in the two seasons is very slight. Maximum emergence was not attained until one month later, or about August 1. The last of the first-brood moths emerged in the rearing cages on September 1.

TABLE XIX.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1913.* (See fig. 14.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 30	1	Aug. 4	28
July 2	1	7	28
5	3	10	37
8	19	13	3
11	10	16	5
14	5	19	2
17	9	22	2
20	10	25	4
23	16	29	2
26	33	Sept. 1	1
29	45		
Aug. 1	62	Total	326

BAND COLLECTIONS.

In 1913 bands were placed on 12 old apple trees in an orchard located about 2 miles south of Winchester. The rough bark was

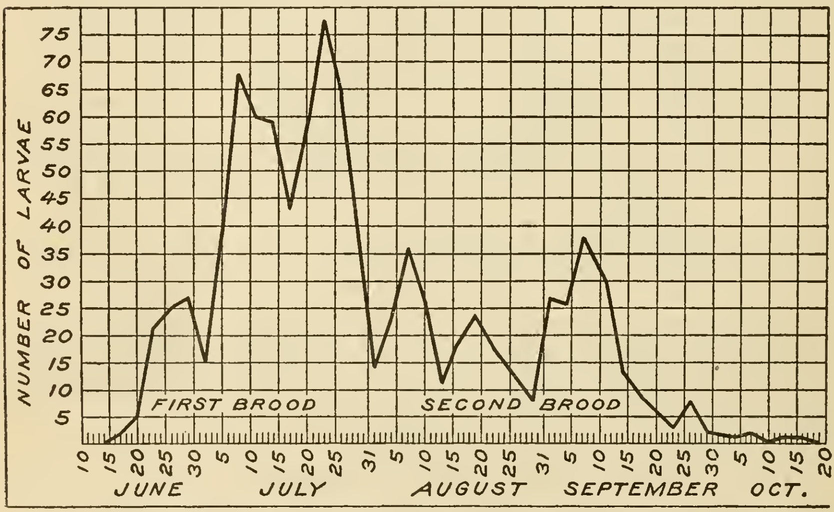

FIG. 15.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1913.

scraped down and other hiding places of the insect destroyed, and on the whole probably most of the larvæ that left the fruit during the season found their way under the bands. The record of collections is given in Table XX.

TABLE XX.—*Record of codling-moth larvæ taken from the bands and reared at Winchester, Va., in 1913.* (See fig. 15.)

Date of collection.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emerged, 1913.		Number overwintering.
			Moths.	Parasites.	
June 17	2		2		
20	5	3	2		
23	22	4	14	4	
26	25	9	16		
29	27	5	15	7	
July 2	15	6	9		
5	38	23	15		
8	68	14	40	13	1
11	60	8	47		5
14	59	19	31	2	7
17	43	8	24	5	6
20	57	6	31	8	12
23	84	9	38	11	26
26	63	3	22	12	26
29	38	14	8	3	13
Aug. 1	14	7	3		4
4	23	6	3		14
7	36	11	3		22
10	26	9	2		15
13	11	6	1		4
16	19	9			10
19	24	9			15
22	18	9			9
25	14	5			9
29	8	2			6
Sept. 1	27	16			11
4	26	7			19
7	38	7			31
11	30				30
14	13				13
17	9				9
20	6				6
23	3				3
26	8				8
29	5				5
Oct. 1	2				2
4	1				1
7	2				2
10					
13	1				1
16	1				1
Total	971	234	326	65	346
Per cent	100	24.10	33.57	6.70	35.63

Careful examination of the bands was made, beginning about June 1, but no larvæ were taken until June 17, only two days earlier than in 1912, in spite of the fact that the first of the spring-brood moths were probably 10 to 15 days earlier than in the former season. From June 17 the collections increased until about August 1, when the numbers of insects collected decreased slightly, the proportion of those wintering increasing, and probably by August 7 to 10 most of the larvæ taken were of the second brood. The fact that the second brood did not equal the first in numbers and were somewhat irregular in their appearance under the bands is explained by the short fruit crop of the year.

Altogether 971 larvæ were collected and reared. Of this number 24.10 per cent were killed by handling, cannibalism, etc., the loss from this source being about the same as the 27.19 per cent that died from similar causes in 1912; 33.57 per cent were transformed to first-brood moths and 6.70 per cent were parasitized. The light fruit crop already noted reduced the number of wintering larvæ to 35.63 per cent.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began to emerge May 6, and a few first-brood larvæ were probably entering the fruit by May 16. First-brood larvæ began to appear under the bands in the orchard June 17, and from these larvæ a few first-brood moths emerged in the laboratory on June 30. Second-brood larvæ were probably entering fruit in numbers by July 15; they began leaving fruit about August 13.

INVESTIGATIONS AT FISHERSVILLE, VA.

DESCRIPTION OF LOCALITY.

Fishersville is the shipping point for a part of the Shenandoah Valley, in which commercial fruit growing has for years been of considerable importance. While in approximately the same latitude as Charlottesville, the seasonal conditions of this section are decidedly different chiefly on account of the much higher altitude; in fact, there is a much greater similarity of conditions between Fishersville and Winchester, both of which are in the Shenandoah Valley, than between Fishersville and Charlottesville, between which two points the Blue Ridge Mountains intervene. Differences in humidity and other climatic conditions occur between these two regions that may effect the development of the codling moth and that may not be entirely accounted for by differences in altitude. The band-record experiments were carried on in locations 1,400 to 1,500 feet above sea level, which is probably about the average elevation of orchards in this section.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

In a limited way the emergence dates of 119 moths given in Table XXI probably represent fairly well the occurrence of the spring brood at Fishersville in 1912. The rearing material was collected from the bands in the fall of 1911.

TABLE XXI.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 18	5	June 15	1
22	13	19	.....
26	14	23	.....
30	42	27	1
June 3	27		
7	5	Total	119
11	11		

Emergence began on May 18 and reached its highest numbers on May 30, 12 days later. However, since first-brood larvæ appeared under the bands on June 11, it is probable that moths emerged in the field several days prior to May 18. The moths continued to emerge through the remainder of May and in lessening number through the most of June, ceasing to appear altogether after June 27.

The records of the appearance of 273 moths of the first brood that issued from band-collected material at Fishersville in the summer of 1912 are given in Table XXII.

FIRST-BROOD MOTHS.

TABLE XXII.—*Emergence of first-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 2	5	Aug. 1	15
5	7	5	13
9	35	9	16
13	30	13	1
17	55	17	3
21	35	21	1
25	31		
29	26	Total	273

The work at Fishersville in 1912 was carried on under very ideal conditions, and July 2, the time when the first-brood moths began emerging in the rearing cages, represents field conditions as nearly as is possible with band-collected rearing material. The time of first appearance for the first-brood moths was seven days in advance of Winchester, while between the first emergence of spring-brood moths there was a four-day difference in the two sections.

Moths appeared in numbers through July and the first half of August, attaining their maximum on July 17. The last moth appeared in the rearing cages on August 21. The relative time of appearance of the two broods of moths at Fishersville in 1912 is shown in figure 16.

BAND COLLECTIONS.

About 12 smooth-bodied young York Imperial and Ben Davis apple trees were banded at Fishersville in 1912. On the whole the records given in Table XXIII and figure 17 represent fairly well the time the two broods of larvæ were leaving the fruit that season. Three larvæ were taken under the bands on July 11 and the number increased in the succeeding collections until about July 1, when the number gradually decreased until the fore part of August. By August 1 a large part of the first brood had left the fruit, as is evidenced in the band-record curve of figure 17.

Since first-brood moths emerged in the rearing cages on July 2, larvæ hatching from eggs laid by these moths might reasonably be expected to begin feeding by July 12 to 15. After August 9 the

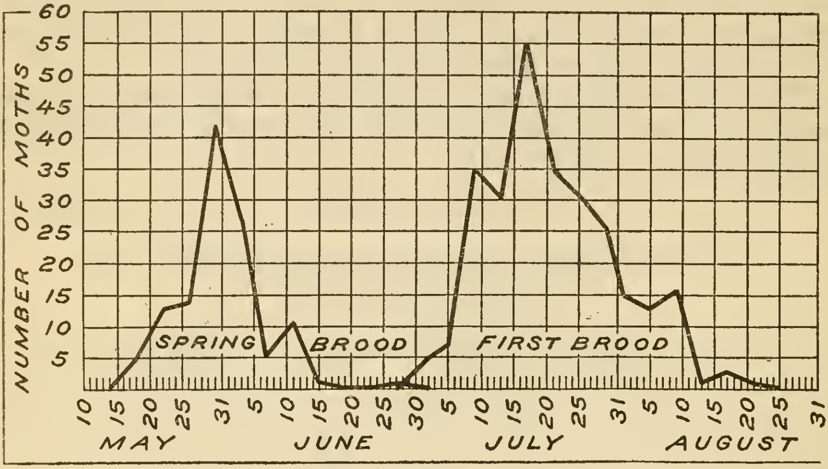

FIG. 16.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Fishersville, Va., in 1912.

collections increased to the middle of September. Second-brood larvæ continued to appear under the bands until November 1, when the fruit was picked and the records discontinued.

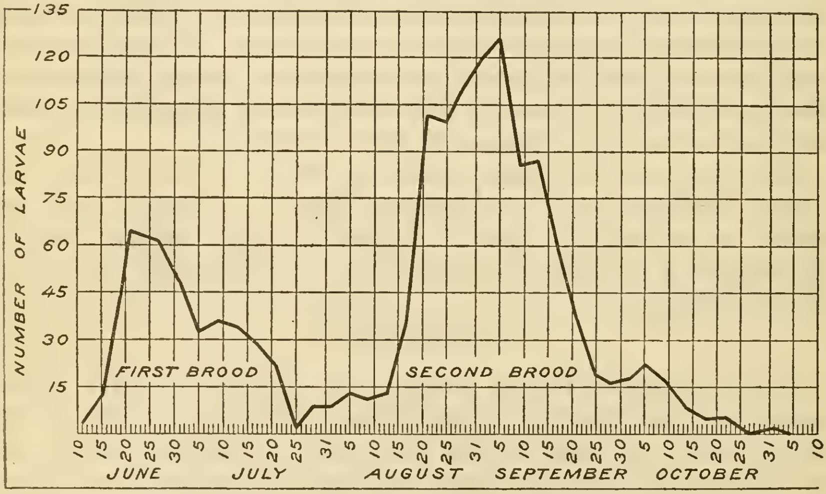

FIG. 17.—Diagram to illustrate band collections of larvæ of the codling moth at Fishersville, Va., in 1912.

In Table XXIII are recorded the numbers of larvæ taken in the orchard at different dates through the season. Altogether 1,418 larvæ were collected and reared, of which 12.90 per cent were killed by handling or devoured by their fellows in the rearing cages; 19.96 per cent emerged as adults during the summer of 1912; 67.14 per cent wintered and 24.19 per cent were winter killed; and 42.95 per cent emerged as moths in the spring of 1913.

TABLE XXIII.—*Number of larvæ of the codling moth taken from the bands and reared at Fishersville, Va., during the summer of 1912 and the spring of 1913.* (See fig. 17.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from cannibalism, etc.	Number of moths emerging, 1912.	Number of larvæ over-wintering.	Number of larvæ winter killed.	Number of moths emerging, 1913.
June 11	3	1	2			
15	12	3	9			
19	43	13	30			
21	64	41	23			
27	61	11	50			
July 1	48	14	34			
5	32	5	27			
9	35		28	7		7
13	34	3	28	3		3
17	29		23	6		6
21	22	2	16	4		4
25	1		1			
29	9	1	2	6		6
Aug. 1	9		5	4	2	2
5	14		4	10		10
9	11	1	1	9		9
13	13	2		11	9	2
17	36			36	12	24
21	101	2		99	46	53
25	100	17		83	43	40
28	109	14		95	44	51
Sept. 1	120	23		97	34	63
5	127	15		112	39	73
9	86	6		80	28	52
13	88	2		86	37	49
17	61	2		59	32	27
21	37			37	11	26
25	19			19		19
28	16			16	3	13
Oct. 2	18			18		18
5	22	3		19		19
9	17	1		16	3	13
14	8			8		8
18	5			5		5
22	6	1		5		5
27						
Nov. 1	2			2		2
Total	1,418	183	283	952	343	609
Per cent	100	12.90	19.96	67.14	24.19	42.95

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 and probably several days earlier in the field. Ten to 12 days later first-brood larvæ were probably beginning to enter fruit. First-brood larvæ began leaving the fruit June 11. First-brood moths emerged July 2 to August 21, and second-brood larvæ probably were entering fruit by July 12. Soon after August 5 to 9 the number of larvæ appearing under the bands increased, and most of the larvæ taken after this date may be considered to be of the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Figure 18 represents the occurrence of 608 moths of the spring brood that appeared in the rearing cages at Fishersville in 1913. Moths emerged first on May 3, but maximum emergence was delayed until May 30, the emergence curve in figure 18 for Fishersville being very different in this respect from the spring-brood curve at Winchester, as it appears in figure 14. Adults continued to emerge until June 27. (See also Table XXIV.)

TABLE XXIV.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.* (See fig. 18.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 3	6	June 5	44
6	1	8	10
9	3	11	9
12	9	14	22
15	11	17	10
18	53	20	7
21	28	24	3
24	94	27	2
27	91		
30	124	Total	608
June 2	81		

First-brood larvæ were probably entering the fruit in the field by May 10 to 13, from eggs laid by moths emerging May 1 to 3.

On account of the light crop of fruit in 1913 the records at Fishersville for the remainder of the season are of little value and are not included in this report

INVESTIGATIONS AT FRENCH CREEK, W. VA.

DESCRIPTION OF LOCALITY.

French Creek is located near the lower border of the Transition Life Zone in a hilly region not far from the center of West Virginia. Commercial apple growing is just beginning to attract attention, and several orchards of considerable size are being planted in that general locality. Bearing orchards of from 5 to 25 acres are not uncommon. The orchards from which banding records were obtained are located at an approximate elevation of 1,600 feet above the level of the sea.

INVESTIGATIONS IN 1911.

On June 19, 1911, 15 suitable apple trees in an orchard that had never been sprayed were banded, but it was found that the bands were placed too late in the season to obtain a complete record of the time of emergence from the fruit of the first-brood larvæ. The bands furnished a supply of wintering larvæ to be used for emergence records of the spring brood of moths in 1912.

Predaceous and parasitic enemies of the codling moth were possibly more abundant here than in any other orchard in which banding records were made during the investigation. The second-brood larvæ were very extensively parasitized by hairworms (*Mermis* sp.). Of the larvæ of this brood, 71 out of 159, or nearly 50 per cent, died from this cause.

The first-brood moths began to appear in the jars on July 5, when five were found. The maximum was reached on July 8, and from that time the numbers gradually diminished until September 13, when the last two of the season appeared.

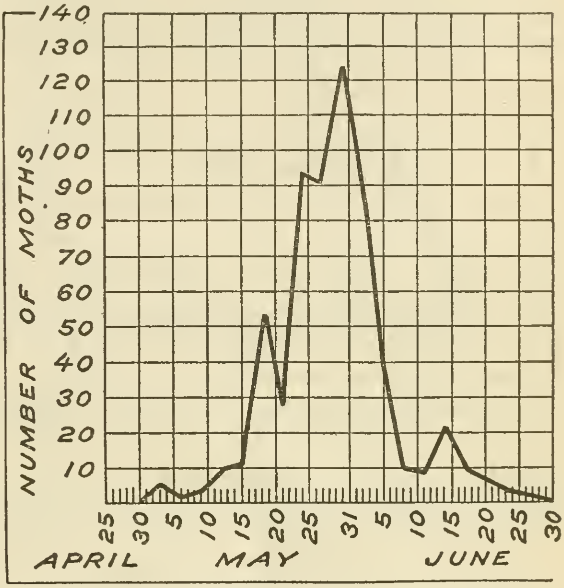

FIG. 18.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

On account of the high mortality, due to parasites and other causes, only about 50 wintering larvæ were alive to pupate in the spring. Pupation took place from April 22 to 28.

TABLE XXV.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1912.* (See fig. 19.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 13	1	May 25	16
14	2	29	4
16	3	June 1	2
21	8	Total	36

Table XXV shows that the first moths of this brood issued on May 13, the last on June 1, and the greatest number on May 25. The last petals were dropping from apple on May 10, so that the first moth appeared 3 days after the blossoms were off and the maximum moth emergence occurred from 10 to 12 days later.

FIRST-BROOD MOTHS.

As indicated in Table XXVI, first-brood moths made their appearance in the jars on July 20, when seven were found. The number increased up to July 28, and from that date until August 17 maximum

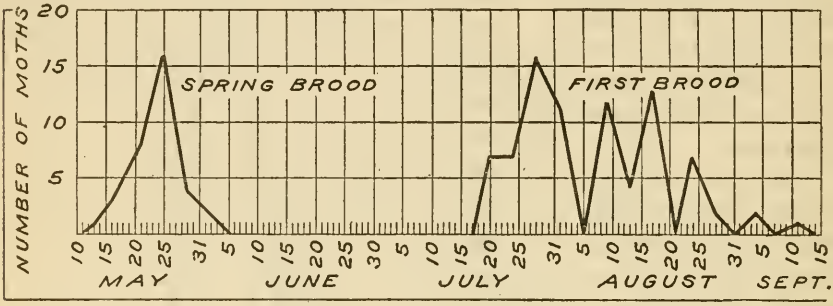

FIG. 19.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1912.

numbers appeared. After the latter date the numbers decreased until September 11, when the last one issued.

TABLE XXVI.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1912.* (See fig. 19.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 20	7	Aug. 24	7
24	7	28	2
28	16	31	.....
Aug. 1	11	Sept. 4	2
5	.....	7	.....
9	12	11	1
13	4		
17	13	Total	82
21	.....		

BAND COLLECTIONS.

About the middle of June, 12 apple trees were banded in an old orchard that had never been sprayed. The bands were examined twice each week. This year the larvæ were later by at least a week in beginning to leave the fruit than in 1911. The extent and dates of the collections are set forth in Table XXVII and figure 20.

TABLE XXVII.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., during the season of 1912.* (See fig. 20.)

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
June 24..	2	Aug. 5...	7	Sept. 18...	20
26..	0	9...	8	21...	22
29..	2	13...	10	25...	24
July 3...	5	17...	12	28...	13
6...	7	21...	12	Oct. 2....	8
10...	19	24...	6	5....	14
13...	12	28...	7	9....	8
17...	16	31...	5	12....	5
20...	10	Sept. 4....	17	16....	2
24...	16	7....	11		
28...	13	11...	10	Total.	339
July 31....	5	14...	11		

The first two larvæ were found on June 24. After June 26 the numbers increased with each collection until July 10. From that

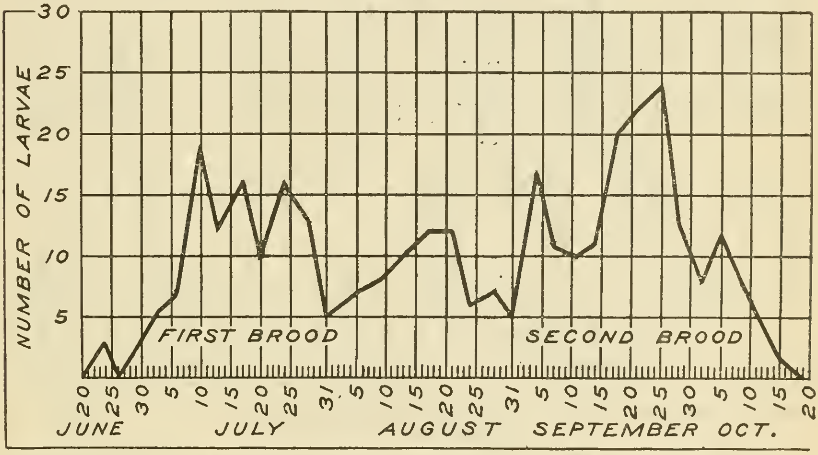

FIG. 20.—Diagram to illustrate band collections of codling moth larvæ at French Creek, W. Va., in 1912.

date until July 28 the size of the collections remained fairly constant. Collections were smaller from July 31 to August 13, after which time they increased until September 25, decreasing thereafter until October 16, when the last two were taken.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The details of the spring-brood moth emergence are set forth in Table XXVIII and are also shown graphically in figure 21.

TABLE XXVIII.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6	1	June 7	11
10	11	10	0
13	4	14	8
17	18	17	6
20	25	21	5
24	4	24	2
27	11		
31	9	Total	134
June 3	19		

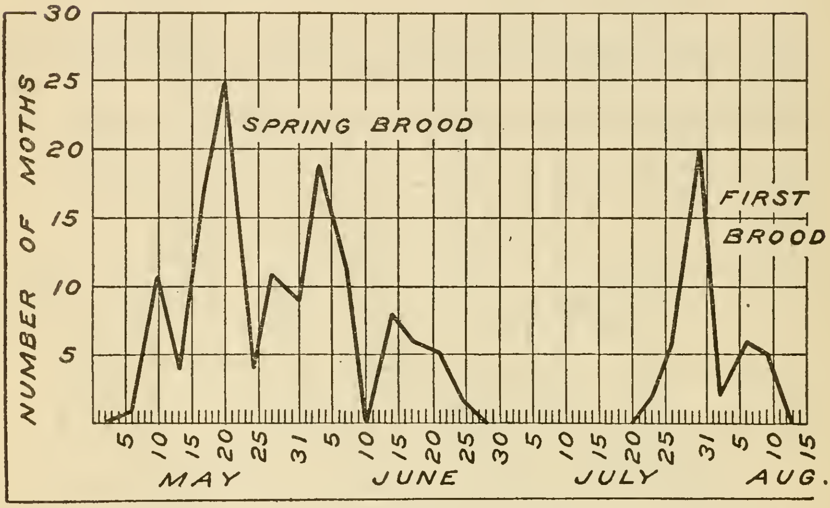

FIG. 21.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1913.

The first moth was found in the jars on May 6, the maximum numbers from May 17 to June 7, and the last on June 24. A freeze occurring on the night of April 20 caught the apple trees just coming into full bloom, practically destroying the entire crop of blossoms. The first moth appeared 16 days after the date of the freeze, and the maximum emergence was a little more than four weeks after the freeze.

FIRST-BROOD MOTHS.

Owing to the light crop of apples only a few larvæ were obtained, and the number of first-brood moths emerging was insignificant. Table XXIX shows the number that were obtained.

TABLE XXIX.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 23	2	Aug. 6	6
26	6	9	5
30	20		
Aug. 2	2	Total	41

It will be seen from this table that only 41 first-brood moths were obtained. Of these the first emerged on July 23, the maximum number on July 30, and the last on August 9.

BAND COLLECTIONS.

A period of cold, occurring April 20 and 21, when the temperature dropped to 20° F., followed by another drop to 25° F. on the night of May 10, destroyed practically all the apple crop in the locality. One old orchard containing a few bearing trees that were not sprayed was found and eight of the trees were banded on July 1. Table XXX shows the number of larvæ collected under these bands.

TABLE XXX.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., in 1913.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 5	6	Aug. 6	6	Sept. 6	4
9	17	9	4	10	1
12	19	13	7	13	2
16	18	15	6	17	2
19	5	20	7	20	0
23	8	23	6	24	1
26	10	27	4		
30	3	30	4	Total	143
Aug. 2	1	Sept. 3	2		

This table shows that the first larvæ were found under the bands on July 5, the greatest number, which was 19, on July 12, and the last on September 24. The second-brood larvæ were few in number, the collections being nearly uniform from August 6 to 23, after which time they decreased until the last was found.

INVESTIGATIONS AT PICKENS, W. VA.

DESCRIPTION OF LOCALITY.

The orchard at Pickens in which banding records were obtained in 1911 and 1912 is located in a mountainous region at an elevation of 3,500 feet above the level of the sea. The native flora and fauna of the immediate locality indicate the junction of the Transition and

Canadian Life Zones. Fruit growing is not extensively engaged in, although a considerable quantity of apples is produced and disposed of in lumber camps and other local markets.

The codling moth was less abundant here than in other localities where banding records were made. This was probably due to the higher elevation and the consequently shorter breeding season. Data were collected only in 1911 and 1912, the apple crop being an entire failure in 1913.

INVESTIGATIONS IN 1911.

On the 22d of June, 18 apple trees were banded in the orchard of Mr. Lewis Wunchner, 4 miles southeast of the village of Pickens. The orchard had never been sprayed and most of the trees banded were bearing heavy crops of fruit.

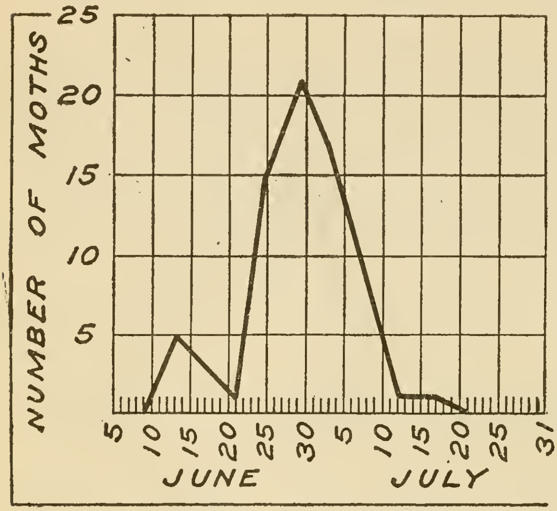

FIG. 22.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Pickens, W. Va., in 1912.

BAND COLLECTIONS.

The first larvæ were found under the bands on July 7, on which date 27 were collected. The maximum number were found on July 19. The last were found on September 29, at which time the fruit was gathered from the trees by the owner of the orchard. The number of larvæ found had dropped from 75, on September 11, to 17 on September 29, and it is probable that only a few more individuals would have gone under the bands had the fruit remained on the trees longer. The details of the band collections are shown more fully in Table XXXI.

TABLE XXXI.—*Record of codling-moth larvæ and pupæ collected under bands at Pickens, W. Va., in 1911.*

Date of collection.	Number of larvæ.	Number of pupæ.	Total.	Number of larvæ wintering.	Per cent of larvæ wintering.
July 7	27		27		
19	82	36	118	4	3.5
29	36	7	43	6	13.9
Aug. 8	23	6	29	15	51.7
18	58	3	61	47	77
28	28	1	29	23	79.3
Sept. 11	75		75	75	100
29	17		17	17	100
Total number collected			399		

FIRST-BROOD MOTHS.

Table XXXII shows that of the 59 first-brood moths reared the first were found in the breeding jars on July 29, the maximum numbers from August 8 to 28, and the last on September 11.

Table XXXII.—*Emergence of first-brood moths of the codling moth at Pickens, W. Va., during the season of 1911.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 29	14	Aug. 28	5
Aug. 8	20	Sept. 11	1
18	19	Total	59

INVESTIGATIONS IN 1912.

In 1912 the same orchard was used for the banding records as in 1911, although in most cases different trees were banded. Twelve trees were used.

SPRING-BROOD MOTHS.

Table XXXIII indicates the numbers and dates of emergence of this brood of moths at Pickens.

Table XXXIII.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1912.* (See fig. 22.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 13	5	July 3	17
17	3	8	8
21	1	12	1
25	15	17	1
29	21	Total	72

Moths from the larvæ that had wintered in the rearing jars did not begin to emerge until nearly the middle of June, as is shown in the table. The first were found in the jars on June 13, the greatest numbers from June 25 to July 3, and the last on July 17.

BAND COLLECTIONS.

Larvæ were exceedingly scarce, as is shown in Table XXXIV, only 47 being taken under the bands during the entire season. The first was found on July 24 and the last on October 5. The numbers are so few that no distinct line can be drawn between the first and second broods.

TABLE XXXIV.—*Record of codling-moth larvæ collected under bands at Pickens, W. Va., during the season of 1912.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 24..	1	Aug. 24..	2	Sept. 18..	7
30..	2	28..	1	21..	1
Aug. 5..	......	31..	4	25..	5
10..	2	Sept. 4..	3	28..	5
14..	1	7	2	Oct. 5..	2
17..	1	11..	5		
21..	2	14..	1	Total..	47

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Of the 47 larvæ collected in 1912, 28 wintered and transformed to moths in 1913. Table XXXV shows the time of emergence.

TABLE XXXV.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1913.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 21	0	July 1	8
24	8	5	4
28	8	8	0
		Total	28

The jars in which the larvæ had wintered were examined twice a week and on June 24 eight moths, which were the first of the season, were found. The same number were found on June 28, and also on July 1. The last were found on July 5.

RÉSUMÉ OF REARING EXPERIMENTS IN MARYLAND, VIRGINIA, AND WEST VIRGINIA.

Tables XXXVI and XXXVII summarize the rearing experiments of 1912 and 1913 in the different localities.

TABLE XXXVI.—*Résumé of rearing experiments on the codling moth at five points in Virginia, West Virginia, and Maryland in 1912.*

Observation.	Hagerstown, Md.		Winchester, Va.		Fishersville, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Larvæ collected	1,706	100.00	798	100.00	1,418	100.00	905	100.00	339	100.00	5,166	100.00
Larvæ dying from handling, cannibalism, etc	448	26.26	217	27.19	183	12.90	164	18.12	80	23.60	1,092	21.12
Moths reared same season	148	8.68	228	28.57	283	19.96	247	27.29	82	24.19	988	19.12
Moths reared following season	404	23.68	219	27.44	609	42.95	355	39.23	134	39.53	1,721	33.31
Wintering larvæ	1,110	65.06	342	42.86	952	67.14	494	54.59	172	50.74	3,070	59.42
Winter-killed larvæ	706	41.38	120	15.04	343	24.19	139	15.36	38	11.21	1,346	26.06
Parasitized larvæ	......	......	14	1.76	......	......	......	......	5	1.47	19	.36

TABLE XXXVII.—*Résumé of rearing experiments on the codling moth at four points in Virginia, West Virginia, and Maryland in 1913.*

Observation.	Hagerstown, Md.		Winchester, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Larvæ collected	2,756	100.00	971	100.00	542	100.00	143	100.00	4,412	100.00
Larvæ dying from handling, cannibalism, etc	883	32.04	234	24.10	223	41.14	48	33.58	1,388	31.46
Moths emerging same season	227	8.24	326	33.57	270	49.82	41	28.67	864	19.58
Wintering larvæ	1,646	59.72	346	35.63	49	9.04	51	35.66	2,092	47.38
Parasitized larvæ	......	......	65	6.70	......	......	3	2.09	68	1.55

It will be noted that the proportion of larvæ dying in the rearing cages, due to handling, cannibalism, disease, etc., varied from 12.90 per cent to 41.14 per cent. The latter figure, however, is unduly high, the average loss from this source being 21.12 per cent in 1912 and 31.46 per cent in 1913. The proportion of larvæ transforming the same season as that in which they were collected varied from 8.24 per cent at Hagerstown to 49.82 per cent at Charlottesville, with an average of 19.12 per cent in 1912 and 19.58 per cent in 1913. For 1912 from 42.86 per cent to 67.14 per cent of all larvæ collected spun up and wintered, the average for all points being 59.42 per cent. The proportion of wintering larvæ in 1913 was abnormally small on account of the light fruit crop of that year. Loss from winter killing amounted to from 11.21 per cent to 41.38 per cent, the average for all points being 26.06 per cent. Observations on parasitism were made only at Winchester and French Creek, the highest recorded being 6.70 per cent at Winchester in 1913. It must be remembered, however, that the foregoing facts are taken from observations of insects kept in confinement, and only in a limited way indicate what occurs under normal out-of-door conditions.

Table XXXVIII gives the numbers of codling-moth larvæ collected and reared in the course of the work in the different localities.

TABLE XXXVIII.—*Number of codling-moth larvæ collected and reared in the different localities in Virginia, Maryland, and West Virginia during 1911, 1912, and 1913.*

Locality.	Year.	Number of larvæ collected and reared.	Locality.	Year.	Number of larvæ collected and reared.
Charlottesville, Va	1911	1,218	Hagerstown, Md	1911	1,761
	1912	905		1912	1,706
	1913	542		1913	2,756
Greenwood, Va	1911	1,979	French Creek, W. Va	1911	633
	1912	1,862		1912	339
Fishersville, Va	1911	910		1913	143
	1912	1,418	Pickens, W. Va	1911	399
Winchester, Va	1911	2,079		1912	47
	1912	798			
	1913	971	Total	....	20,466

NUMBER OF FIRST-BROOD LARVÆ TRANSFORMING FIRST SEASON.

Table XXXIX shows the numbers of transforming and wintering band-collected larvæ of the first brood for several localities. These data are tabulated for their value in determining the relative size of the second brood of larvæ.

TABLE XXXIX.—*Number of first-brood larvæ of the codling moth transforming to moths the first season.*

Locality.	Year	Number of first-brood larvæ living to transform.	Number of first-brood larvæ transforming first season.	Per cent transforming first season.	Number of first-brood larvæ wintering.
Charlottesville, Va	1912	259	247	95.37	12
Do	1913	278	269	96.76	9
Hagerstown, Md	1912	1,122	147	13.19	974
Do	1913	1,356	227	16.74	1,129
Fishersville, Va	1912	308	278	90.26	30
Winchester, Va	1912	266	228	85.71	38
Do	1913	476	325	68.28	151
Keyser, W. Va	1911	226	221	97.78	5
French Creek, W. Va	1911	202	201	99.50	1
Do	1912	93	81	87.10	12
Pickens, W. Va	1911	154	59	38.31	95
Total		4,740	2,284	48.19	2,456

Since an indeterminate number of larvæ always die in the jars on account of artificial conditions, only those that lived to emerge as moths are considered in this table. It will be seen that there is a great variation in the percentage of the larvæ wintering in the different localities, and that in no case did all the first-brood larvæ transform to moths the first season. At Charlottesville, Fishersville, Keyser, and French Creek the proportion transforming the first season was so great as to insure nearly a full second brood of larvæ, while at Hagerstown and Pickens the large proportion wintering would indicate only a partial or scant second brood.

Where the banded orchards were bearing a full crop of fruit and other conditions were favorable for normal development of the larvæ, the relative sizes of the first-brood and second-brood band collections support the conclusions to be drawn from the data given in the table.

EFFECT OF DIFFERENCES IN ALTITUDE AND LATITUDE UPON THE DEVELOPMENT OF THE CODLING MOTH.

The stations at which the codling-moth rearing work reported in this paper was conducted comprise a range in altitude of 3,100 feet and in latitude of practically 1° 40′, or about 115 statute miles. In correlating the data from the various stations an effort has been made to determine whether or not definite differences in altitude and latitude have a corresponding and constant effect on the time of metamorphic changes in this species of insect. The results indicate that the codling moth in its development is so responsive to transient weather conditions and other local disturbing factors that the time of appearance of a certain brood in one locality can not be determined with certainty by any mathematical calculation based on the known time of appearance of the same brood in another locality of a known difference in altitude or latitude. It is probable that local differences in humidity, susceptibility to sudden changes in temperature as effected by topography, and, possibly, soil conditions, are more or less direct factors influencing the time of developmental changes in the insect.

In Table XL the results of these observations are given. In this table use is made of the law laid down some years ago by Dr. A. D. Hopkins that in phenological phenomena a fourth of a degree of latitude, or 100 feet in altitude, is equal to one day of time. The table shows that in this particular case the law does not apply. Charlottesville, being at the lowest altitude and the most southerly of the stations, is taken as a base and the other points considered in their relation thereto. In considering this table it should be borne in mind that data were collected but twice a week and that the dates given for the first appearance of the insect in its various stages may be from one to three days later than the actual occurrence. Differences in latitude that are equivalent to less than half a day are not considered; those equivalent to more than half a day are counted as full days.

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ.*

Locality.	Year.	Date of emergence of first spring-brood moths.	Date of first larvæ collected under bands.	Date of emergence of first-brood moths.	Elevation above sea level.	Elevation above Charlottesville.
					Feet.	*Feet.*
Charlottesville, Va.	1912	May 7	June 6	June 20	400	....
	1913	Apr. 18	June 5	June 14	400	....
Greenwood, Va.	1912	May 8	June 6	June 23	900	500
	1913	....	....	....	....	....
Hagerstown, Md.	1912	May 30	June 29	July 13	500	100
	1913	May 15	June 27	July 8	550	150
Winchester, Va.	1912	May 22	June 19	July 9	750	350
	1913	May 6	June 17	June 30	750	350
Fishersville, Va.	1912	May 18	June 11	July 2	1,500	1,100
	1913	May 3	June 14	....	1,500	1,100
French Creek, W. Va.	1912	May 13	June 24	July 20	1,600	1,200
	1913	May 6	July 5	July 23	1,600	1,200
Pickens, W. Va.	1912	June 13	July 31	Aug. 20	3,500	3,100
	1913	June 24	....	....	....	....

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ*—Continued.

Locality.	Year.	Distance north of Charlottesville.		Number of days later than Charlottesville according to law of latitude and altitude.	Actual number of days later than Charlottesville.		
		Degrees and minutes.	Miles.		First spring-brood moths.	First larvæ under bands.	First summer-brood moths.
		° ′					
Charlottesville, Va	1912						
	1913						
Greenwood, Va	1912	0 4	5	5	1	Same day	3
	1913						
Hagerstown, Md	1912	1 40	115	7	23	23	23
	1913			7	27	22	24
Winchester, Va	1912	1 10	80	8	15	13	19
	1913			8	18	12	16
Fishersville, Va	1912	0 4	5	11	11	5	12
	1913			11	15	9	
French Creek, W. Va	1912	0 50	60	15	6	18	30
	1913			15	18	30	39
Pickens, W. Va	1912	0 40	45	34	37	55	61
	1913			34	67		

RELATIVE NUMBERS OF LARVÆ ASCENDING AND DESCENDING THE TREES.

In 1911 several trees in a number of orchards were banded around the trunks and also around the bases of the larger branches. The lower bands were used to secure larvæ that had dropped with the infested fruit and ascended the trunk to spin up, and the upper bands were used for those that left the fruit before it dropped and descended toward the trunk for the same purpose. The following table shows the relative number of larvæ secured under the two sets of bands in the six orchards. In considering Table XLI due allowance should be made for an unknown number of larvæ that crawled across the bands or that spun up under the bark before reaching the bands.

TABLE XLI.—*Relative numbers of codling-moth larvæ collected from bands around the trunks and bases of branches, season of 1911.*

Locality.	Number of larvæ collected.			Per cent.	
	On trunk.	On branches.	Total.	On trunk.	On branches.
Hagerstown, Md	543	602	1,145	47.42	52.58
Smithsburg, Md	179	619	798	22.44	77.56
Hancock, Md	75	91	166	45.18	54.82
Fishersville, Va	96	68	164	58.54	41.46
French Creek, W. Va	146	96	242	60.33	39.67
Pickens, W. Va	29	30	59	49.15	50.85
Total	1,068	1,506	2,574	41.49	58.51

SEASONAL EFFECT OF WEATHER CONDITIONS ON THE DIFFERENT STAGES OF THE CODLING MOTH.

The beginning of emergence of the spring-brood codling moths varies greatly from season to season, depending in any given year upon the temperature conditions that prevail during March, April, and May.

It will be noted, however, that in spite of the wide variation in the time of emergence of the spring-brood moths in 1912 and 1913 there was a tendency for the later stages of the insect to appear at more nearly the same periods both years. This is probably due to an equalization of midsummer weather conditions subjecting the later stages of the insect to the influences of a more constant seasonal temperature factor. At Winchester, where the codling moth was under closer observation than at other points, we find that while spring-brood moths emerged at least 10 days later in 1912 than in 1913, the second-brood larvæ began entering the fruit at practically the same time both years.

Hammar,[1] in his report on the codling moth in Pennsylvania, gives the following in his general summary:

> The time of the emergence of the spring brood of the moths is variable under different seasonal conditions and depends largely upon the relative lateness of the spring.
>
> The time of emergence of the summer brood, or first brood, of moths is fairly constant and generally commences about the 1st of August.

From the results of the band records and rearing work of 1912 and 1913 it would seem, therefore, that in all except very unusual seasons we may expect the feeding of second-brood larvæ to begin in the different sections about as follows: Charlottesville, Va., July 1; Fishersville, Va., July 10; Winchester, Va., July 15; Hagerstown, Md., July 25.

CANNIBALISM AMONG CODLING-MOTH LARVÆ.

During the progress of these studies it was noticed frequently that when a collection of codling-moth larvæ was confined in a rearing jar a considerable loss in their numbers from cannibalism was likely to occur. This habit, of the stronger larvæ devouring their weaker fellows, has been commented on by Hammar.[2] He states that cannibalism among the larvæ probably takes place also under normal conditions. In the jars the loss from this cause during the present investigations was frequently sufficient to amount to a considerable factor in influencing the number of moths to appear later.

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[1] Hammar, A. G. The codling moth in northwestern Pennsylvania. U. S. Dept. Agr., Bur. Ent., Bul. 80, Pt. VI, p. 111, 1910.

[2] Hammar, A. G. Life-history studies on the codling moth in Michigan. U. S. Dept. Agr., Bur. Ent., Bul. 115, Pt. 1, p. 1-86, 1912. See p. 83.

NATURAL ENEMIES.

PREDACEOUS INSECTS.

It seems probable that many codling-moth larvæ, after leaving the fruit, are caught and destroyed by ants. A small red ant (*Solenopsis molesta* Say) was frequently met with on the bark of apple trees and under the bands engaged in killing and devouring the larvæ. Colonies of these ants that had their homes in the vicinity of banded trees seemed to form a habit of visiting the bands to obtain food. The collections of larvæ from trees in several localities were very considerably reduced in numbers from this cause. *Lasius niger* L. var. *americana* Emery, a species less abundant about the trees than the other, was also found killing the larvæ. These ants were determined by Prof. W. M. Wheeler.

Several species of beetles were found to be predatory on the larvæ and pupæ at the various stations. The most abundant of these was *Tenebroides corticalis* Melsh., both the larvæ and adults of which were frequently found under the bands devouring the larvæ and pupæ. Another beetle, *Hololepta lucida* Lec. (Pl. I, fig. 2), was found at Winchester with a codling-moth larva in its jaws. Two species of carabid beetles (*Calanthus opaculus* Lec. and *Platynus angustatus* Dej.) were common under the bands but were not observed to be feeding on the codling-moth larvæ. These beetles were determined by Mr. E. A. Schwarz, of the Bureau of Entomology. A coleopterous larva, which was determined as a species of Telephorus by Mr. H. S. Barber, was observed in the act of eating a codling-moth larva at Hancock in 1911.

HYMENOPTEROUS AND DIPTEROUS PARASITES.

Six species of hymenopterous parasites were reared from the codling-moth larvæ in the jars. Of these, *Ascogaster carpocapsæ* Vier. (Pl. I, fig. 1) was found at Winchester, Hagerstown, Smithsburg, Keyser, and French Creek, and outnumbered all others. An undetermined secondary parasite was found to be destroying this species in considerable numbers at Keyser in 1911. *Itoplectis marginatus* (Prov.) (fig. 23) occurred at Greenwood, Hagerstown, Winchester, and French Creek. A female of this species was observed on the trunk of an apple tree at French Creek ovipositing in a larva that had spun up under a scale of bark. *Macrocentrus* sp.[1] was reared at Greenwood in July, 1911; *Meteorus* sp.,[2] at French Creek in July, 1913; (*Microdus*) *Bassus*, n. sp. (Pl. I, fig. 4), at Smithsburg in July, 1911; and *Phanerotoma tibialis* Hald. at Charlottesville in 1911. The last species was determined by Mr. H. L. Viereck and the others by Mr. R. A. Cushman, of the Bureau of Entomology.

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[1] Quaintance No. 7457.

[2] Quaintance No. 7569.

A dipterous parasite, reared from codling-moth larvæ at Keyser in 1911, was determined by Mr. W. R. Walton, of the Bureau of Entomology, as (*Hypostena*) *Tachinophyto variabilis* Coq. (Pl. I, fig. 3). Only a few specimens of this species were obtained.

HAIRWORM PARASITES.[3]

Hairworm parasites of the codling moth (Pl. I, figs. 5, 6) were found at Greenwood, Keyser, and French Creek, being abundant in the second-brood larvæ at the latter place in 1911. These parasites were within the bodies of the codling-moth larvæ at the time collections

FIG. 23.—*Itoplectis marginatus*, a parasite of the codling moth. Enlarged. (Original.)

were made from the bands and usually issued from their hosts 10 days or 2 weeks after the larvæ were placed in the rearing jars. Occasionally dead larvæ, surrounded by a mass of dead hairworms, were found under the bands, and in a few cases the hairworms were found within apples borne by the banded trees. It was evident that infestation occurred at an early stage in the larval development and that all infested individuals died as full-grown larvæ. Most of the parasitized larvæ died within 10 days after being placed in the rearing jars.

The hairworms were from $2\frac{1}{2}$ to 5 inches in length, and three or four were frequently observed to inhabit one larva. In leaving the host they passed through the anal opening or broke through the

[3] *Mermis* sp. Material was referred to Dr. B. H. Ransom, of the Bureau of Animal Industry, but as the specimens were all immature, they could not be determined specifically.

skin at some other point. After freeing themselves from the host, all that were observed writhed about actively for a few minutes and then died. Many of the hairworms did not escape from the codling-moth cocoons, but were found, at the time of the regular examinations of the jars, knotted together and dead, beside the flattened and shriveled larval remains. Table XLII shows the extent of parasitization at French Creek in 1911.

TABLE XLII.—*Extent of parasitization of codling-moth larvæ by hairworms at French Creek, W. Va., in 1911.*

Date larvæ were collected.	Number of larvæ collected.	Number of larvæ parasitized.	Per cent parasitized.
June 26	139	0	....
July 3	68	0	....
July 14	48	6	12.50
July 24	24	1	4.17
Aug. 4	14	3	21.43
Aug. 15	51	7	13.72
Aug. 23	34	11	32.35
Sept. 2	36	23	63.90
Sept. 13	43	21	48.84
Sept. 19	23	10	43.48
Oct. 3	22	6	27.27
Total	502	88	17.53

SUMMARY.

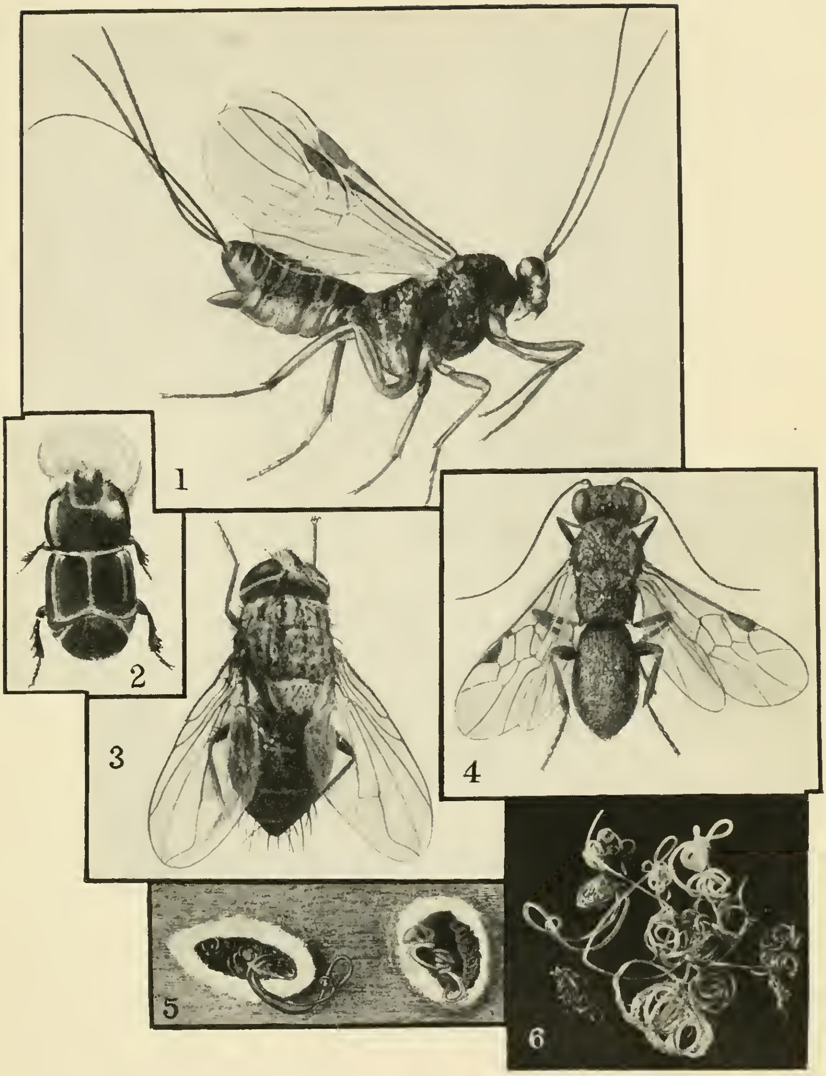
The foregoing account of the codling moth is based upon band-record studies conducted in 1911, 1912, and 1913 in several different localities of Virginia, West Virginia, and Maryland.

The stations at which the investigations were conducted comprise a difference in latitude of about 1° 40′ and in altitude of about 3,100 feet. The most southerly and least elevated station was at Charlottesville, Va., the most northerly at Hagerstown, Md., and the one at highest elevation at Pickens, W. Va.

The chief features of the investigations consisted of banding suitable apple trees with strips of burlap, collecting at regular periods the larvæ that went beneath the bands to spin up, and rearing these larvæ in jars kept in the localities where the larvæ were collected. Examinations of the bands and rearing jars were made every week or ten days in 1911 and twice a week in 1912 and 1913. No detailed life-history studies were attempted.

During a single year the codling moth, in the region covered by the present studies, produces one full brood of larvæ and a partial second brood, the size of the second brood depending more or less on the latitude and altitude of the locality.

The studies show a marked difference in the time of appearance of the different broods in different localities. Charlottesville gave the earliest records for practically all broods and Pickens the latest.



NATURAL ENEMIES OF THE CODLING MOTH (CARPOCAPSA POMONELLA).

Fig. 1.—*Ascogaster carpocapsae*. Fig. 2.—*Hololepta lucida* devouring codling-moth larva. Fig. 3.—(*Hypostena*) *Tachinophyto variabilis*. Fig. 4.—(*Microdus*) *Bassus* n. sp. Fig. 5.—Codling-moth larvæ killed in cocoons by hairworms (*Mermis* sp.). Fig. 6.—Mass of hairworms (*Mermis* sp.) taken from rearing jar, French Creek, W. Va. (Original.)

There seems, however, to be no constant rate of difference between the earlier and later localities. This seems to be largely due to the responsiveness of the species during its metamorphic changes to local and transient weather conditions.

During the time of the investigation the first-brood larvæ began entering the fruit at Charlottesville from April 28 to May 15, and second-brood larvæ from June 25 to July 1. At Pickens first-brood larvæ began entering the fruit from June 20 to July 1, and second-brood larvæ about August 10. Between these two localities there is a greater difference in the time of the regular periodical changes of the insect that occur late in the season than of those that occur early in the season. This is probably due to the cumulative retarding effect of the more frequent unfavorable weather conditions at the higher point.

For any given locality the variation in the time of appearance of spring broods in different years is greater than that of corresponding summer and fall broods of the same years.

Records of the numbers of larvæ collected from trees on which bands were placed around the trunks and also around the bases of the larger branches indicate that 41.49 per cent drop to the ground and then ascend the trunk to pupate and 58.51 per cent crawl down the branches from the infested fruit to pupate.

Where a collection of larvæ is confined in one jar there is apt to be a considerable loss due to cannibalism. It is probable that the weaker larvæ are sometimes devoured by their fellows under normal conditions.

Two specimens of ants (*Solenopsis molesta* Say and *Lasius niger* L. var. *americana* Emery) were found in several localities devouring codling-moth larvæ. Larvæ and adults of the beetle *Tenebroides corticalis* Melsh. were found frequently feeding on codling-moth larvæ and pupæ. Six species of hymenopterous and one of dipterous parasites were reared in the jars. Of these the most destructive to the codling moth were *Ascogaster carpocapsæ* Vier. and *Itoplectis marginatus* Prov. Hairworm parasites (*Mermis* sp.) were abundant in one locality and very materially reduced the number of wintering larvæ in the year 1911.

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DIV. INSECTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 192

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
April 8, 1915.

(PROFESSIONAL PAPER.)

INSECTS AFFECTING VEGETABLE CROPS IN PORTO RICO.[1]

By Thomas H. Jones,
Entomological Assistant, Truck Crop and Stored Product Insect Investigations.

INTRODUCTION.

The following article can not be considered to include references to all the many insects which attack vegetable crops in Porto Rico. Undoubtedly there are many other insect species which are pests on plants, commonly classed as vegetables, that are grown on the island. Nevertheless it seems well to present the data available—data which have been obtained from references already published and from observations made by the writer since November, 1911, while a member of the staff of the experiment station of the Porto Rico Sugar Producers' Association. Especially does it seem timely to publish this paper because of the effort being made by the United States Department of Agriculture to obtain information upon the obnoxious insects liable to introduction into the United States, and because of the steps that are being taken to prevent them from being introduced. While it will be noted that many of the species mentioned in the following pages already occur in the United States, several are not known to be present on the mainland.

The determinations of the insects mentioned as having been observed by the writer have been made, with few exceptions, by specialists of the Bureau of Entomology, United States Department of Agriculture. The names of several of the wild host plants and of the fungi have been supplied by Mr. J. R. Johnston, pathologist of the experiment station of the Porto Rico Sugar Producers' Association.

It may be said in general that vegetables suffer severe injury in Porto Rico from insects. The vegetables grown are, for the most part, the same as those of the markets of the United States, although

[1] The observations on which this paper was founded were conducted by the author while a collaborator in Porto Rico.

Note.—This bulletin enumerates the more common insects attacking vegetable crops in Porto Rico; of interest to entomologists.

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there are some with which the visitor from the North is not familiar. Among these may be mentioned a cucurbit, the "chayote" (*Sechium edule*); the "lleren" (*Calathea allouya*), a canna-like plant with edible tubers; and the various members of the genera Xanthosoma Colocasia, known as "yautias," the latter known also as the "dasheen" in the southern United States.

The following figures, taken from the Summary of Transactions in the United States Customs District of Porto Rico, show the value of the vegetables brought into Porto Rico during the fiscal year ended June 30, 1912:

Vegetables, dried, canned, and pickled, imported by Porto Rico during fiscal year ended June 30, 1912.

Commodity.	Domestic merchandise from United States.		Merchandise imported from foreign countries.	
	Quantity.	Value.	Quantity.	Value.
	Bushels.		*Bushels.*	
Beans and dried peas	179,131	$543,577	7,315	$21,020
Onions	16,446	25,624	42,574	33,224
Potatoes	141,797	164,410	51,960	48,682
All others (canned)		43,083		12,571
All others (including pickles and sauces)		15,427		82,703
Total value		792,121		198,200

These figures indicate that the cultivation of vegetables could well be extended by those who have sufficient land at their disposal, and further study of the various vegetable insects, especially as regards control measures, would be of great importance in encouraging such cultivation.

THYSANOPTERA AND HEMIPTERA, OR SUCKING INSECTS.

Thrips tabaci Lind.

This well-known species, the onion thrips, has been found attacking onions.

Peregrinus maidis Ashm.

Where it occurs in abundance down among the unrolling leaves of corn, as it often does in Porto Rico, this "leafhopper" injures the leaves so that they have the appearance of having been scorched by fire. The presence of the "honeydew" which they secrete is responsible for the attendance of various ants and flies.

Jassidæ.

"*Agallia tenella* Ball," presumably *Eutettix tenella* Baker, was mentioned by Mr. Barrett in 1904 [1] as having "injured beans and other small crops," and in the same year this species was mentioned on

[1] Barrett, O. W. Report of . . . entomologist and botanist. In Porto Rico Agr. Expt. Sta. Ann. Rpt. for 1903 [U. S. D. A. Office Expt. Stas. Rpt. 1903], p. 448, 1904.

page 84 of Bulletin No. 44 of the Division of Entomology, United States Department of Agriculture, as having been sent from Porto Rico by Mr. Barrett, with the statement that it damaged the leaves of beans, cowpeas, and other plants.

Mr. Barrett also mentioned *Empoasca mali* LeB., the currant leaf-hopper, in his 1903 report, above referred to (p. 448), as the "severest insect enemy of beans and cowpeas."

The writer has found *Empoasca mali* causing acute injury to garden beans, the leaves being badly curled and distorted.

APHIDIDÆ.

Though several species of aphides, or plant lice, attack vegetables, the well-known "melon aphis," *Aphis gossypii* Glov., is apparently the only one specifically recorded from the island. Mr. Barrett mentioned it in 1905,[1] and in 1906 Mr. Henricksen,[2] in discussing the cultivation of watermelons, stated that it "often infests the undersides of the leaves."

Aphis gossypii has been observed in abundance on cucumber, while other aphides have been found attacking corn, okra, and mustard. In his report for 1903 (p. 447) Mr. Barrett also stated that "a black aphid was found on a plant purchased as *Alocasia marshallii*, but believed to be a Xanthosoma" (yautia), and that "the malanga (*Colocasia antiquorum esculentum*) is occasionally attacked by an aphid which is usually parasitized by a whitish fungus and a hymenopter."

In the article in Bulletin No. 44 of the Division of Entomology the statement is made, on page 84, that, according to Mr. Barrett, an unknown species of Aphis seriously affects squashes.

Mr. Henricksen has mentioned, in the previously cited bulletin on vegetable growing (p. 38), an "eggplant aphis, a small light gray, mealy looking insect," which "appears on the underside of the leaves."

Aphis gossypii and other aphides found on okra are attacked by an internal parasite, perhaps *Aphidius testaceipes* Cress. A fungus, *Acrostalagmus albus* Preuss, attacks various species, and at least five species of ladybird beetles which feed upon aphides are present in Porto Rico. These are: *Cycloneda sanguinea* L., *Megilla innotata* Vauls., *Scymnus roseicollis* Muls., *Scymnus loewii* Muls., and *Hyperaspis apicalis* Muls. Syrphid flies are also common.

ALEYRODES sp.

Mr. Tower[3] in 1908 stated that "a white fly (*Aleyrodes* sp.) appeared in great numbers on the peppers and tomatoes" at the experiment station at Mayaguez, P. R. He further mentions that "there

[1] Barrett, O. W. Report of . . . entomologist and botanist. In Porto Rico Agr. Expt. Sta. for 1904 [U. S. D. A. Office Expt. Stas. Rpt. 1904], p. 396, 1905.

[2] Henricksen, H. C. Vegetable growing in Porto Rico. Porto Rico Agr. Expt. Sta. Bul. 7, p. 58, 1906.

[3] Tower, W. V. Report of the Entomologist and Plant Pathologist. Porto Rico Agr. Expt. Sta. Ann. Rpt. for 1907, p. 36.

appears to be a great number of parasites." Two species of syrphid flies were reared and a parasitic fungus was observed.

COCCIDÆ.

The following scale insects have been taken on truck crops: *Saissetia hemisphærica* Targ. (Pl. I, fig. 1) and *Hemichionaspis minor* Mask. on eggplant, and *Diaspis pentagona* Targ. on okra and pepper.

A mealybug has been found at the roots of celery and corn which has been determined as *Pseudococcus* sp. near *citri* Risso. It was abundant on the crowns of plants growing in rather dry soil, and was in many cases attended by the "fire ant," *Solenopsis geminata* Fab.

SPARTOCERA BATATAS Fab.

Adults (Pl. I, fig. 2) and nymphs of *Spartocera batatas* have been observed in great abundance on sweet potato, their beaks embedded in the stalks and leaf petioles of the plants.

CORYTHUCA GOSSYPII Fab.

The tingitid *Corythuca gossypii*, which breeds on the undersides of yautia leaves, also occurs in the same situation on the sword bean (*Canavalia ensiformis*) and the castor bean (*Ricinus communis*).

PHTHIA PICTA Drury.

This coreid bug (Pl. I, fig. 3) attacks tomato and *Solanum nigrum* var. *americanum* at Rio Piedras, and both adults and nymphs have been observed by the writer inserting their beaks into the fruit of both host plants.

CORYTHAICA MONACHA Stål.

Nymphs and adults of *Corythaica monacha* have been observed to be so abundant on the undersides of the leaves of eggplant that all the foliage withered, turned brown, and fell from the plant. Although this was an unusual instance, this tingitid is an important enemy of the eggplant. Plants of a common solanaceous weed, *Solanum torvum*, are also often attacked.

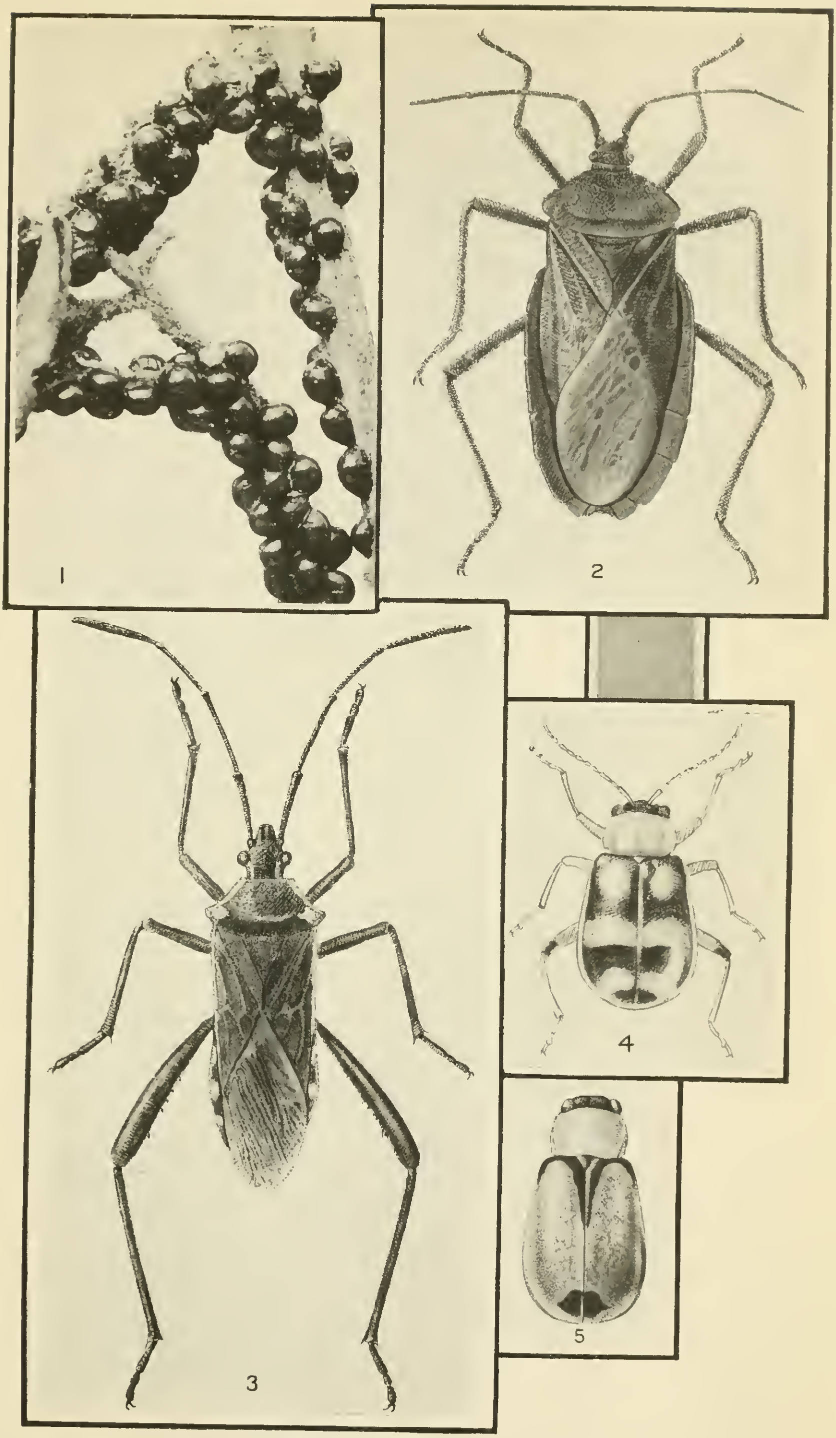
ORTHOPTERA.

SCAPTERISCUS DIDACTYLUS Latr.

Probably the most notorious of Porto Rico insects is the "mole cricket," or "changa" (*Scapteriscus didactylus*), which injures many vegetables by cutting off the plants at or just below the surface of the soil.

In the most complete article on this species so far published in English[1] it is stated that "among the small crops the tomato, egg-

[1] Barrett, O. W. The changa or mole cricket (*Scapteriscus didactylus* Latr.) in Porto Rico. Porto Rico Agr. Exp. Sta. Bul. 2, 19 p., 1 fig., 1902.



INSECT ENEMIES OF VEGETABLE CROPS IN PORTO RICO.

FIG. 1.—The hemispherical scale (*Saissetia hemisphærica*) on eggplant. FIG. 2.—*Spartocera batatas:* Adult. Greatly enlarged. FIG. 3.—*Phthia picta:* Adult male. Much enlarged. FIG. 4.—*Cerotoma denticornis:* Beetle. Enlarged. FIG. 5.—*Cerotoma denticornis:* Pale variety. Enlarged. (Original.)

FIG. 1.—PIERIS MONUSTE: MALE BUTTERFLY. MUCH ENLARGED. (ORIGINAL.)

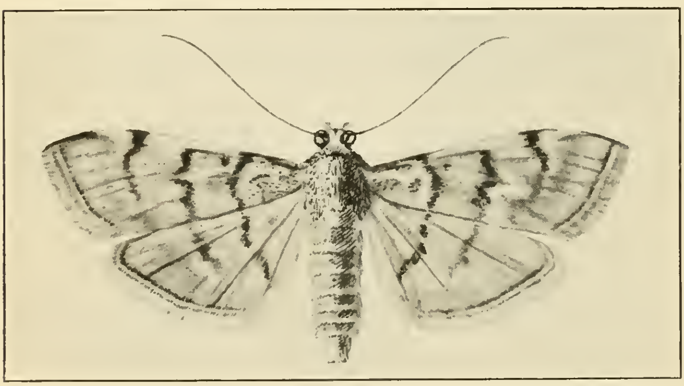


FIG. 2.—NACOLEIA INDICATA: MALE MOTH. ENLARGED. (ORIGINAL.)

LEPIDOPTERA INJURIOUS TO VEGETABLES IN PORTO RICO.

plant, turnip, and cabbage are most affected," and that the watermelon, bean, sweet potato, and yautia are seldom or never attacked.

COLEOPTERA.

Diabrotica bivittata Fab. and D. innuba Fab.

These two chrysomelid beetles occur in abundance on cucumber, squash, and melon, especially on the flowers. They quite closely resemble *Diabrotica vittata* Fab. in appearance and habits, and those authors who have referred to *vittata* as being present on the island have apparently failed to differentiate between the species.

Diabrotica graminea Bal.

This chrysomelid beetle is very common in Porto Rico. Mr. Van Dine has reported the adults as feeding on the leaves of sugar cane to a slight extent.[1]

The beetles are bluish-green in color and about one-fourth of an inch in length. So far as the writer has observed, the injury is most severe on corn and okra, which are, in fact, the only two plants of this group upon which the writer is certain that they feed, although they have been observed feeding on the flowers of cowpeas, the fruit of *Solanum nigrum* var. *americanum*, and the foliage of "jobo" (*Spondias lutea*) and "bledo" (*Amaranthus spinosus*).

The injury to corn is apparently confined to the silk of the ear and the blossom spike. On these parts of the plant the beetles congregate in great numbers, and the results of their feeding are very apparent, especially on that portion of the silk which, ordinarily projecting from the tip of the husk, is completely destroyed. On okra they feed upon the blossoms and the young leaves.

An assassin bug, *Zelus rubidus* Stål., has been taken with a beetle of this species impaled upon its beak.

Cerotoma denticornis Oliv.

In appearance this beetle resembles the bean leaf-bettle (*Cerotoma trifurcata* Forst.), which also occurs in the United States, and, as is the case with the latter species, there is a marked difference in the markings on the wing-covers. This difference is shown in figures 4 and 5 of Plate I.

Adults of *Cerotoma denticornis* have been found feeding upon garden beans and cowpeas, plants which have been reported on the mainland as food plants of *trifurcata*. The habits of the two species are quite similar. Mr. Barrett, in his 1903 report (p. 448), mentioned *denticornis* as being common.

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[1] Van Dine, D. L. Report of the Entomologist. Sugar Producers' Association of Porto Rico. Ann. Rpt. 3, p. 34, 1913.

Epitrix cucumeris Harr.

Flea-beetles have been taken on eggplant and tomato, which agree with those taken in company with *Epitrix parvula* Melsh. on a weed (*Physalis* sp.). Those taken on the latter plant were said by Mr. E. A. Schwarz to be "properly not different from the U. S. cucumber flea-beetle, *Epitrix cucumeris*." On the eggplant the beetles were causing the familiar "flea-beetle injury" to the leaves.

Chætocnema apricaria Suffr.

This insect injures sweet potato leaves in much the same manner as does *Chætocnema confinis* Lec. in the United States, searing them with short, continuous, curved lines. The beetle is of a dark metallic-green color and has been observed in abundance at certain seasons on a common weed, related to the sweet potato.

Coptocycla signifera Herbst.

An adult of this "tortoise beetle" has been taken on the leaves of sweet potato. In the United States the species is known as an enemy of this crop.

Cryptorhynchus batatæ Waterh.

The writer is able to record this enemy of the sweet potato through the kindness of Mr. R. H. Van Zwaluwenburg, Entomologist of the Porto Rico Agricultural Experiment Station. Mr. Van Zwaluwenburg has found it attacking sweet potato tubers at Mayaguez. The species has been mentioned as an enemy of the sweet potato in the Lesser Antilles, where it seems to be a more important pest than *Cylas formicarius.*

Cyclas formicarius Oliv.

The "sweet-potato root-borer" is present in Porto Rico, it having been observed working in the tuberous root of a wild convolvulaceous plant.

LEPIDOPTERA.

Pieris monuste L.

The "southern cabbage worm" was mentioned by Mr. Tower in his 1907 report (pp. 35 and 36) as feeding on cabbage, radish, turnip, kale, and mustard. The male butterfly is shown in Plate II, figure 1.

The larvæ have also been found feeding on horseradish and an uncultivated plant, *Cleome spinosa*, of the family Capparidaceæ. This weed is evidently an important wild food plant of *P. monuste* in Porto Rico and is commonly found, especially on the lower lands, near the rivers. Prof. Ignatius Urban gives it the local Spanish common name of "jasmin del rio" in his Flora Portoricensis.

Eudamus proteus L.

This hesperid, the so-called "bean leaf-roller," feeds upon garden beans, cowpeas, and a related weed, *Phaseolus lathyroides*.

Eggs that probably belonged to this species, found on the leaves of the last-mentioned plant, were parasitized by *Trichogramma minutum* Riley.

Phlegethontius sexta Joh.

Mr. Barrett reported this species, under the name of *Protoparce carolina*, in his 1903 report (p. 448) as occurring commonly on tomato and tobacco throughout the island, and made the interesting note that the larvæ were usually killed by a thrust of a knife made from a "maya" (*Bromelia pinguin*) leaf. The larva also feeds upon the common "berengena cimarrona" (*Solanum torvum*), and Mr. Tower has stated in his 1907 report (p. 36) that the parasite *Telenomus monilicornis* held in check the "tobacco hornworm" (probably this species), eggs of which were found on tomato and pepper.

Phlegethontius convolvuli L.

Adults of this species, which is known elsewhere as a sweet potato pest, have been collected at Rio Piedras, P. R.

Laphygma frugiperda S. & A.

Although corn and onions are the only vegetables so far observed to be attacked by the larvæ of *Laphygma frugiperda*, or "grass worm," the list of such plants upon which they feed is undoubtedly much larger.

In addition to the enemies previously recorded by the writer,[1] namely, the three tachinid flies, *Frontina archippivora* Will., *Gonia crassicornis* Fab., and *Archytas piliventris* V. d W., the larvæ are attacked by two fungi, *Botrytis rileyi* Farlon and *Empusa* sp., and by an assassin bug, *Zelus rubidus* Stål. An interesting parasite, *Chelonus insularis* Cress. (?), the egg of which is laid in the Laphygma egg, the parasite issuing from and killing the host larva when the latter is about one-half inch in length, has also been observed.

A carabid beetle, *Calosoma alternans* Fab., is predaceous upon the larvæ, and another carabid, *Cymindis marginalis* Dej., probably has the same habit.

Heliothis obsoleta Fab.

The corn ear-worm attacks corn in Porto Rico and is to be considered an important pest to this crop. Mr. Barrett mentioned it in his 1903 report (pp. 443 and 444).

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[1] Some notes on *Laphygma frugiperda* S. & A. in Porto Rico. Jour. Econ. Ent., v. 6, no. 2, p. 235, April, 1913.

OTHER NOCTUIDÆ.

Three other noctuid moths, that have been reared from larvæ, belong to the species known to injure truck crops in the United States. *Xylomyges eridania* Cram., the larvæ of which occurred on *Amaranthus* sp., has been mentioned by Messrs. Chittenden and Russell under the name of *Prodenia eridania* Cram.[1] as attacking Irish potatoes, eggplant, pepper, okra, and sweet potato in Florida, and they give, on another's authority, beets, cabbage, and carrots as food plants.

Prodenia ornithogalli Guen., the cotton cutworm, reared from larvæ found feeding on a weed of the family Convolvulaceæ, is stated by Dr. Chittenden to be an enemy of several vegetable crops.[2]

The larvæ of *Feltia annexa* Treits., which species has been reared from larvæ found in an area where "grass worms" (*Laphygma frugiperda* S. & A. and *Remigia repanda* Fab.) were abundant, is known as a cutworm on the mainland.

DIAPHANIA HYALINATA L.

Cucumbers and squashes are frequently severely attacked by the larvæ of this species, the melon caterpillar. Mr. Barrett mentioned the species in his 1903 report (p. 448).

PACHYZANCLA BIPUNCTALIS Fab.

The "southern beet webworm" has been found feeding on garden beans, sword bean (*Canavalia ensiformis*), and weeds belonging to the genus Amaranthus. Upon the garden bean and Amaranthus it was feeding on the leaves, which it webs together, forming for itself a shelter, as is commonly done by pyralid larvæ. The leaf or leaves of which the shelter is formed are skeletonized and the pupæ are sometimes found in the shelters, but more often in earthen cells just below the soil surface. The larvæ found on sword bean were feeding within the green pods.

Exorista pyste Walk., a tachinid parasite of the larvæ, has been observed.

In connection with *Pachyzancla bipunctalis* it may be mentioned that another pyralid, *Hymenia* (*Zinckenia*) *fascialis* Cramer, occurs in Porto Rico. It has been observed under conditions that would indicate that the larvæ feed upon *Amaranthus* spp. Mr. H. O. Marsh has studied this species in the Hawaiian Islands, and in Bulletin 109, Part I, of the Bureau of Entomology, states that various beets and several species of Amaranthus are among the plants which suffer from its attack there.

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[1] Chittenden, F. H., and Russell, H. M. The semitropical army worm. (*Prodenia eridania* Cram.). U. S. D. A., Bur. Ent., Bul. 66, pt. 5, p. 53-70, figs. 8-11, Jan. 28, 1909.

[2] Chittenden, F. H. Some insects injurious to the violet, rose, and other ornamental plants. U. S. D. A., Div. Ent., new ser. Bul. 27, rev., p. 64, 68, 69, 70, 1901.

FIG. 1.—WORK OF THE LARVA OF PACHYZANCLA PERIUSALIS ON SOLANUM TORVUM. (ORIGINAL.)

FIG. 2.—PILOCROCIS TRIPUNCTATA: MOTH. ENLARGED. (ORIGINAL.)

LEPIDOPTERA INJURIOUS TO VEGETABLES IN PORTO RICO.

MUSTARD LEAF SHOWING INJURY BY THE DIAMOND-BACK MOTH (PLUTELLA MACULIPENNIS). (ORIGINAL.)

PACHYZANCLA PERIUSALIS Walk.

Larvæ of this pyralid moth feed upon the leaves of eggplant and *Solanum torvum*. The young larvæ live at first as miners in the leaves, but later web the leaves together. (See Pl. III, fig. 1.) The shelter is usually formed near the edge of the leaf, a portion of which is folded in toward the midvein and held in place by silken threads. Sometimes, however, parts of two or more leaves form the shelter. The larvæ feed from within these areas and are often common on both plants mentioned as hosts.

The moth has a wing expanse of three-fourths to seven-eighths of an inch and is gray in color. The wings are glistening and marked above with three darker, wavy, transverse lines, the two inner ones extending across both wings, while the outer one extends from the costal margin to a point near the middle of the front wing.

NACOLEIA INDICATA Fab.

The larva feeds upon the leaves of garden bean, webbing together parts of the same leaf or separate leaves. It also occurs on cowpea.

The adult, Plate II, figure 2, is golden yellow, the wings marked with black along the outer margin, and above with three black wavy lines extending across them, much as do the dark lines on the wings of *Pachyzancla periusalis*.

PILOCROCIS TRIPUNCTATA Fab.

Sweet-potato leaves have been found webbed together and injured by the larvæ.

The moth, shown in Plate III, figure 2, is light yellow, the wings being marked with black and brown, and having an expanse of about an inch.

PLUTELLA MACULIPENNIS Curtis.

Larvæ of the "diamond-back moth" are at times very abundant on and destructive to the leaves of cabbage. Mr. Barrett mentioned the species in his 1903 report (p. 448) and Mr. Tower, in his 1907 report (p. 35), listed cabbage, kale, mustard, and turnips as food plants, briefly summarized its life history, made note of a parasite, and mentioned remedies to be applied. A mustard leaf which has been severely injured by the larvæ is shown in Plate IV.

HYMENOPTERA.

SOLENOPSIS GEMINATA Fab.

The "fire ant," or "hormiga brava," has been found injuring okra plants by cutting away parts of the flowers and portions of the younger growth.

It is often stated in Porto Rico that ants destroy certain vegetable seeds after they have been planted in the soil. The writer has been told on good authority that ants, which from the description were apparently the "hormiga loca" or "crazy ant," *Prenolepis longicornis* Latr., were seen to dig small holes along the rows in a propagating box in which lettuce had been planted, remove the seeds, and carry them away.

DIPTERA.

AGROMYZA PARVICORNIS Loew.

The "corn-leaf blotch miner," which has been recently made the subject of a paper [1] by Mr. W. J. Phillips, is present in Porto Rico, adults having been reared from larvæ found working in leaves of corn at Rio Piedras.

SUMMARY.

The following summary, arranged alphabetically according to host plants, indicates the insects known to attack the various vegetable crops grown in Porto Rico. The "changa" (*Scapteriscus didactylus* Latr.) is credited in this list as injuring only those plants which, according to Mr. Barrett, are most affected, though in reality the list of plants attacked by it is not so limited.

Beans:
- *Eutellix tenella* Baker. (?)
- *Eudamus proteus* L.
- *Empoasca mali* Le B.
- *Cerotoma denticornis* Oliv.
- *Nacoleia indicata* Fab.

Beets:
- *Pachyzancla bipunctalis* Fab.

Cabbage:
- *Scapteriscus didactylus* Latr.
- *Plutella maculipennis* Curtis.
- *Pieris monuste* L.

Celery:
- *Pseudococcus* sp. near *citri* Risso.

Corn:
- *Peregrinus maidis* Ashm.
- *Pseudococcus* sp. near. *citri* Risso.
- *Diabrotica graminea* Baly.
- *Laphygma frugiperda* S. & A.
- *Heliothis obsoleta* Fab.
- *Agromyza parvicornis* Loew.

Cucumber:
- *Aphis gossypii* Glov.
- *Diabrotica bivittata* Fab.

Cucumber—Continued.
- *Diabrotica innuba* Fab.
- *Diaphania hyalinata* L.

Eggplant:
- *Saissetia hemisphærica* Targ.
- *Hemichionaspis minor* Mask.
- *Corythaica monacha* Stål.
- *Scapteriscus didactylus* Latr.
- *Epitrix cucumeris* Harris (?).
- *Pachyzancla periusalis* Walk.

Horse-radish:
- *Pieris monuste* L.

Kale:
- *Pieris monuste* L.
- *Plutella maculipennis* Curtis.

Melon:
- *Aphis gossypii* Glov.
- *Diabrotica bivittata* Fab.
- *Diabrotica innuba* Fab.

Mustard:
- *Pieris monuste* L.
- *Plutella maculipennis* Curtis.

Okra:
- *Diaspis pentagona* Targ.
- *Diabrotica graminea* Baly.
- *Solenopsis geminata* Fab.

[1] Phillips, W. J. Corn-leaf blotch miner [*Agromyza parvicornis* Loew]. *In* U. S. Jour. Agr. Research, v. 2, no. 1, p. 15-31, 6 figs., 5. pl., Apr. 15, 1914.

Onion:
- *Thrips tabaci* Lind.
- *Laphygma frugiperda* S. & A.

Pepper:
- *Aleyrodes* sp.
- *Diaspis pentagona* Targ.

Radish:
- *Pieris monuste* L.

Squash:
- *Diabrotica bivittata* Fab.
- *Diabrotica innuba* Fab.
- *Diaphania hyalinata* L.

Sweet potato:
- *Spartocera batatas* Fab.
- *Chætocnema apricaria* Suffr.
- *Pilocrocis tripunctata* Fab.
- *Cryptorhynchus batatæ* Waterh.

Sweet potato—Continued.

Other insects, known as sweet-potato pests in the United States, are also present, namely—
- *Coptocycla signifera* Herbst.
- *Cylas formicarius* Oliv.
- *Phlegethontius convolvuli* L.

Tomato:
- *Scapteriscus didactylus* Latr.
- *Phlegethontius sexta* Joh.
- *Aleyrodes* sp.

Turnip:
- *Scapteriscus didactylus* Latr.
- *Pieris monuste* L.
- *Plutella maculipennis* Curtis.

Yautia:
- *Corythuca gossypii* Fab.

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DIV. INSECT-.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 197

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
March 31, 1915.

HOMEMADE LIME-SULPHUR CONCENTRATE.

By E. W. Scott,
Entomological Assistant, Deciduous-Fruit Insect Investigations.

During the past few years much attention has been given by investigators to the home preparation of lime-sulphur concentrate and also to an inquiry into the chemical reactions involved, as affecting the conditions under which the work should be done. These investigations have had for their purpose the encouragement of orchardists in the preparation of concentrates for their own use, or for the use of the neighborhood. The success of these efforts is shown by the fact that many fruit growers now prepare their own lime-sulphur concentrates, thus effecting a material saving over the cost of the commercial article.

Orchardists, as a rule, are not able consistently to obtain a product of uniform density, even though the same formula be employed and the work be accomplished as nearly as possible in an identical manner for the different batches. This defect, however, is really of little importance, since it is easy to test the density of the concentrate and make dilutions in conformity with the purpose for which it is to be used.

During the past few years the Bureau of Entomology has given attention to the making of lime-sulphur concentrates in connection with work in deciduous-fruit insect investigations. No particular chemical study was planned in connection with these cooking tests, as it was merely desired to know the degree of density and percentage of the "sludge" which would result by the employment of different formulas. The cooking tests for the most part were made at lime-sulphur plants operated by orchardists, or by individuals who supplied the concentrate to orchardists in the immediate territory.

EXPERIMENTS AT BERRYVILLE, VA.

Six experiments were conducted at a small plant at Berryville, Va. This plant consisted of a 12-horsepower boiler and two 150-gallon cooking vessels. The cooking was done by steam which was

Note.—Describes experiments in making lime-sulphur concentrates and gives the most satisfactory formulas. Of interest to all practicing spraying in insecticide work.

ejected through perforated coils in the bottom of the tanks. There was no mechanical agitator, the mixture being agitated by hand by the use of a long wooden paddle. The mixture was allowed to cook 50 minutes, when, after taking samples for testing purposes, the remainder was drained into a storage tank. The results of these tests are given in Table I.

TABLE I.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Berryville, Va., 1912.*

Experiment No.	Formula.			Percentage in volume of sludge.	Degrees Baumé.
	Lime.	Sulphur.	Water.		
	Pounds.	*Pounds.*	*Gallons.*		
1	50	100	50	39.0	28.5
2	50	100	50	50.0	30.0
3	50	100	50	35.0	29.5
4	50	100	50	41.5	30.5
5	45	100	50	41.0	29.0
6	55	100	50	44.0	28.0

The 50–100–50 formula was used in the first four of these experiments. The Baumé test of the cooked wash varied from 28.5° to 30.5°, and the percentage in volume of sludge, after standing 24 hours, varied from 35 to 50. The preparation of the wash in experiments 1 and 3 was as nearly the same as was possible, the lime being added first and the sulphur immediately afterwards. In experiment 2 the sulphur was added first.

In experiment 4 the mixture was not stirred after the steam was turned on, the steam being depended upon for agitation. Otherwise the treatment was the same as in experiment 1.

In experiments 5 and 6 the quantity of lime was decreased and increased 5 pounds, respectively, from the amount previously used. This was done to determine, if possible, whether more or less of this particular brand of lime should be used. In every other respect the treatment was the same as in experiment 1. The only points considered in this experiment were the Baumé test and the percentage in volume of sludge.

EXPERIMENTS AT WINCHESTER, VA.

A lime-sulphur cooking plant located at Winchester, Va., also was visited. This plant, which has a capacity of 500 gallons per day, consists of a 150-gallon rectangular sheet-iron tank embedded in a brick furnace in which wood is burned to furnish the heat. This plant supplies a number of the surrounding fruit growers with lime-sulphur solution. As soon as the cooking has been completed, the solution is piped directly through a 20-mesh strainer into 50-gallon barrels and is delivered to the growers without being filtered. The strainer, of course, takes out only the coarser particles; therefore it is necessary for the grower thoroughly to shake the barrel each time any of the solution is taken out in order to get an even distribution of the sludge. The following data were obtained, which show the variation in density of the different batches. Four batches in which the 50–100–50 formula was used tested 25°, 26°, 28°, and 29° Baumé, respectively. Seven batches in which the 55–110–50 formula was used tested 28°, 29°, 29°, 30°, 30°, 30°, and 31° Baumé, respectively. It will be noted that there was considerable variation in degrees Baumé for the different batches, although each was cooked as nearly as possible in the same way.

Similar variations in density were observed at a steam-cooking plant at Chewsville, Md.

EXPERIMENTS AT HAGERSTOWN, MD.

A new lime-sulphur cooking plant at Hagerstown, Md., was visited. The cooking vessels, two in number, consisted of the hulls of two large boilers standing on end. Each held about 1,500 gallons. The cooking is done by steam. A few experiments were conducted at this plant to determine, if possible, what formula should be used under these conditions of manufacture to obtain a highly concentrated solution. The results of these trials are given in Table II.

TABLE II.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Hagerstown, Md., 1912.*

Experiment No.	Formula.			Percentage in volume of sludge (estimate).	Degrees Baumé.
	Lime.	Sulphur.	Water.		
	Pounds.	*Pounds.*	*Gallons.*		
1	800	1,600	800	35.0	25.5
2	800	1,600	800	35.0	26.0
3	750	1,500	285 gallons sludge, 715 gallons water	40.0	23.0
4	200	400	Added to above 1,000 gallons of 23° Baumé material	45.0	27.0
5	1,000	2,000	280 gallons sludge, 620 gallons water	45.0	32.5

In Experiments 1 and 2 800 gallons of solution were cooked at a time. The 50–100–50 formula was used in each of the two experiments with a result of 25.5° and 26° Baumé test solution respectively. In each case there was about 35 per cent in volume of sludge. The solution in Experiment 1 was allowed to remain in the vessel 24 hours, then the clear solution was drawn off and 285 gallons of sludge remained in the tank. In order to see what effect this sludge would have on the solution by cooking it over with the next batch (Experiment 3), 715 gallons of water were added to it, making 1,000 gallons in all; 750 pounds of lime and 1,500 pounds of sulphur were added to this and the mixture was cooked for one hour. After allowing the solution to settle 24 hours the clear liquid tested 23° Baumé and there was 40 per cent in volume of sludge. An attempt was made to raise the test of this solution (Experiment 4) by adding to it 200 pounds of lime and 400 pounds of sulphur. After cooking this for an hour and allowing it to settle there was 45 per cent in volume of sludge and the clear solution tested 27° Baumé. In an attempt to make a high-test solution by using a reduced quantity of water mixed with sludge Experiment 5 was conducted. To the 280 gallons of sludge remaining in the cooking vessel from Experiment 2 there were added 620 gallons of water, making a total of 900 gallons. To this was added 1,000 pounds of lime and 2,000 pounds of sulphur. This was cooked for one hour, and after allowing it to settle for 24 hours there was 45 per cent in volume of sludge, and the clear solution tested 32.5° Baumé. It will be seen that a high-test solution was obtained by reducing the quantity of water, but the percentage of sludge was also considerably increased.

EXPERIMENTS AT VIENNA, VA.

A few lime-sulphur cooking experiments were conducted at Vienna, Va., in the spring of 1911. A large iron pot placed over a wood fire was used as a cooking vessel. In four of these experiments the 50–100–50 formula was used. The time of cooking was from 45 minutes to one hour. The results, which show variation in Baumé test and a high percentage in volume of sludge, are given in Table III.

TABLE III.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Vienna, Va., 1911.*

Experiment No.	Formula.			Percentage in volume of sludge.	Degrees Baumé.
	Lime.	Sulphur.	Water.		
	Pounds.	*Pounds.*	*Gallons.*		
8	8	16	8	40.0	30.6
9	40	80	40	33.0	28.8
10	40	80	40	40.0	28.7
11	40	80	40	50.0	27.0

EXPERIMENTS AT BENTON HARBOR, MICH.

Some experiments were conducted at Benton Harbor, Mich., in the fall of 1912 for the purpose of making high-test solutions. The cooking plant consists of a 12-horsepower boiler from which steam is conducted into two 50-gallon barrels. There are no coils in the bottom of the barrels, the steam simply being emitted through the open end of a straight pipe extending to within a few inches of the bottom of the barrel.

Small batches amounting to 25 gallons of the finished product were cooked at a time. About 20 gallons of water were put into the barrel, then the steam was turned on and the water brought to boiling. The lime was then put in and after it had begun to slake the sulphur was added. The mixture was stirred thoroughly throughout the time of cooking, which lasted 1 hour. It was allowed to settle about 12 hours, and then the clear solution was siphoned off. The sludge was put into a cider press and the clear solution pressed out, using 10-ounce canvas cloth for filter. A good grade of stone lime was used in experiments 1 to 5. Hydrated lime was tried in experiments 6 and 7. Commercial ground sulphur was used in all the experiments. The results are given in Table IV.

TABLE IV.—*Results of cooking different lots of lime and sulphur in preparation of lime-sulphur wash, Benton Harbor, Mich., 1912.*

Experiment No.	Formula.				Degrees Baumé.
	Lime.	Sulphur.	Water.	Sediment.	
	Pounds.	*Pounds.*	*Gallons.*	*Pounds.*	
1	25	50	25	32	27.0
2	25	50	25	36	27.0
3	40	80	25	80	34.0
4	40	80	25	90	35.5
5	40	80	25	85	32.5
6	[1] 60	80	25	110	30.0
7	[1] 60	80	25	100	31.5

[1] Hydrated.

In Experiments 1 and 2 the 50–100–50 formula was used, with a result of 27° Baumé test solution in each case and 32 pounds of sludge in Experiment 1 and 36 pounds in Experiment 2. In Experiments 3, 4, and 5 the same proportion of lime and sulphur as above stated was used, but the amount of water was reduced, the formula being 40 pounds of lime and 80 pounds of sulphur and water to make 25 gallons of concentrate. The Baumé tests of these three batches varied from 32.5° to 35.5°, and the amount of sludge varied from 80 to 90 pounds. The sludge, after it had been run through the cider press, was in the form of a thick paste, so the number of pounds given does not nearly represent the number of pounds of dry sediment.

The formula used in the last two experiments was 60 pounds of hydrated lime and 80 pounds of sulphur with water to make 25 gallons of concentrate. Where the hydrated lime was used the solution did not test so high and there was considerably more sludge.

DIRECTIONS FOR PREPARATION OF LIME-SULPHUR CONCENTRATE.

The 50–100–50 formula has been generally recommended for the preparation of home-boiled concentrated lime-sulphur solution. The method of preparation is to boil together for 50 minutes to 1 hour 50 pounds of lime, 100 pounds of sulphur, and water to make 50 gallons of the concentrated solution. A good grade of fresh stone lime containing not less than 90 per cent of calcium oxid is necessary for the best results. Hydrated lime is sometimes used, but it is necessary to use a good grade and at least 20 per cent more of this form of lime, as it contains a high percentage of moisture.

Place enough water in the cooking vessel to finish with 50 gallons of the solution. Bring the water to the boiling point, start the agitator, if the plant is equipped with one, then put in the lime and immediately add the sulphur. The mixture should be stirred vigorously either mechanically or by hand until the lime is slaked. Agitation should be continued throughout the time of cooking, which should not exceed one hour. If the solution is to be barreled without filtering, it should be drawn off immediately and allowed to run through a 30-mesh strainer into the barrels. The agitation should continue until all the solution is drawn off, so that there will be an equal distribution of the sludge in the different barrels.

PREPARATION OF HIGHLY CONCENTRATED LIME-SULPHUR SOLUTION.

From the experiments above reported, it is evident that a highly concentrated lime-sulphur solution may be made by using the lime and sulphur at the ratio of 1 to 2 as is usually recommended, but with reduced quantities of water. The formula used in the commercial lime-sulphur manufacturing plants visited and also in the foregoing experiments is as follows:

Fresh stone-lime ....pounds..	80
Commercial ground sulphur....do....	160
Water to make the finished product....gallons..	50

While there is about 50 per cent in volume of sludge after allowing this solution to settle for 24 hours, there is only about 5 to 10 per cent in volume of insoluble materials. These consist of sulphites, free lime, free sulphur, magnesium compounds, etc., varying with the kind of lime used and other conditions. Solutions prepared by this formula should test on an average 33° to 34° Baumé.

RELATIVE COST.

Commercial ground sulphur can be bought in car lots for about $1.50 per hundred pounds, and lime at about 60 cents per barrel. At these prices the highly concentrated solution can be made at the following cost per barrel:

80 pounds lime at 60 cents per barrel....	$0.20
160 pounds sulphur at $1.50 per hundredweight....	2.40
Labor and fuel, estimated....	.70
Total cost per barrel of 50 gallons....	3.30

This does not include interest and wear on outfit, and cost of containers for storing. At the foregoing prices of ingredients the high-test concentrate would cost about 98 cents more per barrel than the lower-test concentrate made by the 50–100–50 formula.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

DIV. INSECTS

G. C. Hamid.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 200

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
May 4, 1915.

A MAGGOT TRAP IN PRACTICAL USE; AN EXPERIMENT IN HOUSE-FLY CONTROL.

By R. H. Hutchison, *Scientific Assistant.*

INTRODUCTION.

During the season of 1913 experiments were carried out independently by Levy and Tuck at Richmond, Va., by C. G. Hewitt at Ottawa, Canada, and by the writer at Arlington, Va., and New Orleans, La., all of which agreed in demonstrating a most pronounced migratory habit in house-fly larvæ just before pupation. It was found very easy to trap them at this particular stage of their development, and experiments with small maggot traps showed that as high as 98 or 99 per cent of the larvæ could be caught. At the suggestion of Mr. W. D. Hunter the writer has made an attempt during the past season to apply the principles of the maggot trap to practical use and to test its efficiency when used to destroy the maggots in large masses of manure. In this article are reported the results obtained from experimental work along this line, conducted at the Maryland Agricultural College at College Park, Md. Dr. H. J. Patterson, president of the college and director of the experiment station, has been most generous in his cooperation in this work, and through him the materials and labor for the construction of the trap were supplied. The writer wishes also to acknowledge the helpful suggestions of Profs. T. B. Symons and E. N. Cory, of the college.

LOCAL CONDITIONS WITH REGARD TO FLY PREVALENCE AND BREEDING PLACES.

The college was selected as a suitable place for conducting the experiment, partly because the conditions with regard to breeding places for flies seemed such that it would be easy to determine whether or not the maggot trap was effective. The college is some-

Note.—This bulletin describes the operations of a maggot trap based on the migratory habit of house-fly maggots just before pupation. It will be of interest to all farmers and to those industries in which the accumulation of refuse may encourage the propagation of the house fly.

what isolated by its position on a hill and separated a considerable distance from any near-by stables. On the accompanying map (fig. 1), which has been adapted from a map of the Geological Survey, is shown the topography of the surrounding section. The location of only two of the college buildings is given, viz, the college kitchen (K) and the stable (S). The college kitchen, by reason of odors from cooking and the presence of large quantities of garbage kept in iron pails just outside the door, attracted extremely large numbers of flies. One could not approach these garbage pails without stirring up a noisy swarm which had congregated there. However, no flies were breeding out from this garbage, for the reason that it was

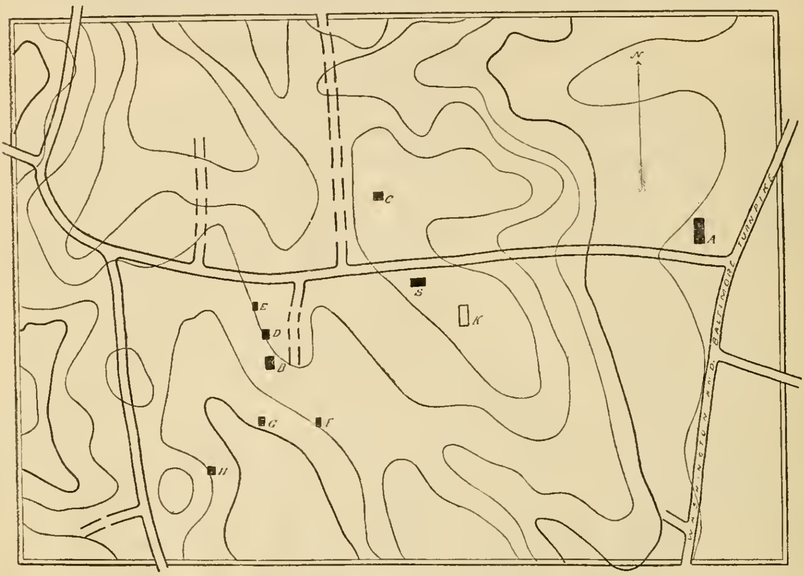


FIG. 1.—Map of vicinity of the Maryland Agricultural College showing the location of the college kitchen (*K*), the stable (*S*), and the proximity of other breeding places of flies (*A*, *B*, *C*, *D*, etc.) (Original.)

entirely removed every two or three days and taken to a near-by farm, where it was fed to hogs.

The breeding ground nearest to the kitchen was the pile of manure heaped just outside the college stable. This is nearly 200 yards northwest of the kitchen. It is probable that a large majority of the flies at the kitchen came from this source. Upon examination at various times during June and July the fresher portions of this heap were always found heavily infested with larvæ. Puparia were also found in great abundance in the loose soil and in the manure at the periphery of the pile. Three horses were kept in this stable, and two of them were standing in the stalls during the greater part of each day. Flies were also very numerous in and about the stable, and during the day the horses were continuously tormented by them.

With the exception of the college stable, there were no breeding places for flies within 400 yards of the kitchen. The stable, indicated by the letter C on the map, is approximately 400 yards from the kitchen and about 200 yards from the college stable. Other stables are located some 400 to 500 yards west of the college stable, the distance from the kitchen being about 100 yards greater.

Another extensive breeding place was found in the large collections of manure at the barns of the experiment station, located about 700 yards northeast of the college. This is indicated on the map by the letter A.

PLAN OF EXPERIMENT.

With these conditions prevailing, it was planned to construct a maggot trap large enough to take care of the entire manure production at the college barn, with the idea that if the trap proved effective there should appear a marked decrease in the prevalence of flies, not only at the barn but at the college kitchen. To determine whether or not the trap was effective the following three lines of observation were undertaken: (1) By collection and careful estimate of the larvæ caught by the trap and subsequent search for puparia in the manure, to get some idea of the percentage destroyed; (2) by making numerous fly counts during the season to find out whether the prevalence of flies at the kitchen and stable was decreased; and (3) to determine whether any of the flies at the college came from nearby breeding grounds (A, B, C, etc.) other than the manure heap at the college stable.

THE MAGGOT TRAP.

The maggot trap used in this experiment was designed and constructed as follows. First, a concrete floor was prepared 22 feet long and 12 feet wide. Around this floor was a rim or wall of concrete 4 inches high and 4 inches thick. An outlet pipe 4 inches in diameter was fitted in one corner toward which the floor sloped a little so that water would run out easily. Water was retained in the concrete floor by stopping the pipe outlet with a plug of soft wood. The pipe outlet led to a small cistern 5 feet square and 4 feet deep, the walls and floor of which were made of concrete. Standing on the floor of the concrete basin was constructed a wooden platform 20 feet long and 10 feet wide, supported on legs 1 foot high. The framework of the platform was made of 2 by 4-inch studding. There were 6 of these pieces running lengthwise 2 feet apart, and one fastened across each end. Each of the long pieces was supported on four legs set at intervals of nearly 7 feet. Across the top of the framework were nailed strips 10 feet long by 1¼ inches thick and 1 inch wide. These strips were nailed 1 inch apart. Plate I shows most of the details of construction. Plate II gives another view, including also the outlet pipe (in this case consisting of 4-inch terra cotta) and the pump in place over the cistern. On account of various obstructions it was necessary to place the cistern some distance away from the trap, although, as will be pointed out later, it is desirable to have the cistern close to the trap and the pump so arranged as to return the contents of the cistern to the manure heap on the platform.

THE METHOD ADOPTED IN USING THE MAGGOT TRAP.

The maggot trap was put into operation on July 25. On this date the manure pile which had accumulated in front of the barn during June and July was hauled away and spread on the fields, so that, beyond the hatching out of the pupæ and larvæ already present, it ceased to exist as a breeding ground for flies. On and after July 25 each day's production of manure was heaped on the platform. Beginning at the end farthest from the barn door, the manure was piled up to a height of from 3½ to 4 feet. The heap was maintained at about this height, and with the daily additions it kept increasing in length. Plates I and II show the appearance of the heap after a little more than four weeks' accumulation. The platform was found large enough to hold a little more than two months' production of manure from three horses and could easily have been made to hold the total production for three months by making the pile higher. Each day, after the addition of manure and litter from the stable, the manure on the platform was sprinkled with enough water to moisten it thoroughly without causing any leaching. Water was run into the concrete basin below the platform, so that the floor beneath the manure was covered to a depth of ½ inch in the shallowest part. Larvæ migrating from the manure dropped into the water below and were drowned.

At least once a week, and sometimes oftener, the water was drawn off from the basin into the cistern and the floor was washed clean by a strong stream of water from a hose. The larvæ which had fallen into the water, together with the débris which had sifted through the platform or fallen from the sides, were collected at the cistern end of the outlet pipe in a strainer. The matter thus retained in the strainer was then spread out on a smooth concrete surface near by, and the number of larvæ present was carefully estimated. The outlet was then plugged, and the basin again partly filled with water by pumping back what had run into the cistern.

THE PERCENTAGE OF MAGGOTS DESTROYED.

Without going into details of the weekly or biweekly counts, it will be enough to state that during the period from July 25 to October 1 a total of about 112,000 dead larvæ were collected in this way.

But this number does not represent all that dropped out of the manure into the water below. A flock of young turkeys roamed at large during the summer over the college grounds and adjoining fields. Having once found the maggot trap they made frequent visits and were seen to devour the larvæ with great avidity, sometimes completely clearing the floor except where the water was more than 2 or 3 inches deep or when it was so badly discolored as to conceal the larvæ. Sparrows also were seen frequently on this floor, but one could never get close enough to see whether they actually devoured any larvæ or not. It is more than likely that they did. The actual number of larvæ which were destroyed by the maggot trap was undoubtedly much greater than 112,000.

After October 1 the writer and an assistant examined all the manure on this platform in search of puparia. The manure was thrown off, a few bushels at a time, onto a smooth concrete surface near by and very carefully examined, all straw being shaken out and all solid parts being finely broken up. In a very literal sense this was like looking for a needle in a haystack. A few scattered puparia were seen in various parts of the heap, but in only two spots were they to be found in the characteristic clusters or "nests" which can be found so readily at the edges of manure piles on the ground. These two nests were found at the end of the platform where the most recent additions had been made. The manure at this end had not been sprinkled with water after the day it was put on. Failure to keep this moist as long as larvæ were present is, in the writer's opinion, the explanation of the pupation in this part. One nest contained about 400, and the second about 700 puparia. Allowing for some that may have escaped notice, the number of puparia may be given in round numbers as 1,500. No larvæ whatever were found in any part of this heap, the oldest part of which had been on the platform for two months, and even the freshest portion of which had been standing for at least 10 days before it was examined. If, then, 1,500 represents the total number which pupated in the manure and 112,000 the number which was destroyed by drowning, it shows a percentage destruction of about 98.5 per cent of the possible total. This is illustrated in figure 2, above. Taking into account the larvæ devoured by turkeys, etc., it is probable that the effectiveness of the trap could be rated as above 99 per cent.

In a former bulletin the claim was made that manure will be practically free from maggots after standing 10 or 12 days. Special attention was given to this point during the course of the experiment, and all observations tended to support the claim. Moreover, there was no evidence that larvæ ever migrated from the fresher portions of the manure to the older parts to pupate. That old manure does not serve as a breeding place for flies is a point that deserves some emphasis entirely aside from its bearing on the practical use of the maggot trap. The explanation is probably to be found in the changes which take place in the manure heap during storage. As the pile stands it settles considerably, with a consequent decrease of air spaces, and, especially if watered, air does not penetrate far below the surface. Dehérain and Dupont (1900) have shown that in manure well heaped so that air can not penetrate readily, the confined gases consist largely of carbon dioxid and methane, and that oxygen is not found except near the surface. It may well be that the lack of oxygen and the abundance of carbon dioxid render old manure unfavorable for the breeding of flies. It may also be that the composition of the gases in the manure is one of the factors which influence migration and the choice of a place for pupation.

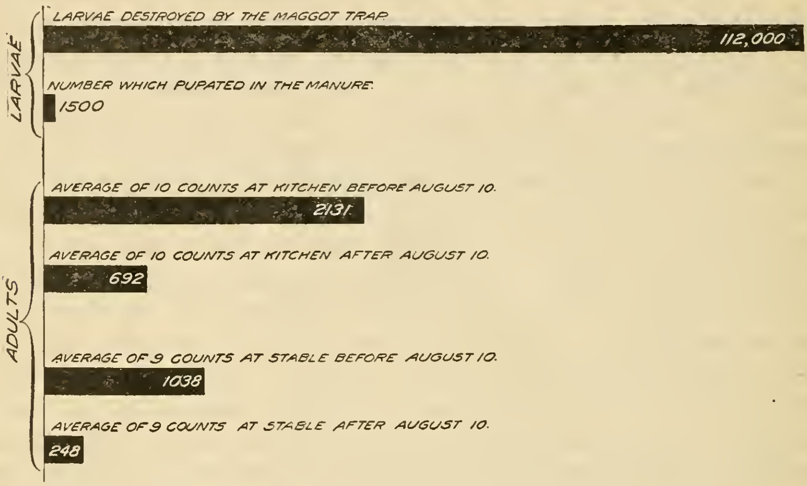


FIG. 2.—Graphical representation of the work of the maggot trap and its effect on the prevalence of flies. (Original.)

EFFECT ON THE FLY PREVALENCE AT THE STABLE AND KITCHEN.

Turning now to the second line of observation, it will be of interest to determine to what extent the maggot trap influenced the number of flies at the stable and kitchen. An answer to this is to be found in the series of fly counts made during the season, both before and after the trap was started. In taking these counts "tanglefoot" sticky fly paper was used. The papers were exposed for 24-hour intervals and counted immediately at the end of that period. Figure 3 is a graphic representation of these series of counts at the stable and kitchen. In each case the number given is the total caught on two papers exposed at the same time. At the kitchen the two papers were always exposed in the same way on top of the garbage pails, and at the stable one paper was put on the floor just outside the door and the second just inside the door, which faces the east. On several occasions papers were exposed, but the counts are not given in the diagram for the reason that a shower of rain or a strong wind spoiled some of the papers. The numbers which are plotted are those obtained on clear, warm days, on which the climatological conditions were nearly the same except for the direction of the wind. This will account for the irregular time intervals between the successive counts.

It is recognized that this method is not all that could be desired as an accurate index of fly prevalence. The use of a small number of fly papers in this way is nothing more than a method of sampling, but since the papers were exposed always in the same places and under nearly the same climatological conditions, the method may be considered as reliable as any method of sampling used in other lines of

FIG. 3.—The broken line connects series of fly counts at the garbage pails near kitchen; the solid line, those at the stable. (Original.)

work. The use of a few fly papers in this way would not of itself have any appreciable effect on fly prevalence. It was thought that the use of fly traps would complicate the situation in that any apparent reduction in the number of flies might be ascribed to their use rather than to the maggot trap.

A study of the fly counts shown in figure 3 reveals that there was a decided drop in the number of flies both at the kitchen and stable very shortly after the maggot trap was put into operation. Assuming that all the flies at the stable and kitchen at the time the experiment began (July 25) were freshly emerged and that they would all die off within three weeks (there is some evidence that flies seldom live longer than this in midsummer), one would expect to find a reduction in the number of flies about August 10 or 12. As a matter of fact this is what occurred. Although the counts fluctuate considerably after this date, in no case do the highest counts rise to the level of the lowest counts made before August 10.

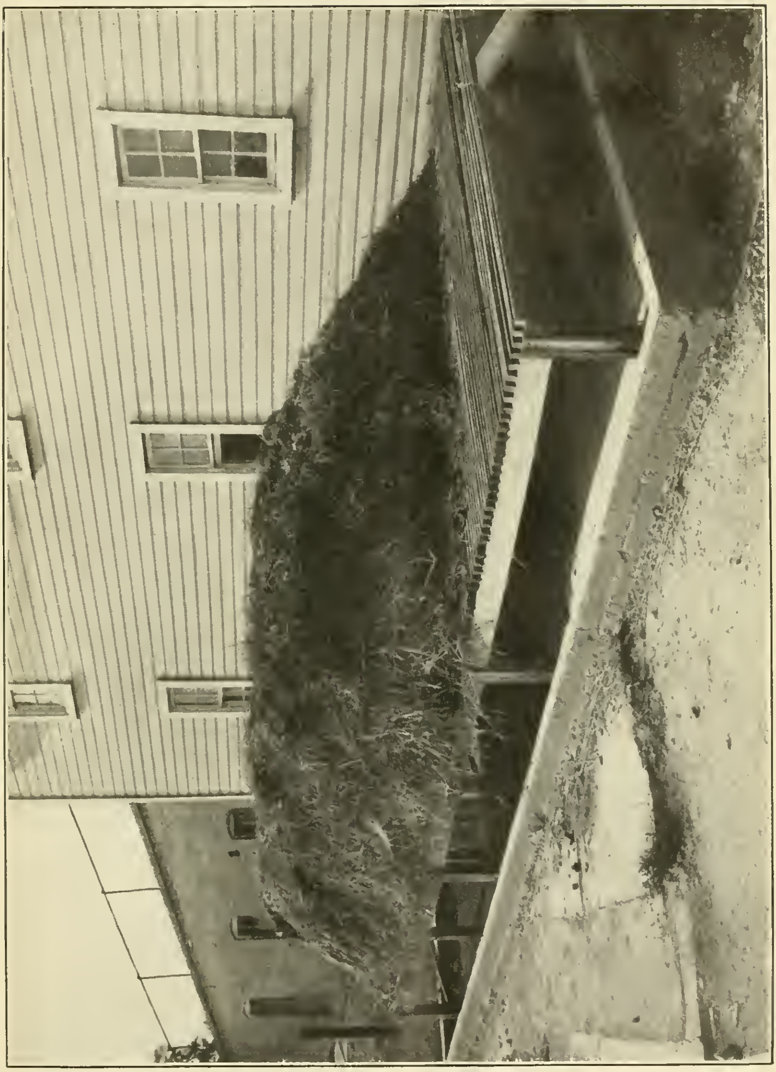
In one respect these counts hardly give a fair indication of the effect of the maggot trap, this for the reason that the college kitchen was closed from August 7 to September 7. It will be seen that flies almost completely disappeared from the kitchen during the latter part of August, but as soon as the garbage pails were again in use the fly counts go up fairly high, although not as high as the lowest count at this place before the experiment started. It is interesting to note that while the kitchen was closed the fly counts at the stable were somewhat increased and that after the kitchen reopened the flies almost disappeared from the stable. Taking the counts at the kitchen, we find that the average of the 10 counts before August 10 is 2,131, while the average of the 10 counts after August 10 is 692, an average reduction of 67.5 per cent. At the stable the average of 9 counts before August 10 is 1,038, and the average of 12 counts after August 10 is 248, an average reduction of 76 per cent.

The behavior of the horses standing in the stalls was also a fairly good index of fly prevalence in the stable. As noted above, the horses were constantly tormented during June and July. During the day the stamping of feet and switching of tails was incessant. After the maggot trap had been in operation for some time there was a noticeable change. The horses stood much more quietly, and their efforts to get rid of flies were less continuous. Several men at the college observed this and volunteered the information.

INFLUENCE OF OTHER BREEDING PLACES ON THE NUMBER OF FLIES AT THE COLLEGE.

If the maggot trap was really destroying 98 per cent of the flies breeding in the manure at the college stable, why is there not a corresponding reduction in the number of adult flies instead of an average reduction of from 67 to 76 per cent? The third series of observations points to a probable explanation of this. As indicated on the map, there are several breeding places within 700 yards of the college, and 700 yards is well within the range of flight of flies, a fact which has been proved by several workers. A few flight experiments with marked flies were carried out during the season, not with the idea of determining the range of flight, but merely to make sure whether or not flies from these various breeding places found their way to the college stable and kitchen.

First, about 600 recently emerged flies were thoroughly dusted with finely powdered red crayon and liberated on August 31 at a point near the stable indicated by the letter B (fig. 1). The point of liberation was about 400 yards west of the college stable and perhaps 500 yards from the kitchen. In spite of the presence of several houses

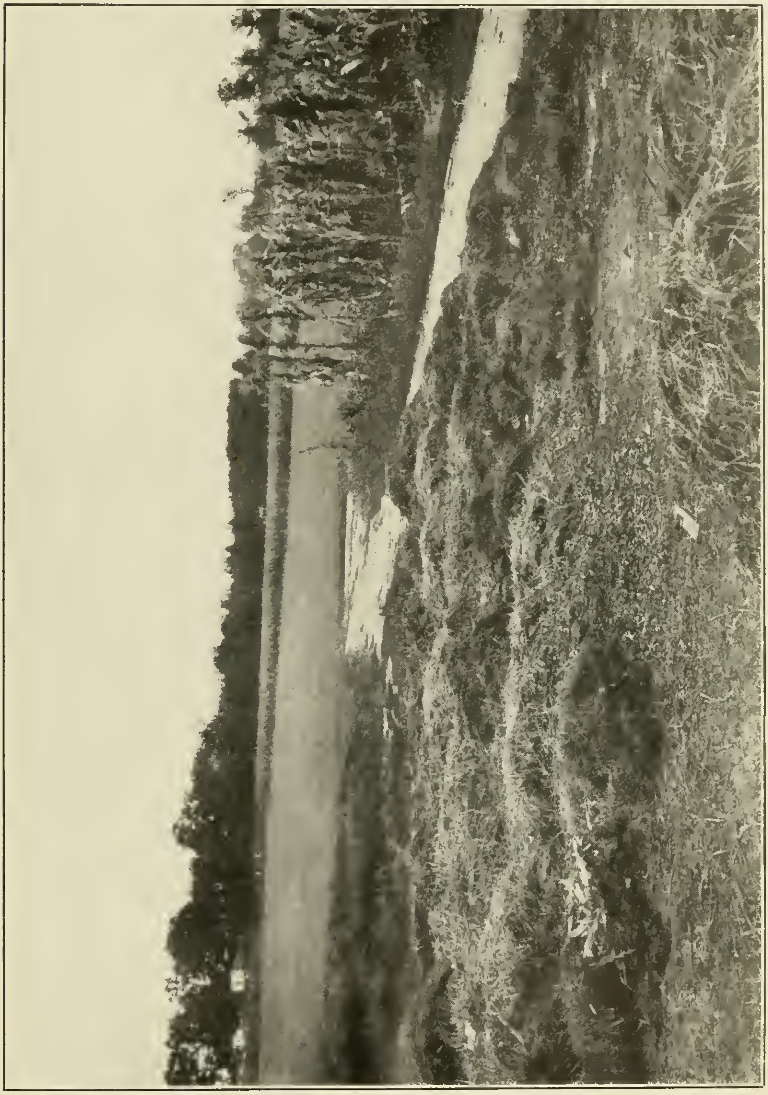


A MAGGOT TRAP FOR HOUSE-FLY CONTROL.

View of the maggot trap, showing the concrete basin containing water in which larvæ are drowned, and the wooden platform on which manure is heaped. (Original.)

A MAGGOT TRAP FOR HOUSE-FLY CONTROL.

Another view of the maggot trap, showing the pipe leading to the small cistern, and the pump used to force water back to the concrete basin. (Original.)



UNDESIRABLE CONDITIONS WHICH ARE OVERCOME BY USE OF THE MAGGOT TRAP.

A manure pile covering a large area and having little depth. Illustrating the conditions which favor the greatest loss of nitrogen, and at the same time offer the best breeding ground for flies. (Original.)

and stables in the immediate vicinity, some of these marked flies found their way to the college barn. Here two of this lot were recovered within the first 24 hours, and a third one during the third 24-hour period. That no flies were recovered at the kitchen is to be explained by the fact that the kitchen was closed and there was nothing there to attract flies.

A second lot of about 500 flies, sprayed with rosolic acid, were liberated at the dairy barn (A) of the experiment station, 700 yards due east from the college stable. The distance from the kitchen is slightly less. They were liberated at 3.30 p. m. September 1. On September 3 two marked flies were found on papers exposed at the dairy barn, but none was recovered at the college stable or kitchen. A strong southwest wind was blowing at this time and may have had some influence on the result. It is hardly to be doubted that when the kitchen is in use numbers of flies from this source are attracted to it. The manure pile back of the dairy barn was found to be heavily infested at all times during the summer, and flies bred out here by the thousands.

In a third experiment about 800 flies marked with powdered red crayon were liberated on September 15 at the stable marked by the letter C (fig. 1). Within the first 24 hours 11 marked flies were recovered on fly papers at the garbage pails, and two more during the second 24-hour period after liberation. No marked flies were recovered at the college stable in this experiment. The kitchen was in use at this time, and it must be considered significant that the flies were recovered only at the kitchen, although they had to pass right by the stable. This indicates the sharp rise in fly counts at the kitchen when it reopened in September.

The same thing happened on September 22. A lot of about 600 flies sprayed with rosolic acid had been liberated on September 21 near the stable marked on the map by the letter D (fig. 1). None of these were recovered at the college stable, but three were found within the first 24 hours on papers exposed on the garbage pails at the kitchen.

These few experiments indicate that a large number of the flies which congregate at the college kitchen and stable come from near-by breeding grounds other than the manure pile at the college barn. And it may be said that a reduction of from 67 to 76 per cent in the average number of flies, in spite of the proximity of these other breeding places, speaks well for the efficiency of the maggot trap.

SOME DEFECTS OF THE MAGGOT TRAP.

The experience during the past season with the platform maggot trap has directed attention to certain defects in its practical working. These defects, however, are not of such a serious nature that they can not be overcome. In the first place, some trouble resulted from smaller particles of manure sifting through between the cross strips and accumulating in the water below. This was especially the case when sawdust and shavings were used for bedding instead of straw. If this material were allowed to accumulate there would finally be enough of it to provide a breeding place on the concrete floor, where the maggots should be killed by drowning. Much of this sifting could be prevented by placing the cross strips closer together, so that only ½-inch or even ¼-inch spaces were afforded. It is not at all likely that ¼-inch spaces would interfere with migration; but in spite of such improvement there would be, even with the most careful handling, a certain amount of straw or small particles of manure which would fall from the sides of the heap or from the fork at the time it was put on the platform. It will always be necessary to clean out the concrete floor more or less regularly, and for this purpose a long-handled stable broom will be satisfactory when the water supply does not permit the use of a strong stream from a hose. To facilitate the cleaning of the floor the platform should not be less than 1 foot high nor more than 10 or 12 feet wide. The solid matter which happens to be washed into the cistern will decompose in time and be pumped back with the liquid onto the manure heap.

In dry weather evaporation of the water on the concrete floor will leave large areas of floor surface dry. Larvæ falling from the manure above onto the dry floor will crawl away and can crawl up the vertical sides of the surrounding rim; in fact, they could crawl up this surface even if it were as smooth as glass. To insure that all larvæ are drowned it is necessary to keep this in mind, and every day, when the manure is added to the heap, more water can be supplied if necessary. This operation will consume very little time.

The most serious defect was found in the fact that mosquitoes bred very freely in the water standing in the concrete basin and in the cistern. In order not to have one pest multiplying at the expense of another, it is necessary to run all water out of the concrete floor at least once a week and to clean the floor at this time; if then a little oil is poured over the surface of the liquid in the cistern, mosquito breeding will be prevented entirely. This method was used during the last weeks of the experiment with satisfactory results. If the cistern were carefully and tightly covered, perhaps the use of oil would not be necessary.

No counts or estimates were made of the larvæ destroyed during October and November. It is known, however, that larvæ continued to appear in the water on the floor during the most of October and during the warmer parts of November. On December 10 the manure was examined without removing it from the platform, and therefore not as thoroughly as on the former occasion, but there were found at the fresher end of the pile at least four nests of several hundred puparia each. It is not possible to estimate the percentage destroyed, but it was quite plain that the trap was not as effective during the autumn as in the summer. This may have been due partly to carelessness in the matter of watering the heap, but more probably to the lower air temperatures of this period. When the outside temperature is low, the difference between the air and the temperature of the manure heap is so great that the larvæ will not leave the heap; and if the low temperatures prevail for a long period the larvæ will eventually pupate in the manure. The following experiment shows the effect of low air temperature. This experiment was conducted at New Orleans, La., in December, 1913. A small wire basket was filled with fresh horse manure on December 1 and was continually exposed to flies. The number of larvæ caught and the temperature during the period are tabulated below.

Experiment to show effect of low air temperature in preventing migration of house-fly larvæ, New Orleans, La., December, 1913.

	Number of larvæ caught.	Minimum temperature.	Maximum temperature.	Mean temperature.
		° *F.*	° *F.*	° *F.*
Dec. 2	12	57	74	65.5
3	15	56	67	61.5
4	47	57	68	62.5
5	199	56	73	64.5
6	745	57	70	63.5
7	....	48	61	55
8	[1] 4,000	40	61	55
9	0	32.5	50	41.7
10	1	34.5	56	45.3
11	43	38	59	48.5
12	465	41	65	53
13	[1] 900	47	68	53
14	....	58.5	73	65.8
15	[1] 700	49	66	57.5
16	115	50	62.5	56.2
17	185	52	69	60.5
18	160	55.5	60	57.8
19	32	51	58	54.5

[1] Approximate. Counts of Dec. 8 and 15 include catch of preceding day.

Probably most of those that were caught on December 8 had migrated during the night of December 6. Not much migration from the manure takes place during the day, because of the maggots' negative reaction to light; therefore the minimum temperature is probably more significant than the daily mean temperature. It will be seen from the table that minimum temperatures of 40° F. or less will stop all migration from the heap.

It may be said, then, that the maggot trap has another defect in that it is not effective when temperatures are low, and that it is not at all effective when the air temperature is below 40° F.

SOME ADVANTAGES OF THE MAGGOT TRAP.

Some of the advantages of the maggot trap are obvious enough and need be only briefly mentioned here. It is an exceedingly simple arrangement, and the initial cost of construction need not be very great. Once having been constructed, no continuous money outlay for its maintenance is necessary. The concrete parts are permanent, and the wooden platform would require renewal only at intervals of several years, depending partly on the kind of wood used. The writer is of the opinion that in the long run the maggot trap would be less expensive than the investment which many farmers now make in screens for their dwellings and repellents, sprays, and fly nets for the protection of their animals.

The labor required in the operation of the maggot trap is a very small item. It is just as easy to place the manure on the platform as to dump it on the ordinary pile. It requires only a few minutes each day to see to it that the daily addition is carefully and compactly heaped and the entire heap well moistened. The work of cleaning out the floor below the platform will require about one-half an hour once a week.

It is very easy to run a wagon or manure spreader close alongside the maggot trap, as a glance at the photographs will show, and it would be just as easy, or indeed easier, to load from such a platform than from the ground. To facilitate loading as well as the cleaning of the floor below, the platform should be no more than 10 or 12 feet wide.

The maggot trap can be adapted for use on farms where the daily production of manure is very great. As was stated on a preceding page, the trap used in this experiment would hold the total production from three horses for three months. Now the problem of constructing a trap of reasonable size to take care of the manure of 40 or 50 horses is not as hopeless as might at first appear. The production of manure per horse per day may be safely estimated at 2 cubic feet. It will be seen that a platform 10 by 20 feet would hold manure produced by 50 horses during a period of 10 days if the heap is made 5 feet high. If two platforms are arranged as suggested in figure 4 they could be operated as follows: Platform No. 1 would be gradually filled up during the first 10 days; then, while this remains on the platform, the manure produced during the second 10 days would be placed on platform No. 2; at the end of 20 days the manure on platform No. 1 would be hauled away and the platform refilled during the third 10-day period while heap No. 2 was standing the length of time required to rid it of maggots. In this way the two piles would alternate, the one being in the process of formation and the other standing till practically all maggots had left it. It would be convenient, as indicated in the diagram, to have a cistern located between the platforms and a pump that could be used in applying water to both piles. In making plans for a maggot trap one must take into consideration the volume of manure produced and the length of time it must remain on the platform. As previously stated, it will be safe to estimate that the production of manure per horse per day is 2 cubic feet and that after 10 days it will be practically free from maggots, provided it has been well watered.

THE INFLUENCE OF THE MAGGOT TRAP ON THE VALUE OF THE MANURE.

Plate III illustrates an all-too-common method of keeping manure. It covers a large area of ground, and no attempt at heaping has been made. The manure in such a pile is loose and shallow, and air penetrates into practically all parts. These are the conditions

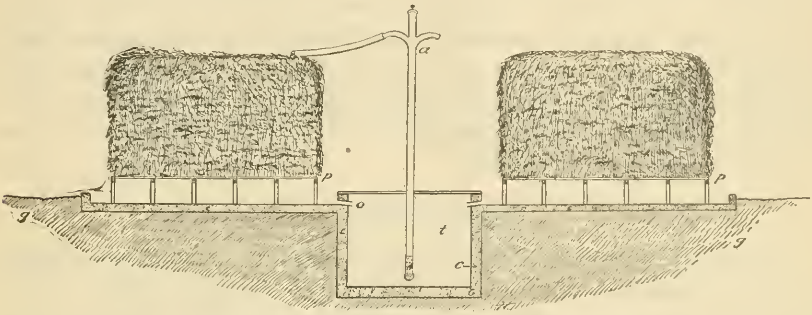


FIG. 4.—Imaginary cross-section of an arrangement suggested for use where manure production is large. *a*, Pump; *c*, concrete floor and walls of cistern; *o*, outlet pipes leading from floor of maggot trap to cistern; *p*, platform maggot trap; *t*, cistern for liquid manure; *g*, ground level. (Original.)

which give rise to the maximum loss of ammonia and nitrogen. It also happens that the conditions which tend to the loss of nitrogen are the same which favor the development of fly larvæ. An immense surface is exposed for deposition of eggs, and the penetration of air makes it possible for larvæ to feed in practically all parts. The fresher portion of the manure shown in this photograph was found heavily infested all through the season.

It has been shown that the losses occurring in manure thus carelessly stored will vary from 30 to 64 per cent of the total amount of nitrogen (Beal, 1906), and that by careful methods of storage this loss may be reduced to 15 per cent. Several methods of storage for the purpose of preventing loss of ammonia and nitrogen have been proposed. Among others is that recommended by Dehérain, Beal, Thorne, Ringelmann, and others, which consists in keeping the manure compactly heaped and well watered. Both heaping and watering tend to prevent the penetration of air and thus check the destructive aerobic fermentation. This method is used to a considerable extent in parts of France and Germany and is fully discussed by Ringelmann. A cistern is provided into which drain all the liquids from the stables, and the manure heap is watered by pumping the liquid manure from the cistern from time to time.

It is the writer's intention here merely to point out that the disposal of manure on the platform maggot trap is but a slight modification of the method just mentioned. Figure 4 differs from a diagram given by Ringelmann only in the platform and in the outlets through which the drowned larvæ may be washed into the cistern. Here is shown the cistern in which the liquid manure collects. Watering with the liquid manure adds to the heap the valuable constituents of the urine and promotes the anaerobic fermentation. If it is true, as just suggested, that lack of oxygen and the presence of carbon dioxid render the manure unfavorable for the development of the larvæ, it follows that compact heaping and watering, by excluding air and increasing the moisture content, also insure the greatest percentage of migration. As a matter of fact, compactness and high moisture content are the very factors which make the maggot trap most effective, whether the explanation is to be found in the temperature, or moisture, or lack of oxygen.

CONCLUSIONS.

In this paper we have described the structure of, and the method adopted in using, a platform maggot trap. All the manure from a stable in which three horses were kept was stored on this platform. The results obtained during August and September seemed to show that at least 98 per cent of the larvæ breeding in this manure were destroyed. Fly counts made before and after the trap was installed indicated an average reduction of from 67 to 76 per cent. That the reduction of flies did not correspond to the percentage of larvæ destroyed was probably due to the presence of several other breeding places well within the range of flight.

Two difficulties were experienced in the practical working of the trap, viz, the accumulation of a certain amount of straw and débris on the floor under the platform and the breeding of mosquitoes in the water used to drown the fly larvæ. It was also found that low air temperatures hinder migration and consequently decrease the efficiency of the trap.

Among the merits of the maggot trap were mentioned (1) the comparatively small initial cost and absence of money outlay necessary for its maintenance, (2) the very small amount of additional time or labor required in its operation, (3) the ease with which wagons or manure spreaders can be loaded from the platform, and (4) its adaptability for use at stables where the daily production of manure is large. Finally, it is suggested that the same conditions which render the trap most effective are the ones which tend to preserve the value of the manure.

REFERENCES TO LITERATURE.

Beal, W. H.

1904. Barnyard Manure. (A revision of Farmers' Bulletin No. 21.) U. S. Dept. Agr., Farmers' Bul. 192, 32 p., 4 figs.

Brown, P. E.

1913. Farm Manures. Agr. Expt. Sta. Iowa State Col. Agr. and Mechanic Arts, Circ. 9, 16 p., illus., April.

Dehérain, P. P., and Dupont, C.

1900. Sur la composition des gaz confinés dans le fumier de ferme. *In* Ann. Agron., Paris, t. 26, p. 273–294.

Hewitt, C. G.

1914. Further observations on the breeding habits and control of the house fly, *Musca domestica*. *In* Jour. Econ. Ent., v. 7, no. 3, p. 281–293, figs. 20–21, June.

Howard, L. O.

1911. The House Fly—Disease Carrier. New York.

Hutchison, R. H.

1914. The migratory habit of house-fly larvæ as indicating a favorable remedial measure. An account of progress. U. S. Dept. Agr., Bul. 14, 11 p., Feb. 28.

Levy, E. C., and Tuck, W. T.

1913. The maggot trap—A new weapon in our warfare against the typhoid fly. *In* Amer. Jour. Pub. Health, v. 3, no. 7. p. 657–660, illus., July.

Ringelmann, Max.

1913. Aménagement des Fumiers et des Purins, 187 p., 103 figs. Paris. (Nouvelle Bibliothèque du Cultivateur.)

Thorne, C. E.

1913. Farm Manures, 242 p., illus. New York and London.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

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