U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 92.

L. O. HOWARD, Entomologist and Chief of Bureau.

WHITE FLIES INJURIOUS TO CITRUS IN FLORIDA.

BY

A. W. MORRILL, Ph. D.,

AND

E. A. BACK, Ph. D.

Issued July 12, 1911.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

FIG 1.—ORANGE COVERED WITH SOOTY MOLD.

FIG. 2.—LEAF OF ORANGE COATED WITH SOOTY MOLD.

A Hoen & Co Baltimore

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BUREAU OF ENTOMOLOGY.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., March 2, 1911.

SIR: I have the honor to transmit herewith, for publication as Bulletin 92 of the Bureau of Entomology, a manuscript prepared by Drs. A. W. Morrill and E. A. Back, dealing with the life history of the white flies injurious to citrus trees in Florida.

The investigation of the citrus white flies in Florida, under the general direction of the assistant chief of this bureau, Mr. C. L. Marlatt, was begun in 1906, and is now approaching completion. There has already been published a bulletin (No. 76) dealing fully with the general subject of fumigation with hydrocyanic-acid gas for the white fly. A circular (No. 111) has also been issued, giving brief directions for winter fumigation.

The present publication is a general account of the two species of white flies which are of special economic importance to the citrus grower in Florida. The publication includes the history of these insects in the United States, their distribution and food plants, and a very detailed study of the habits and life cycle of the two species. A great deal of painstaking and minute work has been done, and the information secured furnishes an accurate foundation for the developing of the best means of control.

Supplementing this publication, which deals largely with life history and habits, it is proposed to publish a bulletin on control by sprays, fungi, and other enemies, and to supplement or reissue in revised form the bulletin dealing with fumigation.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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WHITE FLIES INJURIOUS TO CITRUS IN FLORIDA.

INTRODUCTION.

The present bulletin includes the principal results of studies of the two species of white flies most destructive to Citrus in the United States, commonly known as the citrus white fly (*Aleyrodes citri* R. & H.) and the cloudy-winged white fly (*Aleyrodes nubifera* Berger). With these pests successful control measures must be based on a complete understanding of the insects themselves. On this account the study of the insects, their life history, seasonal history, habits, food-plant relationships, and related topics has occupied an unusually important position in the white-fly investigations.

The authors have concluded that unless natural enemies capable of controlling the two white-fly pests are existent and are secured, control measures will require permanent expert supervision for the most satisfactory and economical results—not supervision of work in individual citrus groves, but supervision aimed principally to properly correlate individual efforts and to take full advantage of favoring local conditions. For supervision of this nature, a good foundation of extensive and reliable studies of the insects is necessary. While the portion of the white-fly investigations herein reported is comparatively extensive, it is necessarily not exhaustive and in the course of time certain features of this work can undoubtedly be continued with profit as an aid to the future improvement of control measures.

The white-fly investigations now in progress were begun in July, 1906, by the senior author, who was in field charge up to the time of his resignation from the bureau in August, 1909. The junior author's connection with these investigations dated from June, 1907. The life-history studies of the first two years have been largely superseded by the more extensive work of the third year. Practically all of the data presented under the subjects of the life history and habits and the seasonal history of each species are based on studies by the junior author and were written by him. The remainder of the bulletin was written by the senior author.

SPECIES OF WHITE FLIES AFFECTING CITRUS.

Twelve species and one subspecies of the family Aleyrodidæ are known to breed upon citrus. The list of these insects, the authority for the original description, the recorded distribution, and the food-plant records are given in Table I:

Table I.—*Aleyrodidæ that breed upon citrus.*

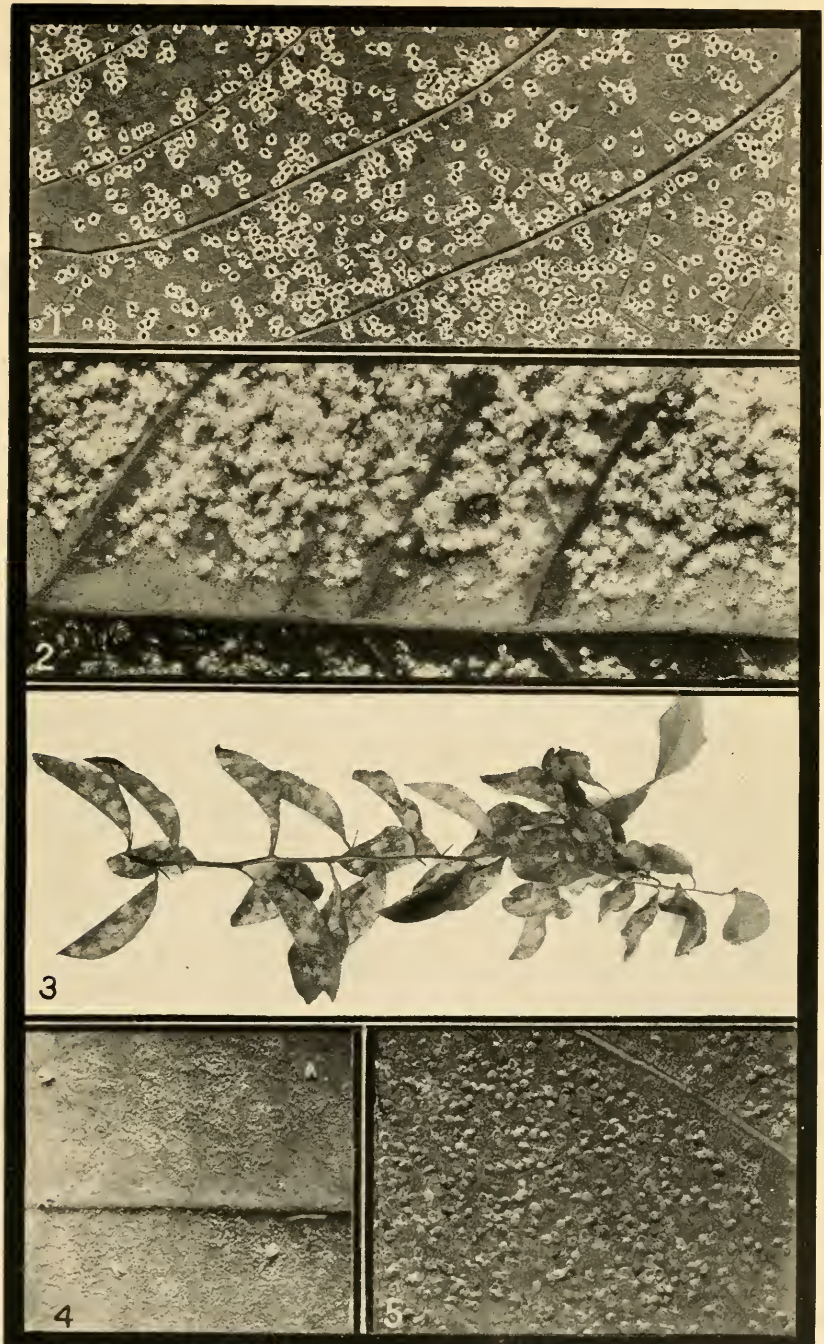
Species.	Described by—	Occurrence.	Food plants other than citrus.
Aleyrodes citri (syn. aurantii).[1]	Riley and Howard.	North and South America, Asia, Japan.	See list, p. 29.
Aleyrodes floccosa	Maskell	Mexico, Jamaica	Guaiacum officinale.
Aleyrodes floridensis	Quaintance	United States (Florida)	Persea gratissima (alligator pear), Psidium guajava (guava).
Aleyrodes giffardi	Kotinsky	Hawaii	None recorded.
Aleyrodes howardi	Quaintance	Cuba, United States (Florida).	Do.
Aleyrodes marlatti	do	Japan	Do.
Aleyrodes mori	do	United States (Florida)	Do.
Aleyrodes mori arizonensis	Cockerell	United States (Arizona)	Do.
Aleyrodes nubifera	Berger	United States (Florida, Louisiana), Cuba.	Do.
Aleyrodes spinifera	Quaintance	Java	Rosa spp.
Aleyrodes struthanthi	Hempel	Brazil	Michelia flava, Loranthus (struthansus) flexicaulis.
Aleyrodes vitrinellus[2]	Cockerell	Mexico	None recorded.
Paraleyrodes perseæ	Quaintance	United States (Florida)	Do.

[1] Mr. A. L. Quaintance, after careful comparison of material from Maskell's collection, evidently type material, with *A. citri*, concluded that Maskell's *aurantii* was the same as Riley and Howard's *citri*. Through the kindness of Mr. Quaintance the authors have had an opportunity to examine the material referred to and agree with him in considering *aurantii* a synonym of *citri*.

[2] There seems to be some doubt as to the identity of the food plant of this species, for in connection with the description the authority for it gives the following food plant record: "On the under side of leaves which appear to be those of orange."

Of the Aleyrodidæ referred to above, *A. citri*, *A. giffardi*, *A. howardi* (Pl. II, figs. 2, 4), and *A. nubifera* are known to be orange pests or capable of becoming orange pests. *A. floridensis*, *A. mori* (Pl. II, fig. 1), *A. mori arizonensis*, and *Paraleyrodes perseæ* (Pl. II, fig. 3) apparently are not likely to cause injury to citrus, while the remainder of those listed are doubtful in this respect.

Paraleyrodes perseæ is found in all sections of Florida and is frequently quite abundant, but in only one instance has it been known to cause blackening of the foliage of citrus trees. This was in the winter of 1906–7 and occurred in a pinery where in one section citrus nursery trees were being grown. In the course of two or three months after being first noticed the insects were reduced to the point of scarcity through parasitism by a new species of Encarsia, which Dr. L. O. Howard has described under the name of *Encarsia variegata*. Observations extending over three years indicate that this parasite will effectively control *P. perseæ* and that it is unlikely that this aleyrodid will ever cause noticeable injury under ordinary conditions. It is, however, possible that the appearance of a prolific hyperparasite of *Encarsia variegata* might seriously interfere with the present equilibrium in nature.



FLORIDA WHITE FLIES MISTAKEN FOR CITRUS AND CLOUDY-WINGED WHITE FLIES.

Fig. 1.—*Aleyrodes mori* on mulberry. Fig. 2.—Woolly white fly (*Aleyrodes howardi*) on orange. Fig. 3.—*Paraleyrodes perseæ* on orange. Fig. 4.—Woolly white fly (*Aleyrodes howardi*), showing eggs in circles and adults. Fig. 5.—*Aleyrodes* sp. on sea grape. (Original.)

The woolly white fly (*Aleyrodes howardi* Quaintance (Pl. II, figs. 2, 4)) was first discovered in this country at Tampa, Fla., by the junior author in November, 1909. The insect appears to be of recent introduction, since the infested area has been under observation at intervals during the past three and a half years by the several men connected with these investigations.[1]

Of the four species known to be destructive to citrus, *Aleyrodes citri* and *A. nubifera* are included in the investigations herein reported.

THE CITRUS WHITE FLY.

(*Aleyrodes citri* R. & H.)

HISTORICAL REVIEW.

Origin.

The origin of the citrus white fly is by circumstances quite definitely indicated to be Asiatic. The present known occurrence of it in Japan, China, and India will be referred to under the subject of distribution. The list of food plants, showing as it does the natural adaptations in this respect, indicates in itself that the fly is not native to either North or South America, but to Asia. Moreover, if the citrus white fly were a species native to the Gulf coast region of North America, or if it had been introduced before 1850, it would almost certainly have become a pest worthy of mention by Townend Glover in his reports on the orange insects of Florida published in the United States Agricultural reports for 1855 and 1858. According to these reports orange growing was very extensive in proportion to the population and very profitable in spite of the temporary check due to the freeze of 1835. The principal orange-growing district in Florida was, at the time of the reports of Glover, already mentioned, the northeastern section of the State, along the St. Johns River and at St. Augustine. Orange growing on a large scale gradually spread to the south and southwest, the center of production being correspondingly moved. To-day citrus fruits are generally grown in all the counties of the peninsula of Florida, yet, according to the authors' estimates, only about 40 per cent of the orange groves of the State are infested by *A. citri*.[2] These infestations in the different sections are almost without exception readily traceable to the ordinary sources of dissemination, with all the evidence strongly against the fly having been a native species infesting uncultivated food plants. The same may be said in regard to the occurrence of the citrus white fly in orange-growing regions in Mississippi, Alabama, Louisiana, and Texas.

[1] The Woolly White Fly, a New Enemy of the Florida Orange. Bulletin 64, Part VIII, Bureau of Entomology, U. S. Department of Agriculture, 1910.

[2] *A. nubifera* alone occurs in not more than 5 per cent of the groves. In 15 of the 40 per cent above mentioned both *A. citri* and *A. nubifera* occur.

Early History in the United States.

Riley and Howard give the following account of the status of the citrus white fly previous to 1893:

For many years an important and interesting species of the type genus has been known to infest orange trees in Florida and in more northern greenhouses, and more recently the same form has appeared in injurious numbers in the orange groves of Louisiana. In the Florida Dispatch, new series, volume 11, November, 1885, this species received the name of *Aleyrodes citri* at the hands of Mr. Ashmead. The Florida Dispatch, however, is a local newspaper of no scientific pretensions, and the description accompanying the name was entirely insufficient to enable recognition aside from the food plant. We adopt the name in connection with a full description, not with a view of encouraging such mode of publication, which is not sanctioned by the canons of nomenclature formulated and generally accepted, but as a manuscript name, satisfactory in itself, the authority to be recognized for it being comparatively immaterial.

Our first acquaintance with the species was in June, 1878, when we found it occurring in profuse abundance on the leaves of the citrus trees in the orangery of this department. Some observations were made upon its life history during that summer, and all of its stages were observed. During the following years we observed it in Florida, and it was studied by two of our agents, Mr. H. G. Hubbard, at Crescent City, and the late Joseph Voyle, at Gainesville. The species was not treated in Mr. Hubbard's report on the insects affecting the orange, as we wished to give it a fuller consideration than could then have been given, and other duties prevented doing so in time. Moreover, at the time when Mr. Hubbard's report was prepared the insect had not become of especial economic importance.

Since that time many further notes have been made in Washington, and we have received the species from Pass Christian, Miss.; New Orleans, La.; Baton Rouge, La.; Raleigh, N. C.; and many Florida localities; and during the past year or two it has become so multiplied in parts of Louisiana and Florida as to deserve immediate attention.

The authors quoted above specifically recorded the occurrence of the white fly in Florida only at Gainesville (Alachua County), Crescent City (Putnam County),[1] and Manatee (Manatee County). Dr. H. J. Webber in 1897 (basing his statement on records in 1893 and 1894) referred to the occurrence of the white fly at the following additional points: Evinston (Alachua County), Ocala and Citra (Marion County), Ormond (Volusia County), Panasoffkee (Sumter County), Orlando (Orange County), Bartow (Polk County), and Fort Myers (Lee County). Prof. H. A. Gossard in 1903 mentioned only the following additional localities specifically: Tallahassee (Leon County), Lake City (Columbia County), Jacksonville (Duval County), and Candler (Marion County). In the same publication the following additional

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[1] Examination of the specimens of white flies in the collection of the Bureau of Entomology, collected by Mr. H. G. Hubbard in 1895 and bearing the locality label "Crescent City," indicate that this record with little doubt refers to *Aleyrodes nubifera*. Circumstances known to the authors, but which need not be discussed here, show that with little doubt the citrus white fly was the species present at Crescent City before the freeze of the winter of 1894–5. The specimens collected by Mr. Hubbard probably came from the Hubbard grove at Haw Creek, several miles southeast of Crescent City.

counties were reported more or less infested without reference to definite localities: Baker, Jefferson, Leon, and Brevard.

Messrs. Riley and Howard and Dr. H. J. Webber advance no theories in regard to the original Florida infestations. Prof. Gossard, however, has the following to say in regard to the matter:

> The fly seems to have been first known throughout the region comprised in Volusia, Marion, Lake, Alachua, and Orange Counties, from which I have little or no doubt it was transferred to the Manatee country and to local centers along the northern borders of the State.

According to reliable information received from Mr. M. S. Moreman, of Switzerland, Fla.; Mr. A. M. Terwilliger, of Mims, Fla., and Mr. T. V. Moore, of Miami, Fla., the citrus white fly appeared in the northern part of St. Johns County at a date which indicates that this section was one of the first or possibly the first to be infested in the State of Florida. Mr. Terwilliger informs us that he first observed the white fly at Fruit Cove on the St. Johns River in 1879 in a grove of large seedling trees owned by Col. McGill. The McGill grove adjoined the grove of the Rev. T. W. Moore, whose son, Mr. T. V. Moore, corroborates Mr. Terwilliger on the point of the occurrence of the white fly in this section prior to 1880. According to Mr. Moreman the white fly was known in the vicinity of Switzerland on the St. Johns River in 1882, and was first discovered in his own grove in 1888. The species concerned is with little doubt the citrus white fly, *A. citri*, for the authors and Mr. W. W. Yothers have been unable to find specimens of any other species at Switzerland or St. Augustine, the two points visited in the northern part of St. Johns County, or at Green Cove Springs, located a few miles below Switzerland on the west side of the St. Johns River in Clay County. These early reports of the citrus white fly in this section of the State are supported by the fact that the earliest collected specimens of this species in the collection of the Bureau of Entomology bear the date 1888 and the locality label "St. Nicholas," a point located in Duval County about 15 miles north of Fruit Cove.

Interesting information concerning the early history of white-fly infestations in Florida has been obtained from Messrs. Borland and Kells, citrus growers at Buckingham, Lee County, Fla., formerly of Citra, Marion County. According to these gentlemen, the presence at or near Panasoffkee, in Sumter County, Fla., of a small white insect which caused blackening of the foliage of orange trees became known among orange growers around Citra, at that time in the heart of the orange-growing district of Florida, in 1881 or 1882. The grove of Bishop Young, of Panasoffkee, was one of the first reported infested. It is believed that Bishop Young, after traveling in Asia (Palestine?), brought back with him plants which he set out, and in a year or two thereafter blackening of the foliage of near-by citrus trees in association with a new insect pest first became noticeable. The white fly affecting citrus trees at Panasoffkee was exterminated by the freeze of 1894–1895 and, so far as the authors can learn, has not reappeared. There seems to be at present no means of determining whether the report given above refers to the citrus white fly or to the cloudy-winged white fly.

Mr. A. J. Pettigrew, of Manatee, Fla., a reliable observer who has been in the citrus nursery and orange-growing business in Manatee County since 1884 and who has been familiar with the white fly since its first discovery in that country, has furnished the authors with a statement concerning the early history of the pest in that section of Florida. According to Mr. Pettigrew, Messrs. C. H. Foster and F. N. Horton each received from Washington, D. C., 6 tangerine trees in 1886 or 1887—as near as can be determined at this time, although possibly earlier by a year or two. A year or two after the trees were received and planted, the fly was noted by Mr. Pettigrew as abundant on a rough lemon near one of these tangerines, and the following year it was first noted as abundant in a seedling orange grove near by. At Mr. Pettigrew's suggestion specimens were sent to the Department of Agriculture at Washington and identified as a white fly. These specimens were probably sent to Washington in 1891, for a letter from Mr. Foster, dated January 8 of that year, was published in Insect Life[1] with the reply. The oldest specimens of the citrus white fly now in the collection of this bureau, which were collected in Manatee County, Fla., bear the date of March 5, 1891, with "Mantee" as the locality record. These were probably sent in by Mr. Foster in connection with later correspondence than that referred to above.

Concerning the history of the citrus white fly in Louisiana, Prof. H. A. Morgan in 1893 made the following statement:

> This pest, common from Baton Rouge to the Gulf, is known as the white fly. Orange growers claim that it has been recently introduced—that is, within the last ten years—and it is supposed to have come in upon plants brought to the New Orleans exposition in the year 1885. The present wide distribution of the white fly in the southeastern United States is due to the lack of restrictions, until very recently, against shipments of infested nursery stock and of privets and the Cape jessamine.

Literature.

The citrus white fly was first given a valid scientific name and adequately described by Riley and Howard in an article published in Insect Life[2] in April, 1893. Following the account of the early history heretofore quoted, these authors describe the different stages of the insect in detail, give an account of the habits and life history, and give records with discussion of results obtained by a correspondent

[1] Insect Life, vol. 4, p. 274.

[2] Id., vol. 5, no. 4, pp. 219–226, 1893.

in Manatee County, Fla., who had undertaken some cooperative experiments in spraying.

During the same year (1893) Prof. H. A. Morgan, then entomologist of the Louisiana Agricultural Experiment Station, gave an account of the citrus white fly in Louisiana in a bulletin of that station.[1]

The Division of Vegetable Physiology and Pathology of the United States Department of Agriculture began investigations of citrus diseases in Florida in 1893. These included investigations of the "sooty mold" resulting from white-fly infestation, and the first report on the subject was published by Swingle and Webber in 1896[2] and a more extended report by Dr. H. J. Webber in 1897.[3] Conclusions from a series of spraying experiments are included in this publication and many important observations are recorded, particularly in connection with the two most useful fungous enemies of the white fly which were discovered by Dr. Webber in the course of his work.

Prof. H. A. Gossard, then entomologist of the Florida Agricultural Experiment Station, published, in 1903,[4] an account of the white fly situation up to that time, with his conclusions from observations extending over several years.

In a volume entitled "Citrus Fruits," published in 1904 by Prof. H. H. Hume, four chapters are devoted to citrus insect pests and methods of control, the white fly receiving due attention.

Since the present investigations by the Bureau of Entomology have been in progress, Dr. Berger, entomologist of the Florida Experiment Station, has published two bulletins[5] which present a summary of white-fly conditions with recommendations for control, particularly with reference to the use of fungous enemies. In the later published of the two mentioned, the specific distinctions are pointed out and illustrated, separating from the common *A. citri* the form which Dr. Berger has named *A. nubifera*.

Messrs. P. H. Rolfs and H. S. Fawcett, in a bulletin issued in July, 1908,[6] discuss in a general way the use of fungous parasites of the white fly in Florida and give recommendations for the introduction of the three most common species. The most important contribution to our knowledge of the fungous parasites of the citrus white fly is contained in a paper by Prof. H. S. Fawcett, published in 1909.[7]

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[1] The Orange and Other Citrus Fruits. By W. C. Stubbs and H. A. Morgan. Spec. Bul. La. Agr. Exp. Sta., pp. 71–73, 1893.

[2] The Principal Diseases of Citrus Fruits in Florida. By W. T. Swingle and H. J. Webber. Bul. 8, Division of Vegetable Physiology and Pathology, pp. 25–28, 1896.

[3] The Sooty Mold of the Orange and its Treatment. Bul. 13, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, 1897.

[4] White Fly. Bul. 67, Fla. Agr. Exp. Sta., June, 1903.

[5] White Fly Conditions in 1906, the Use of Fungi. Bul. 88, Fla. Agr. Exp. Sta., January, 1907; White Fly Studies in 1908, Bul. 97, Fla. Agr. Exp. Sta., February, 1909.

[6] Bul. 94, Fla. Agr. Exp. Sta., July, 1908.

[7] Special Studies No. 1, University of State of Florida, 1909.

In Louisiana the demand for information concerning the citrus white fly has resulted in a publication on this subject by Mr. A. H. Rosenfeld in 1907.[1] The discovery of the white fly in California in the same year led to the publication, by Prof. C. W. Woodworth, of a circular of general information,[2] and of a second circular[3] dealing with the methods of eradication that were being employed in that State. A very complete account of the white-fly infestation in California was given by Mr. C. L. Marlatt, assistant entomologist of the Bureau of Entomology, before the Entomological Society of Washington.[4]

The foregoing paragraphs refer to the principal publications in which the citrus white fly is treated, exclusive of short papers in horticultural periodicals, press bulletins, experiment station reports, and transactions of the Florida State Horticultural Society. Numerous press bulletins have been issued by the Florida State Experiment Station dealing with several phases of white-fly control and written from time to time as the occasion demanded by Prof. Gossard, Dr. Sellards, Dr. Berger, and Prof. Fawcett.

Reviews of the white-fly situation for the year, with notes on new observations, have been included in their annual reports by each of the first three named, who have served successively as entomologist at the Florida Experiment Station. Many important papers and discussions on the white fly have been published in the Transactions of the State Horticultural Society, but for the most part these have been incorporated or the ground covered more fully in the regular bulletins referred to.

Taken as a whole, the literature on the citrus white fly is quite extensive, giving a fairly good idea of the status of the white fly and progress in methods of control from year to year since the publication of the paper by Riley and Howard referred to in the opening paragraph.

The description of the different stages and the account of the life history and habits of the citrus white fly by Riley and Howard have been followed quite closely by subsequent writers, few additional records having been made up to the beginning of the present investigations. Records of food plants, miscellaneous life-history records, general results of field experiments, and conclusions from general observations on the efficiency of spraying, fumigating, and natural control by fungous diseases have been published by Messrs. H. J. Webber, H. A. Gossard, E. H. Sellards, E. W. Berger, and H. S. Fawcett. Comparatively little real data has been published so far in

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[1] Circular 18, State Crop Pest Commission of Louisiana, 1907.

[2] Circular 30, California Agricultural Experiment Station, 1907.

[3] Circular 32, California Agricultural Experiment Station, 1907.

[4] Proceedings of the Entomological Society of Washington, vol. 9, pp. 121–123, 1908.

connection with experimental work with the white fly. A review of all the literature to date shows that data have been published on the effect of kerosene emulsion on white-fly eggs, by Riley and Howard; on the subject of effects of cold upon white-fly larvæ and pupæ, by Prof. Gossard; on the percentage of trees infected by the spore-spraying method of introducing the fungous parasites, and on the amount of honeydew secreted by the larvæ of the insect, by Dr. E. W. Berger; upon subjects related to fumigation,[1] by the senior author of the present bulletin; and on laboratory experiments with the fungous parasites, by Prof. H. S. Fawcett. Aside from the above, practically no data have been heretofore published.

INJURY.

Nature of Injury.

The direct injury by the citrus white fly may be included under two main heads: (1) Injury by removal of sap from foliage, and (2) injury from fungous growth known as sooty mold (Meliola), which develops upon foliage and fruit on the excretions of the insects.

The direct injury is principally included as loss in value of trees, extra expenses of maintenance, and losses from scale insects and diseases, which more seriously affect white-fly infested trees.

LOSS OF SAP.

The amount of sap extracted by the insects is not generally considered an item of great importance compared with the injury from sooty mold. While the extraction of sap by itself probably would not cause sufficient injury to make the white fly rank as an important citrus pest, it is doubtless of considerable importance when combined with the lowered assimilative powers of the foliage due to the sooty mold. As mentioned more in detail under the subject of feeding habits, it has been estimated that the loss of sap per day amounts to about one-half of a pound for 1,000,000 larvæ and pupæ.

SOOTY MOLD.

Sooty mold is the principal evidence of white-fly injury, and is the most important element of damage, affecting both the foliage and fruit. (See Pl. I, frontispiece.) No special attention has been given by the authors to its botanical aspects, but the following notes concerning it are taken mainly from Dr. H. J. Webber's report on this subject:[2]

[1] Fumigation for the Citrus White Fly as adapted to Florida Conditions. Bulletin 76, Bureau of Entomology, U. S. Department of Agriculture, Oct. 31, 1908.

[2] Bulletin 13, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, pp. 5–11, 1897.

The sooty-mold fungus is a species of the genus Meliola [1] of the order Pyrenomycetes. Dr. Webber states that in Florida and Louisiana it is quite generally known as smut or black smut, but as the fungus concerned is not a smut fungus these terms are erroneous, and their use should be discontinued. When abundant on leaves and fruit of citrus, this fungus forms a dark-brown or black membranous coating composed of densely interwoven branched mycelial filaments. At first this coating covers only limited spots or is not thick enough to form a distinct membrane, but later, if the honeydew-secreting insects are abundant, the coating becomes thick enough to be entirely removed from the leaf and torn like paper. (Pl. III, figs. 1, 2.)

Frequently the fungus membrane becomes detached at some point and is caught by the wind and large fragments torn off. These fungus fragments are found scattered about in badly infested groves in the fall, being especially noticeable during the winter after a high wind or after the trees have been sprayed.

Dr. Webber recognized several forms of reproductive agents, which are easily distributed by various means, but principally by winds. The fungus is entirely saprophytic in so far as known, deriving its nourishment from the honeydew secreted by certain insects. As such honeydew falls mostly on the upper surface of the leaves and on the upper half or stem end of the fruit, the sooty mold develops most densely in these places, but it is usually present to a greater or less extent on the lower surface of the leaves, sometimes developing in tufts on drops of honeydew which diseased insects fail to expel in a normal manner. Sooty mold also develops on the twigs and in some cases on the sides of buildings when heavily infested trees are growing near by.

Seasonal history of sooty mold.—The sooty mold resulting from the attacks of the citrus white fly is most abundant late in the season. Very little sooty mold develops during the winter months, while the films of blackish mycelium gradually become removed from the leaves by winds and rains and much is knocked off in picking the fruit, in spraying, pruning, fumigating, etc. The thicker the coating of sooty mold, the more readily and thoroughly it is removed. By the time of the appearance of the new spring growth the greater part of the sooty mold on the old leaves has disappeared and from this time to the 1st of May there is very little, if any, evidence of a new growth of this fungus. Slight blackening of spring growth has been noted as far north as Island Grove in Alachua County, Fla., as early as May 20, the average number of live larvæ and pupæ per leaf being estimated as about 50, not including old leaves which were practically uninfested. By June 20, leaves from McIntosh, in the same county,

[1] Generally referred to *M. camelliæ* (Catt.) Sacc., but perhaps including more than one species.

SOOTY MOLD.

Fig. 1.—Sooty mold on orange leaf following white-fly attack; broken and falling from leaf.
Fig. 2.—Sooty mold on cinnamon tree following attacks by cinnamon scale. (Original.)

with an average of about 11 live larvæ and pupa cases[1] per leaf, were slightly blackened. In general, heavy coats of sooty mold on leaves are common in Florida by the 1st of June in groves heavily infested by the citrus white fly.

Effect of sooty mold on leaf functions.—Dr. Webber has discussed the effect of sooty mold on leaf functions in the report already referred to, and as there is nothing to add at this time, the following paragraph (pp. 10–11) is quoted:

When it is remembered that various investigations have shown that the process of phytosyntax[2] is almost entirely checked in a plant placed in the back part of a living room, opposite a window, where the light is fairly bright, but diffused, it can readily be judged that the effect of the dark, compact mycelial membrane of the sooty mold covering the leaves would be to almost wholly check the process of phytosyntax in the orange tree. Quite bright or direct sunlight is necessary for the best results. The injurious effects of sooty mold on the phytosyntax was clearly demonstrated by Busgen. He removed the fungus membrane from a small portion of a leaf and exposed the leaf to the sun. In the evening, after a sunny day, the leaf was plucked and the chlorophyll extracted with alcohol. After this leaf was treated with iodine, the parts from which the membrane had been removed in every case stained a dense blue, indicating the formation of an abundance of starch, while the surrounding portions of the leaf, which were protected from the sun by the fungus membrane, remained entirely uncolored, showing that no starch was formed. The stomata, or breathing pores, are also to some extent closed by the sooty mold, and in this way the passage of gas is more or less hindered. In the orange leaf, however, the stomata are confined to the lower surface, where generally there is but little sooty mold. In plants where the stomata are on the upper surface of the leaf also, the damage resulting from the obstruction of the passage of gases would probably be considerably greater.

Extent of Injury.

In the following discussion the statements concerning injury and the estimates of the extent of this injury by the citrus white fly refer to groves in which the fly has become well established and in which no remedial measures have been practiced.

INJURY TO FRUIT.

Unless otherwise stated, oranges and tangerines are referred to. These constitute more than 88 per cent of the citrus fruit crop of Florida. The total injury to grapefruit by the citrus white fly is rarely over 15 per cent and is frequently inappreciable.

Ripening retarded.—Ripening of fruit on heavily infested citrus trees is greatly retarded, and in case of the formation of a very heavy coating of sooty mold on the upper half of the orange the rind underneath it may remain green indefinitely while the lower half of the fruit is

[1] Some of the first generation had matured, but are properly included with the insects responsible for the sooty mold present.

[2] "Phytosyntax" refers to the process of the formation of complex carbon compounds out of simple ones under the influence of light; "photosynthesis" is a more common term for this process of assimilation.

well colored. The retardation of ripening, delaying as it does in some cases the time when the fruit is marketable and materially increasing the percentage of culls, causes injury which is very conservatively estimated to range from 2 to 5 per cent of the value of the crop. The injury to grapefruit in retardation of ripening by the citrus white fly is much less, varying from none at all to 2 or 3 per cent.

Number and size.—The greatest injury by the white fly is in the reduction of the salable crop of fruit. Dr. Webber on this point makes the following statement:[1]

> The effect of the sooty mold on the orange is very noticeable, the growth being usually greatly retarded and the blooming and fruiting light. In serious cases growth is frequently entirely checked, and blooming and fruiting wholly suppressed until relief is obtained.

Prof. Gossard has estimated[2] that during a six-year period the reduction in yield due to the citrus white fly is from 25 to 40 per cent.

Replies to a circular letter of inquiry addressed to orange growers and the observation of the authors in Florida indicate that the reduction in yield due to the citrus white fly amounts to 50 per cent, on the average, when no artificial methods of control are practiced.

From information received from many growers and from personal observation, the authors would estimate that with continued good care and with the additional fertilizer usually given infested trees the reduction in yield in different groves in a series of years amounts to an average between 20 and 50 per cent.

The decrease in yield due to white-fly infestation ordinarily consists of a decrease in the actual number of fruit produced and also in the packing size. From information obtained it seems a conservative estimate to consider that oranges and tangerines are reduced either one or two packing sizes as a result of white-fly attack. For each packing size, the number of reduced fruit remaining the same, the reduction in the crop would average about 12.5 per cent.

Expense of cleaning.—Fruit noticeably affected with sooty mold requires cleaning before marketing. One of the most economical machines for washing fruit used in Florida is a California washer used by Mr. F. D. Waite, of Palmetto, and Mr. F. L. Wills, of Sutherland. The cost of washing with these machines ranges from 1.4 to 2.5 cents per box. The cost of cleaning with the simplest machines is about 5 cents per box. Mr. E. H. Walker, of Orlando, Fla., estimates the cost of hand cleaning oranges at 10 cents per box as a minimum and 7 cents a box for cleaning grapefruit. In consideration of the foregoing it is estimated that the range in cost of cleaning the sooty mold from fruit to be from 1 to 10 per cent of the value of the crop.

Shipping and keeping quality.—The sooty mold produced by the white fly and other citrus pests does not, so far as known, affect the

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[1] Loc. cit., p. 9. [2] Bul. 67, Fla. Agr. Exp. Sta., p. 617.

shipping quality of the fruit directly, but the processes of cleaning have been proved to be of considerable importance in this respect. The subject of the deterioration in shipping quality of citrus fruits has been thoroughly investigated in California by agents of the Bureau of Plant Industry under the direction of Mr. G. H. Powell.[1] Their report shows in a conclusive manner that the amount of decay in shipment is very materially increased by brushing or washing the fruit to remove the sooty mold. Table II, arranged from data published in the report referred to, shows the effect of dry brushing and washing fruit on the percentage of decay.

TABLE II.—*Effect, on decay, of cleaning sooty mold from fruit.*

Record No.	Unbrushed fruit apparently sound.	Dry brushed fruit apparently sound.	Washed fruit apparently sound.
	Per cent.	*Per cent.*	*Per cent.*
1	2.7	6.6	17.8
2	1.9	4.2	10.0
3		1.8	2.6

It will be observed that dry brushing increased the amount of decay to about two and one-half times the decay in the unbrushed in record No. 1, and to about two and one-fifth times in record No. 2. Washing increased the amount of decay to about six and two-thirds times in record No. 1, and to about five and one-fifth times in record No. 2.

The injury from cleaning the fruit is due to the increased opportunities for infection with spores of the blue mold and to mechanical injuries in the process of cleaning. The chances of decay are still further increased whenever the fruit is not thoroughly dried before packing. Washing in constantly running water or by running the fruits through brushes with water constantly sprayed over them is considered much less objectionable than the ordinary systems.

Flavor.—The attack of the white fly is generally supposed to affect the quality of the fruit in a marked degree. Dr. Webber and Prof. Gossard describe the flavor as insipid as a result of heavy infestations. The latter presents the results of chemical analyses of samples of the fruit of tangerine trees in two adjoining groves. In one grove the white fly was completely controlled by spraying; in the other the fly was unchecked. The analyses showed that there was, in the samples from the latter grove, 15 per cent less reducing sugar, 15 per cent less sugar dextrose, and 5 per cent less citric acid. While oranges and tangerines are frequently much affected in flavor, thoroughly blackened groves in many cases produce as well flavored fruit as can

[1] Bulletin 123, Bureau of Plant Industry, U. S. Department of Agriculture.

be found in the market. When trees are supplied with as much fertilizer as they can use to advantage the white fly does not ordinarily affect the flavor of the fruit to such a noticeable extent as is commonly believed. It is suspected that a well-grounded prejudice against the white fly rather than a discriminating taste is responsible for a large part of the supposed effect on the flavor of the fruit in infested groves.

Increased injury from scale insects and from plant diseases.—The number of culls is in some cases very much increased by diseases and insect pests which thrive after the trees have been weakened by the white fly. There are no data available showing the usual increase in percentage of fruit injured by scales and by diseases of the trees as a result of white-fly infestation, but this is a consequence observed by many citrus growers and is properly considered a factor of white-fly injury. As such it is conservatively estimated to vary from 1 to 5 per cent in groves thoroughly infested, although an instance of a valuable crop being completely ruined by secondary scale attack has come under the authors' observation.

Market value.—Imperfections in fruit rind due to diseases and insect pests as followers of the white fly and to failure of fruit rind to color up normally, in addition to the direct effect on the size of the marketable crop as heretofore discussed, usually lower the average grade even after the fruit is cleaned by the most approved methods. A few growers claim that after being cleaned their oranges and tangerines bring as good prices as any, and leaving out of consideration instances where it is claimed that most or all of the fruit is rendered absolutely unsalable under any conditions, we may conservatively estimate the depreciation in market value to range from none at all to 10 per cent.

Sooty-mold-blackened oranges shipped without cleaning have a market value ordinarily from 25 to 50 cents less per box than the same fruit would have cleaned.[1] Certain Florida brands of oranges well advertised, carefully graded, and packed, would fail to bring within a dollar a box of their average value if they appeared on the market blackened by sooty mold.

Losses to growers estimated on basis of prices paid by orange buyers.—The authors are indebted to Mr. E. H. Walker, of Orlando, for the information that during the season of 1907–8 orange buyers in Florida paid from \$0.75 to \$1.45 for oranges free from white-fly effects, and from \$0.50 to \$1 per box for fruit blackened by white fly; during the season of 1908–9 the price paid for clean fruit varied from \$0.60 to \$1 per box, and from \$0.50 to \$0.75 for fruit blackened by sooty mold. The loss to the growers is not entirely represented by these

[1] Statement based on information from Mr. E. H. Walker, Orlando, Fla.

figures, since, according to Mr. Walker, the best prices were not paid for sooty-mold-blackened fruit until late in the season after the clean fruit had nearly all been shipped or disposed of. Clean fruit at this time would have been proportionally more profitable.

INJURY TO TREES.

Weakening of vitality.—It is doubtful if the white fly is ever the direct cause of the killing of trees, limbs, or twigs in well-fertilized groves. It does, however, seriously stunt the growth of all heavily infested trees, and may temporarily entirely check the growth of young trees. Its greatest effect on the vitality of the tree is an indirect one. Infestation by the white fly appears to weaken the resistance of orange and tangerine trees to foot rot, die back, melanose, wither tip, and drought, and favors the multiplication of the purple and long scales which are second to the citrus white fly as citrus pests in the Gulf coast regions.

Depreciation in value.—The selling values of citrus groves are greatly reduced by white-fly infestation, and citrus nurseries have their territory for sales much restricted and values reduced. Concerning the reduction in value of groves of bearing trees one of the most experienced dealers in orange groves in the State estimates that it is in general about one-third. For years California has been closed to Florida nurserymen as a field for the sale of citrus nursery trees, and a similar quarantine regulation has recently gone into effect in Arizona. In Florida and in citrus-growing sections of other Gulf coast States a guaranty of freedom from white fly is generally required, especially when the purchaser contemplates planting a more or less isolated grove.

SUMMARY OF LOSSES.

The estimates in the foregoing pages refer to ordinary losses where the white fly is unchecked by natural enemies or by artificial methods of control and not to exceptional or occasional losses. These estimates, as applying to the fruit, are summarized in Table III.

TABLE III.—*Estimates of losses to orange crops by white fly in uncontrolled condition.*

	Maximum.	Minimum.	Mean.
	Per cent.	*Per cent.*	*Per cent.*
Ripening retarded	5	2	3½
Number and size of fruits	50	20	35
Cost of cleaning	10	1	5½
Deterioration in shipping quality	6	2	4
Indirect injury: Increased scale and disease effects on fruit	5	1	3
Loss in market value	10	0	5
Total	86	26	56

The mean of the total percentage of estimated loss is considered by the authors to represent about the normal loss which the citrus white fly is capable of causing in orange groves. It is estimated that the condition is reduced to about 45 per cent loss in the average infested grove as a result of net profits from spraying with contact insecticides and of the natural efficiency of fungous diseases.

From extensive records obtained in the course of their investigations the writers estimate that the citrus white fly infests at present 45 per cent of the citrus groves in Florida. Of this, 5 per cent is a sufficient allowance to represent the groves so recently infested that normal abundance of the pest has not been reached. An injury of 45 per cent in 40 per cent of the groves is equal to about 18 per cent of the entire value of the crop as it presumably would have been if the white fly were not present.

The latest Florida citrus crop concerning which statistics are available is that of 1907–8.[1] The orange crop for that season is valued at $3,835,000. With an estimated total loss of about 15 per cent this represents 85 per cent of the value of the crop if not affected by the white fly. Accordingly, the estimated loss in Florida is calculated to have been about $680,000 for oranges and similarly on the basis of 10 per cent loss to grapefruit on a valuation of $469,700, the percentage of infested groves the same as in the case of the orange groves, a loss of $16,700 is estimated, making the total loss in valuation of fruit about $696,700 for the crop of 1907–8. The crop of 1908–9 was doubtless affected to the extent of $750,000 by the citrus white fly.

At present the spread of the fly into uninfested groves is undoubtedly faster than at the rate of 5 per cent new infestations per year. Even on this basis, however, the annual increase in depreciation in the value of Florida citrus groves due to white-fly infestation is more than $200,000 per year.[2] In addition, the citrus nursery business in Florida is affected to an extent hard to estimate, but which would be only nominally represented by $50,000 per year.

Figures are not available which would allow approximate estimates to be made of the damage by the citrus white fly in the Gulf coast citrus-growing sections outside of Florida, but the widespread occurrence of the white fly in those States indicates that the losses are heavy.

INCREASED COST OF MAINTENANCE.

The items of expense of maintenance principally affected by the white fly are fertilization, spraying, and fumigation. In Florida

[1] Tenth Biennial Report of the Commissioner of Agriculture of the State of Florida.

[2] This is not shown by actual depreciation, for the number of groves coming into bearing for the first time each year more than covers the loss.

ordinarily the expense of the fertilizer necessary to maintain orange trees in good productive condition varies from 10 to 20 cents per box of fruit produced. The wide range given is largely due to differences in soil conditions. Mr. E. O. Painter, in response to an inquiry on the subject, writes that citrus trees infested with white fly in his opinion require at least 15 per cent increase in fertilizer for best results under the circumstances. On the basis of cost of fertilizer amounting to 10 to 20 cents per box and an increase of 15 per cent due to white fly infestation, the extra expense which may be charged as white fly injury amounts to 1.5 to 3 cents per box.

Cost of control measures properly chargeable to increased cost of maintenance.—Estimates based on the experience of the writers in fumigating and in spraying for the white fly give the range in expense of the former method of control as 5.5 to 14 cents per box of oranges produced, and of the latter method 12.5 to 20 cents per box. These estimates refer to thorough control, with the result that production is entirely unaffected by the white fly. The minimum estimate on the expense of fumigation refers to groves so located that the migrations of adults from outside groves does not make treatment necessary more than once in two years. The maximum estimate refers to conditions where treatment every year is required to prevent loss. Increase in production, due to destruction of scale-insect pests, is not taken into consideration. In the estimates of expense of control by spraying the minimum estimate refers to cases where three applications of insecticide per year have resulted in satisfactory control. This result can be attained only after the insect has been brought into complete subjection, such as referred to in the introductory paragraph of the subject of artificial control. Insecticides costing more than 1½ cents per gallon when mixed ready for application have not been taken into consideration.

DISTRIBUTION.

As has been shown in the historical review, the citrus white-fly at present is generally distributed in North America. In the northern part of the United States it occurs in greenhouses, and in the southern part, and in limited districts in California, it occurs on citrus, China trees, privet, cape jessamines, and other food plants. In the present publication we are concerned only with the distribution of the species in the citrus fruit-growing regions of the United States.

IN THE UNITED STATES.

According to the statistics of the Florida commissioner of agriculture, in 1905 there were 17 counties in the State reporting more than 5,000 bearing citrus fruit trees. In all but two of these, Dade and St. Lucie, the citrus white fly (*Aleyrodes citri*) occurs to a greater or less extent. (See fig. 1.) The 17 counties referred to, arranged in order of the number of bearing citrus trees, is as follows: Orange, Lake, Volusia, Polk, Putnam, Brevard, Hillsboro, De Soto, Lee, Manatee, Dade, Marion, St. Lucie, Osceola, Sumter, St. John, and Alachua. Palm Beach as well as Dade and Monroe Counties are infested with the cloudy-winged white fly, as hereafter noted, but so far as known the citrus white fly does not occur there. In order of the percentage of groves infested the foregoing counties which are known to be infested would be arranged about in the following order, so far as our observations and records show: Marion, Alachua, St. John, Manatee, Orange, Lee, Volusia, Polk, Putnam, Lake, Hillsboro, Sumter, De Soto, Osceola, and Brevard. If the groves infested by the cloudy-winged white-fly only were also taken into consideration, Hillsboro and Lake Counties would be transposed in the list, as would Osceola and Brevard, but aside from this there would be no change. The arrangement is only approximate, being based on observations made by the various men connected with the white-fly investigations upon information and samples of infested leaves received from correspondents and upon nearly 250 replies received in response to circular letters sent out in the spring of 1907.

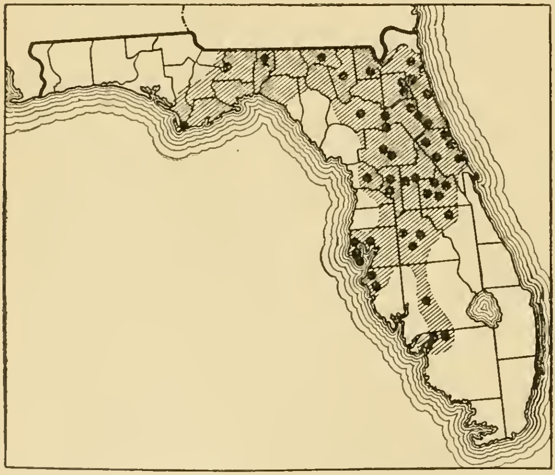


FIG. 1.—Map showing distribution of the citrus white fly (*Aleyrodes citri*) in Florida. (Original.)

At the present time the writers estimate that throughout the State of Florida about 40 per cent of the citrus groves are infested by the citrus white fly, and that an additional 5 (or 10) per cent are infested by the cloudy-winged white fly alone.

The citrus white fly occurs in nearly all the larger towns in northern Florida, infesting the various food plants which are grown as ornamentals as well as the citrus fruit trees which are grown to a limited extent. The insect is of common occurrence, principally on China trees, cape jessamines, and on privet and hedges of *Citrus trifoliata* in South Carolina and in southern Georgia, Alabama, Mississippi, Louisiana, and Texas. In the last two States citrus fruits are being grown quite extensively, and a large percentage of the citrus-growing localities are infested.

Aside from the Gulf coast States, citrus fruits in the United States are grown only in California and Arizona. The citrus white fly does not occur in Arizona. In California the pest was first discovered in May, 1907. Mr. C. L. Marlatt has given the following account of the distribution of the white fly in that State in 1907:[1]

Marysville is situated a few miles north of Sacramento, and the first infestation seemed limited to this town, but toward the end of the summer the white fly was discovered well established at Oroville, in Butte County, some 26 miles to the north of Marysville. The Marysville infestation was confined to the town and to yard trees or small garden orchards. Oroville lies in a considerable orange district, and the white fly had been carried from the town into several of the adjacent orchards and had become rather widely scattered. Shortly after the discovery of the fly at Marysville it was found also to have established itself locally near Bakersfield,[2] in the southern end of the San Joaquin Valley, and separated only by a mountain range from the citrus districts of southern California.

In Foreign Countries.

For years the citrus white fly has been supposed to be an introduced species, and much interest has been attached to its occurrence elsewhere than in North America. Prof. H. A. Gossard in 1903 stated that Mr. Alexander Craw, of the California State commission of horticulture, had received this species on plants from Chile, where it was reported to be a great pest. Mr. G. W. Kirkaldy, in his catalogue of the Aleyrodidæ, in 1907, gives "Mexico, Brazil, and Chile (?)" as the known habitats of the citrus white fly outside of the United States. The writers are informed by Prof. A. L. Quaintance that he was told in person by the late Prof. Rivera, of Santiago, Chile, that the citrus white fly was abundant in that country. Prof. Carlos Camacho, chief vegetable pathologist at Santiago, Chile, is also, according to Prof. Quaintance, authority for the statement that it occurs there.

The Bureau of Entomology received, in 1906, specimens of an aleyrodid on orange leaves from China which Prof. Quaintance determined as *Aleyrodes citri*,[3] and still more recently it received, through Mr. August Mayer, in charge of plant-introduction garden, and through the California state commission of horticulture, specimens of orange leaves infested with what Prof. Quaintance has identified as this species from different parts of China and Japan.

The occurrence of the citrus white fly in India (northwestern Himalayas) has recently been established by Prof. Quaintance, who has compared Maskell's *A. aurantii*, collected in the region mentioned

[1] Proceedings of the Entomological Society of Washington, vol. 9, pp. 121–122, 1908.

[2] Specimens of the species present at Bakersfield were examined by the senior author at the California State Insectary at Sacramento and found to be the cloudy-winged white fly (*A. nubifera*).

[3] Proceedings of the Entomological Society of Washington, vol. 8, Nos. 3–4, p. 107.

above, with *A. citri*, and failing to find any differences in the egg and pupal stages found it necessary to regard the name given by Maskell as a synonym of that given by Riley and Howard.

The citrus white fly does not occur in Cuba, so far as known, although it is not unlikely to be found there, since there have been heavy shipments of nursery stock from infested citrus nurseries in Florida to that country during the last few years.

FOOD PLANTS.

AUTHENTIC AND QUESTIONABLE RECORDS.

The separation as distinct species of two forms formerly considered as belonging to the species *Aleyrodes citri* makes it necessary that all of the reported food plants of the citrus white fly be verified. Nearly 60 species of the genus Aleyrodes have been recorded for North America. Of these less than 20 have been described in the first larval stage in a manner which distinguishes them, although when carefully studied this stage has been found to have striking specific characters. The second and third larval stages rarely possess distinguishing characters. The fourth or pupal stage, or the empty pupa case, is used as the basis of specific descriptions in the Aleyrodidæ, but even in this stage a careful microscopic examination is usually necessary to positively determine the species. Good specific distinctions in the adult stage have been found only in a few species, and even those entomologists who have made a specialty of the Aleyrodidæ do not attempt to distinguish the different species in this stage. It is obvious, therefore, that a list of food plants should properly include only those verified by entomologists, with determinations of the species made since the status of the two most abundant citrus-infesting species of Aleyrodes has been fully recognized. Dr. E. W. Berger has recently arranged the full list of food plants and reported food plants in a graphic manner, separating the list into two classes according to the degree of preference, and each class is subdivided into native and introduced species. This method of grouping the food plants is here adopted (see Table IV) with the transposition of the lilac and coffee from class II to class I and omitting certain reported food plants in order to restrict the list to include only positive records, leaving the others for a separate discussion. Dr. Berger has recently discovered the citrus white fly on wild olive, and has also verified Prof. Gossard's report of the citrus white fly on *Viburnum nudum*. Both of these food plants, together with the green ash, will eventually be found to be subject to heavy infestation and be placed in class I.

TABLE IV.—*Definitely known food plants of the citrus white fly* (*Aleyrodes citri*).

CLASS I. PREFERRED.

Introduced:
1. Citrus (all species cultivated in America).
2. China tree (*Melia azedarach*).
3. Umbrella China tree (*Melia azedarach umbraculifera*).
4. Cape jessamine (*Gardenia jasminoides*).
5. Privets (*Ligustrum* spp.).
6. Japan persimmon (*Diospyros kaki*).
7. Lilac (*Syringa* sp.).
8. Coffee (*Coffea arabica*).

Native:
9. Prickly ash (*Xanthoxylum clava-herculis*).
10. Wild persimmon (*Diospyros virginiana*).

CLASS II. OCCASIONALLY INFESTED.

Introduced:
11. Allamanda (*Allamanda neriifolia*).
12. Cultivated pear (*Pyrus* spp.).
13. Banana shrub (*Magnolia fuscatum*).
14. Pomegranate (*Punica granatum*).

Native:
15. Smilax (*Smilax* sp.).
16. Cherry laurel (*Prunus laurocerasus*).
17. Wild olive or devilwood (*Osmanthus americanus*).
18. Viburnum (*Viburnum nudum*).
19. Green ash (*Fraxinus lanceolata*).

In addition to those in the foregoing list [1] there are several plants reported as food plants of the citrus white fly which, while probably true food plants, can not consistently be included in the recognized list until the observations have been repeated and the infesting species positively identified. In some instances where eggs or larvæ have been found there is doubt as to whether the white fly could develop to maturity on the plants in question. Plants upon which the insect is unable to develop to maturity can not properly be considered true food plants. The following is the list of plants reported as food plants, but which in each case require further observations either as regards the ability of the insect to reach maturity thereon or as regards the species of white fly concerned, in view of the recent separation of *A. citri* and *A. nubifera:* Water oak, reported by Prof. A. L. Quaintance; *Ficus altissima*, *Ficus* sp. (from Costa Rica), and scrub palmetto, reported by Prof. H. A. Gossard; honeysuckle and blackberry, reported by Dr. E. H. Sellards; oleander, reported by

[1] In addition to those already mentioned as being food plants in Florida, the following plants are on record at the State insectary at Sacramento, Cal., as food plants of the citrus white fly observed at Marysville and Oroville by agents of the State commission of horticulture: English ivy (*Hedera helix*), yellow jessamine (*Jasminum odoratissimum*), *Ficus macrophylla*, bay (*Laurus nobilis*), tree of Heaven (*Ailanthus glandulosa*), and crape myrtle (*Myrtus lagerstrœmia*). Information concerning the authorities for the plants listed is not available.

the senior author of the present publication; camellia, reported by Dr. E. W. Berger. In the case of the last two plants mentioned the uncertainty as to their proper standing is on the possibility of the insect reaching maturity thereon and not on the identity of the infesting species.

The present status of the plants which have heretofore been listed by entomologists as food plants of the citrus white fly is shown in the foregoing paragraphs. There are doubtless numerous additional introduced species and a few additional native species of plants occurring in the United States which serve or are capable of serving as food plants of the citrus white fly, but for the reasons connected with the identification of the insects, stated in the opening paragraph under the subject of food plants, reports of food plants other than those included in classes I and II should never be credited unless verified by or made by an entomologist. There are no important food plants occurring in the Gulf coast region omitted from this list, and future additions to the list probably will be of little significance economically as affecting the control of the pest. There is a widespread belief that many other common trees, shrubs, and vines in Florida are food plants of the citrus white fly, but the correctness or falsity of this belief can be readily ascertained in the case of the individual plants suspected by submitting specimens of the foliage and of the infesting insect to the Bureau of Entomology or to the State experiment station.

There are three common causes for erroneous reports concerning citrus white-fly food plants. The first is the presence of sooty mold on many plants, due to other honeydew-secreting insects, such as aphides, scale insects, and mealy bugs. The insects themselves are not seen in this case and the mistaken idea is due to ignorance of the fact that other insects than the citrus white fly excrete honeydew on which the same species of sooty mold fungus thrives. The second cause for erroneous reports in this respect is the misidentification of the insect concerned. The necessity for the identification of the infesting insect by an entomologist has been discussed. The third cause is the frequent occurrence of the adult citrus white fly on the foliage of plants upon which it does not breed and upon which it seldom or never deposits an egg. In the course of the present investigation by the Bureau of Entomology several trees and shrubs have been thoroughly tested as possible food plants by cage experiments, and observations have been made on these and other plants, showing that if it is possible for the citrus white fly to develop on one of them, it is, at the most, of too rare occurrence to be of any significance. Cage tests have been made with oak (*Quercus brevifolia*), Magnolia (*Magnolia fœtida*), blackberry (*Rubus* spp.), Laurel cherry or mock olive (*Prunus caroliniana*), and cultivated figs (*Ficus carica*) and crape myrtle (*Myrtus lagertrœmia*). In each case a rearing cage (Pl. VII) was attached to the end of a branch covering new growth and from 50 to 100 adults of *A. citri* were confined therein. Except in the case of the blackberry, in which no observation was made on the point, the adults were noted as resting contentedly and apparently feeding on the leaves for one or two days after being confined. In every case, however, all the adults were dead on the fourth day after confinement on the plants noted, although check lots of adults collected at the same time but confined on branches of citrus trees lived for a normal period. No eggs were deposited in any of the tests, although the check lots deposited eggs on the citrus leaves in a normal manner.

Each of the five plants tested with the cage experiments have in addition been subjected to very careful examinations by the writers under such circumstances that the opportunities for infestation by the citrus white fly were at their best. In addition, particular attention has been given to examinations of species of oaks (*Quercus* spp.) and bays (*Persea* spp.), guavas (*Psidium* spp.) and mulberries (*Morus* spp.), when located near, and in some cases with branches intermingling with infested citrus or other favorite food plants.

Economic Significance of Food Plants, and Interrelationship Between Food Plants and Insects.

Entomologists familiar with the present white-fly situation agree in their conclusion that a requisite for satisfactory control of this pest is proper attention to food plants other than citrus fruit trees. Mr. H. G. Hubbard, who was a well-known authority on orange insects, being a special agent of the Bureau of Entomology, was a strong advocate of destroying food plants of the white fly that were of no value. Dr. Sellards, formerly entomologist at the Florida Experiment Station, Dr. Berger, the present entomologist, Prof. P. H. Rolfs, director of the Florida Experiment Station, and the authors have each emphasized the importance of the relation of the various food plants to white-fly control.

The following paragraph from the senior author's bulletin on the subject of fumigation for the citrus white fly [1] states in a general way the situation in this respect as viewed by entomologists who have investigated the white fly:

> The presence of food plants of the white fly other than citrus trees, in citrus fruit-growing sections, constitutes a serious menace and in itself often prevents successful results from remedial work. Fortunately the list of food plants is limited, and the greater number of those thus far recorded is subject to infestation only when located near or in the midst of heavily infested citrus groves. The food plants which are of most importance in connection with the white-fly control are the chinaberry trees, privets, and cape jessamine, and these—except for the last, in certain sections where grown for commercial purposes—can be eradicated readily, or their infestation may be prevented where community interests precede those of the individual in controlling

[1] Bulletin 76, Bureau of Entomology, U. S. Department of Agriculture, pp. 9–10.

public sentiment. These food plants favor the rapid dissemination of the white fly from centers of infestation and their successful establishment in uninfested localities. They seriously interfere with the success of fumigation, as well as of all other remedial measures, by furnishing a favored breeding place where the white fly can regain its usual abundance in a much shorter time than would be the case if it were entirely dependent upon citrus fruit trees for its food supply. The plants mentioned, together with *Citrus trifoliata* (except where used in nurseries), and all abandoned and useless citrus trees should be condemned as public nuisances and destroyed in all communities where citrus fruit growing is an important industry.

Not only is a knowledge of the relation of the various noncitrus food plants to white-fly injury of great importance, but it is also of considerable importance to growers to know the capability of the insect for multiplying on the different citrus fruit trees in order that advantage may be taken of it in the arrangement of new groves and the improvement of old groves.

CITRUS.

It is a matter of common observation that injury from the white fly is most marked on citrus fruits of the Mandarin group. This group includes the Tangerine, Satsuma, and King of Siam. The sweet oranges are next to the mandarins in this respect, followed by the kumquats and grapefruits.

The relatively less injury to grapefruit by the citrus white fly (*A. citri*) is sometimes obscured by the presence of *A. nubifera*. Blackening of foliage and fruit by the citrus white fly is more noticeable on grapefruit trees when they are surrounded by or are otherwise unfavorably located in respect to oranges or tangerines. Solid blocks of grapefruit trees rarely show more than slight effects of white-fly infestation when only the citrus white fly is present. An example of this is the Manavista Grove at Manavista, Manatee County, Fla. This grove consists of 22,000 grapefruit trees, and appreciable blackening of the foliage is rarely seen except occasionally where orange groves adjoin. Only one record, based on actual examination of leaves, illustrating the difference in the degree of infestation of adjoining blocks of grapefruit and orange trees is available. The grapefruit block consisted of about 400 trees located immediately north of a block of 200 or 300 orange trees and separated on the west by a public road from a grove of about 800 orange trees. On April 23, 1909, after practically all the overwintering pupæ had matured, an examination of 100 or more leaves collected at random from each grove, counting the pupa cases, showed an average of 8 insects that had reached maturity on the grapefruit leaves, 27 on the orange leaves of the block south, and 56 on the orange leaves of the block west. No studies have been made to determine the different degrees of susceptibility to white-fly injury among the different varieties of grapefruit, but the Royal variety appears to be more nearly immune than any other of those commonly grown. This was first pointed out by Mr. F. D. Waite, of Palmetto, Fla. In this connection it should be noted that the Royal variety in its general characteristics is not a typical grapefruit.

The reason for the partial immunity of grapefruit trees to white-fly injury is as yet obscure. Several observations on grapefruit and orange trees growing side by side give no basis for the supposition that it is a matter of food-plant preferences of the adult flies. In some cases the differences in the amount of new growth must be taken into consideration. Counts of adults, pupa cases, and hatched eggs of the citrus white fly on alternating grapefruit and orange trees, six in all, located on the laboratory grounds at Orlando, were made on June 4, 1909, when no new growth was present on the trees. The leaves were selected at random and, with the exception of a few upon which adults were counted, they represented the spring growth of 1909. The difference between the number of the adults on 500 grapefruit and 500 orange leaves, 87 and 104, respectively, is not as great as would be expected, considering the much greater number of insects that had matured on the orange up to the time of the examination. There were about twenty times as many pupa cases on the 100 orange leaves as on the 100 grapefruit leaves, or 6 and 120, respectively. This was offset by the presence of about three times as many live pupæ on 10 grapefruit as on 10 orange leaves, 41 and 14, respectively, making the sum of the pupa cases and live pupæ 4.16 per leaf in the case of the grapefruit and 2.6 per leaf in the case of the orange. This is about the same proportion as the number of hatched eggs on the two food plants. The condition of the leaves, as shown by this data, fails to indicate any cause for the partial immunity of grapefruit trees.

The examinations by Mr. W. W. Yothers of two leaves picked at random from each tree in a small isolated grove consisting of 41 grapefruit and 28 tangerine trees gave rather striking figures, showing more rapid multiplication of the citrus white fly on the latter than on the former. The first examination was made on November 4, 1908, and the second on June 8, 1909. On the former date the average number of live and dead white-fly larvæ and pupæ per leaf was 31.9 on the grapefruit and 96.2 on the tangerine, 16.6 and 80.9, respectively, being alive. During the winter a series of fumigating experiments reduced the numbers of the white fly so that at the second examination the number per leaf was 1.1 on the grapefruit and 2.25 on the tangerine. The arrangement of the two kinds of trees in the grove was such that they had equal chances of becoming reinfested by the insects which escaped the effects of the experimental tests.

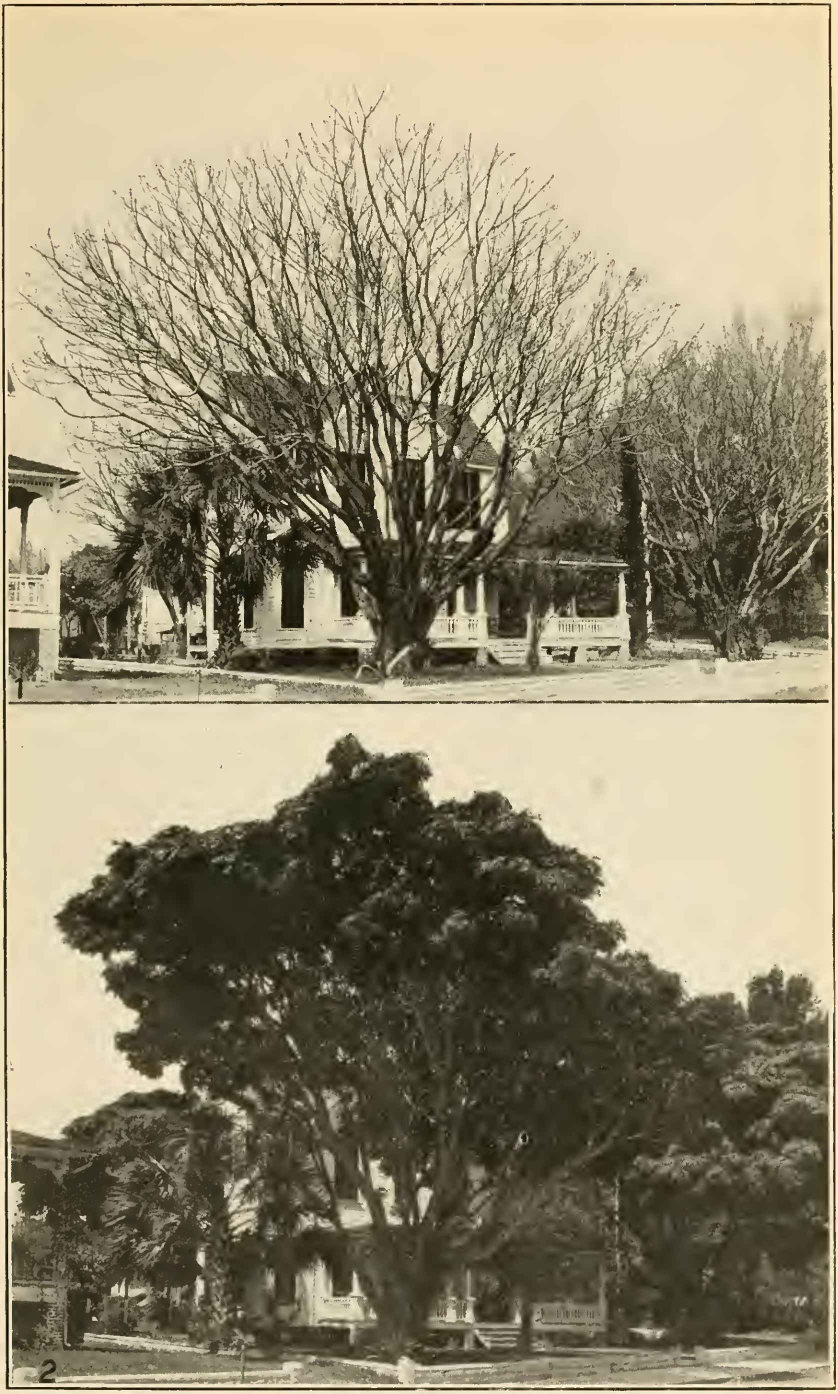
The difference in the degree of injury between orange and tangerine trees is less marked than between tangerine and grapefruit or orange and grapefruit, but the difference is nevertheless usually quite noticeable. The practical application of this difference in the degree of adaptation of the citrus white fly to the various citrus food plants will be discussed in a forthcoming bulletin dealing with the artificial control of the white fly.

CHINA TREES AND UMBRELLA TREES.

While China trees (Pl. IV) and umbrella China trees (Pl. V), when grown for shade and ornamental purposes, are, as has been pointed out, very injurious to citrus fruit-growing interests, the investigation of the utility of these plants as trap foods gives an increased importance to a definite knowledge concerning them as citrus white-fly food plants. Their injuriousness to citrus growers is very clear to professional entomologists, but not as generally appreciated by the citrus growers themselves as is desirable.

The umbrella tree is recognized by botanists as a variety of the China tree. This variety is the one most commonly grown except in a few localities, and observations reported herein specifically refer to it and not to the China tree. The latter tree has, however, been under observation by the authors, and no noticeable difference has been observed between the two trees in their relation to the citrus white fly, and the data and observations are in the main fully as applicable to the one as to the other.

The numbers of the white fly which mature on individual umbrella trees have been estimated in three instances and found to range between 25,000,000 and 50,000,000 where trees are favorably located with respect to nondeciduous food plants. Examinations were made by selecting 10 or more leaves at random and from each selecting a leaflet which appeared to represent the average condition of all the leaflets composing the leaf. In two instances it was found that the infestation was fully as great toward the top of the tree as on the lower parts. In one instance an extensive examination of different parts of an infested umbrella tree showed a decrease from lower branches to top branches of 50 per cent. In order to be fully conservative, this percentage has been used as the basis of the calculations, making the average infestation throughout the tree 75 per cent of the infestation of the leaves of the lower branches. Full-grown leaves were found to consist of about eighty-two leaflets. Complete records were made of eggs and of live and dead larvæ and pupæ, but only a part of this data will be presented. The estimates and counts of both leaves and insects in the case of the first tree were made by the senior author; in the cases of the second and third trees the estimates of the number of leaves per tree represent the average



THE CHINA TREE.

Fig. 1.—China tree defoliated during winter. Fig. 2.—Same tree in full foliage in summer. (Original.)

THE UMBRELLA CHINA TREE.

Fig. 1.—Leaflet of umbrella China tree, showing infestation by *A. citri*. Fig. 2.—Umbrella China tree with orange tree in rear of house. (Original.)

of three estimates—one by the senior author, one by the junior author, and one by Mr. W. W. Yothers. The counts and estimates of insects were made by the senior author in the second instance and by the junior author in the third. The data obtained in these examinations bearing on the number of insects the umbrella trees are capable of maturing are given in Table V.

TABLE V.—*Number of citrus white flies developing on umbrella China trees.*

Tree.	Date of examination.	Estimated number of leaves on tree.	Number of pupa cases per leaf.	Number of live pupæ per leaf.	Estimated number of insects matured on tree.	Estimated number of larvæ and pupæ alive at time of examination.
1	Oct. 28, 1906	20,000	2,478	4.1	49,560,000	82,000
2	Aug. 19, 1908	25,000	1,910	13.2	47,762,000	330,000
3	Aug. 25, 1908	12,000	2,230	4.0	26,760,000	58,800

The three trees examined are not in any way exceptional as regards the degree of infestation, but may be considered as representative of the condition of China trees and umbrella China trees in localities where the citrus white fly is established. Tree No. 1 was located by the roadside near a 5-acre grove of newly bearing budded orange and grapefruit trees which were lightly infested by the white fly and on which it is estimated that not over 100,000 insects could have matured on any one tree during the season. Tree No. 2 was located most unfavorably for a heavy infestation, standing in a vacant lot in the business section of Orlando and having its source of citrus white-fly infestation in the spring almost entirely restricted to two neglected and worthless orange trees of small size growing within a radius of 100 feet. Tree No. 3 was located in front of the laboratory at Orlando, with 36 orange and grapefruit trees on the grounds. The least conservative of the authors' estimates would place the number of white flies which matured on any one of these citrus trees during the year 1908 as not over 500,000, with the average of the 36 trees at about one-half this number. It is estimated, therefore, that the one umbrella tree produced upward of three times as many adult citrus white flies during the year 1908 as the 36 citrus trees on the laboratory grounds combined. The important relation of the remarkable multiplication of the citrus white fly on China and umbrella trees to the spread of the pest will be discussed under the heading "Spread."

Two new points of importance have been established by the present investigations in regard to umbrella China trees as citrus white fly food plants. First, this insect shows in one respect a greater degree of adaptation to this food plant than to citrus plants, as shown by the very low rate of mortality in the immature stages. Table VI gives the data obtained by five counts made at Orlando, Fla., during these investigations.

TABLE VI.—*Mortality of citrus white fly on umbrella China tree leaves.*

Date.	Pupa cases.	Live larvæ and pupæ.	Dead larvæ and pupæ.	Mortality.
				Per cent.
Oct. 28, 1906...	806	1	111	12.0
July 8, 1908....	497	338	192	18.7
July 21, 1908...	113	256	51	12.1
Aug. 19, 1908..	232	49	152	35.1
Aug. 25, 1908..	312	169	70	13.4
Total...	1,960	813	596	18.2

The record made on August 19, 1908, showing the highest percentage of dead stages of the white fly, was based upon 10 leaflets selected from a single leaf and is not considered so typical of the condition throughout the tree examined as is the case in the other records. In contrast to the low mortality records as shown by the insect forms present on the leaves of the umbrella trees, 26 records of mortality in citrus groves gave an average of 57.9 per cent dead on the leaves. These records were based on the examination of about 2,000 leaves and over 100,000 white-fly forms. It should be noted that the mortality in the above records is based on the number of live and dead larvæ and pupæ, and of pupa cases present on the leaves at the times of the examinations. The actual mortality would be represented by the difference between the total live larvæ, live pupæ, and pupa cases and the number of hatched eggs. On umbrella China tree leaves this difference is slight and represented for the most part by the number of dead larvæ and pupæ found on the leaves. In the case of the citrus trees, on the other hand, the number of citrus white-fly forms on the leaves ordinarily represents only from 25 to 30 per cent of the total number of eggs deposited. This disappearance from the leaves is discussed elsewhere. Its significance in this connection is that the actual mortality on citrus leaves is much higher than the average per leaf of 57.9 would indicate. The citrus white fly forms in the leaves show a mortality on the umbrella tree amounting to only one-third of the mortality on citrus trees. The consideration of the number of hatched eggs as a basis for mortality estimates would reduce this to about one-fifth. The figures refer to citrus groves where the citrus white fly is well established. In newly infested groves the rate of mortality is much smaller as a rule.

The second important point established in the course of the investigations reported herein is that adult citrus white flies are so strongly attracted by growing leaves of umbrella trees that under certain conditions with umbrella and citrus trees growing side by side more adults collect on three or four umbrella leaves than are present on entire citrus trees of medium size.

It has been frequently observed that when the citrus white fly is first becoming established in a grove, if China trees or umbrella China trees are near, adults often can be found on these when none can be found on surrounding or intervening citrus trees. In order to obtain a more definite idea of the relative attractiveness of umbrella China trees and citrus trees, 4 records were made by the senior author on the laboratory grounds (fig. 2) at Orlando. In observation No. 1, the count on citrus was made on 4 trees, viz, 4 A, 4 B, 4 C, and 5 C, and the observations on umbrella China trees were made on 2 small trees located about 6 and 20 feet, respectively, southwest of 4 A. These umbrella China trees were slender 2-year-old growths about 4 and 5 feet high and together bearing about 40 leaves.

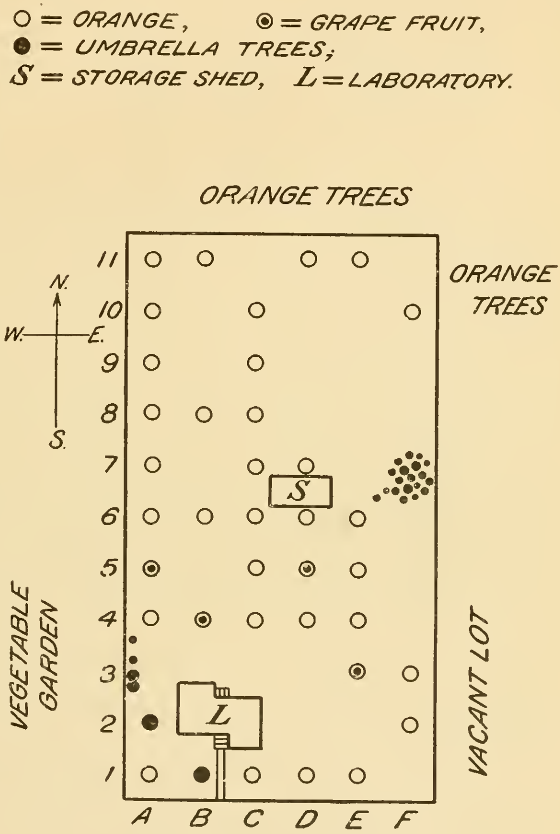


FIG. 2.—Diagram of the laboratory grounds at Orlando, Fla. (Original.)

Observation No. 2 was made on grapefruit and orange trees E 6, E 5, E 4, D 5, D 4, and F 3 and two stems of the umbrella China tree cluster in space F 7 nearest to tree E 6. Observation No. 3 was made on tree A 4 and the nearest umbrella China tree sapling. This latter had been defoliated since observation No. 1 was made. Observation No. 4 was made on citrus trees D 7, E 6, E 5, E 4, E 3, and F 3 and on two stems of the umbrella cluster which had been defoliated since observation No. 2. The data obtained by the four observations are given in Table VII.

TABLE VII.—*Relative attractiveness to the citrus white fly of foliage of umbrella China trees and citrus trees.*

Observation No.	Date.	Citrus trees.			Umbrella China-trees.		
		Number of minutes.	Number of adults counted.	Number of trees examined.	Number of minutes.	Number of adults counted.	Approximate number of leaves examined.
	1909.						
1.......	May 18	5	257	4	5	508	25
2.......	...do....	5	19	6	5	615	30
3.......	June 11	3	34	1	3	477	6
4.......	...do....	5	52	6	5	830	15
	Total.	18	362	17	18	2,427	76

In all, 2,789 specimens were counted, of which 88 per cent were on umbrella China tree leaves. It was estimated that in each record on a citrus tree approximately 2,000 leaves were examined, making 34,000 in all. The individual leaflets composing the 76 umbrella-tree leaves numbered approximately 6,000. For practical purposes these leaflets are more comparable to the citrus leaves although the latter have on the average fully twice as much surface. With this basis for comparison it can be figured from the above data that there was about one adult white fly per 100 leaves on the citrus trees while there were about 40 adults per 100 leaflets on the umbrella trees.

As has been indicated, the difference between the number of China-tree leaves in numbers 3 and 1 and between 4 and 2, respectively, represents the oldest spring growth, which was removed on May 24, leaving only a few growing leaves. No direct comparison was made between the attractiveness of the older growth of citrus and umbrella trees but apparently there is no striking difference between the two food plants in this respect. New watershoots were present on the citrus trees on both dates when observations were made but only in the case of one tree, 4 A, were many adults found on this growth. In observation No. 1 on the tree mentioned (4 A) 200 adults were counted on two watershoots. Except for watershoots there was no new growth on any of the citrus trees.

At Orlando the umbrella trees usually start to put on new foliage in the spring before new growth appears on citrus trees. As a consequence China and umbrella trees located near infested citrus trees receive large numbers of adults of the citrus white fly which migrate in search of attractive food. On February 22, 1909, the authors noted on the laboratory grounds that the shoots of the umbrella tree were beginning to put out new growth, the leaves not fully unfolded. The citrus white fly was found scatteringly on the umbrella leaves but on citrus trees specimens could be found only after careful search.

On March 27, 1907, near the laboratory, then located in the grove of Mr. J. M. Cheney, a striking example of the attractiveness of the umbrella tree was observed. The tree referred to was about 25 feet high and the leaves which were on the average only about half developed were estimated to number 5,000. Ten leaves were selected at random within 10 feet of the ground and the number of adults and eggs was counted, the former numbering 5.3 per leaf on the average and the latter 160 per leaf. The tree was cut down and an examination of the topmost leaves showed an average of 186 eggs per leaf; the adults, being disturbed, were not counted, but judging from the number of eggs present they evidently were more rather than less numerous than on leaves near the ground. Considering the average of 5.3 per leaf, however, the total number of adults on the tree would be estimated at 26,500, and at 160 eggs per leaf the number of eggs deposited would be estimated at 800,000. At the time of this observation about 50 per cent of the insects which overwintered on the citrus leaves had matured. The citrus white fly had been much reduced throughout the grove, in some sections by unexplained influences, in others by these influences and fumigation experiments combined, and on a few tangerine trees by a fungus parasite, red Aschersonia. The location of the umbrella tree did not seem to be a favorable one as regards opportunities for white-fly infestation, but examination showed the infestation to be at least 100 times greater, as regards the number of adults present, than on any citrus tree in the grove. There were, in fact, too few eggs deposited on the leaves of the citrus trees to allow of sufficient multiplication of the white fly during the season to cause any blackening of foliage or fruit.

CAPE JESSAMINE.

The cape jessamine has long been recognized not only as a favorite food plant of the citrus white fly, but as especially important economically on account of its retaining its foliage throughout the year. From a statement by Riley and Howard [1] concerning observations by Mr. H. G. Hubbard and statements by Dr. H. J. Webber, Dr. Montgomery, and others in the discussions on the citrus white fly at a meeting of the Florida State Horticultural Society, [2] it appears that the freezes of December, 1904, and February, 1905, which completely defoliated citrus trees when not especially protected, failed to defoliate cape jessamines. In many localities it is probable that this food plant was responsible for the survival of the white fly at the time referred to. According to Dr. Sellards, [3] temperatures as low as

[1] Insect Life, vol. 7, p. 282.

[2] Proceedings of the Florida State Horticultural Society, 1896, p. 78.

[3] Press Bulletin 56, Florida Agricultural Experiment Station, p. 2.

16° above zero at Lake City, between January 26 and January 29, 1905, failed to defoliate cape jessamine.

Except where grown for commercial purposes, as is the case at Alvin, Tex., where the blooms are shipped to northern markets, or where grown in nurseries, cape jessamines have not been observed growing in sufficient abundance to materially affect near-by citrus trees in sections where the white fly is already established. If overlooked in connection with the fumigation of citrus groves or defoliation of citrus trees by cold, cape jessamines might become a serious hindrance in the control of the white fly. The greatest economic importance of the cape jessamine as a food plant lies in the great danger it presents as a distributer of the white fly. This will be referred to again under the subject of methods of spread.

The subject of the adoption of the cape jessamine by the citrus white fly is not of sufficient importance to have been given more than incidental consideration. In general the degree of adoption seems to be less than is the case with the umbrella and China trees. On November 17, 1907, an examination made of 30 leaves picked at random from both old and new growth of a cape jessamine which appeared to be in an ordinary condition of infestation as observed when growing near infested citrus trees showed that there existed an average of 45.1 forms per leaf.

The extensive growth of cape jessamines, or gardenias, as the blooms are sometimes called, for commercial purposes is known to the authors and occasions a conflict of interests only in Alvin, Tex. From the orange grower's standpoint this, at the most, applies to a location adjoining an orange grove where the citrus white fly is uncontrolled. Fortunately, however, for the citrus growers, it is of great importance to the success of the florist's business that the white fly be kept in subjection in gardenias.

PRIVET HEDGES.

Privet hedges are not uncommon in citrus-growing sections, and heavy infestations by the citrus white fly occur in parts of Georgia and South Carolina, where no citrus trees are grown. As a food plant the privets are of economic interest in the same respects as is the cape jessamine, but they are more extensively grown and of proportionally greater importance. No studies have been made of the degree of adaptation and attractiveness, but the several species of privet observed in infested localities have shown the propriety of classing them with citrus, China trees, umbrella China trees, cape jessamine, and other preferred food plants. The senior author observed a migration of adults from privet hedges in Victoria, Tex., in the summer of 1904, which indicated that a hedge of this material might well be compared in its injurious influence on citrus-growing interests to one or more umbrella or China trees. The privet, like the cape jessamine, is hardy, and the disadvantages of the former in this connection are the same as those mentioned in discussing the latter food plant.

JAPANESE AND WILD PERSIMMONS.

Japanese and wild persimmons are attractive to the citrus white fly early in the season, but appear to be very little or not at all so late in the season. Being deciduous, their economic importance as white fly food plants is proportionally small. Under normal conditions the Japanese persimmons appear much more attractive to the citrus white fly than citrus trees. These conditions have not been investigated, but they are probably dependent upon the appearance of new growth in the spring a little earlier on persimmon than on citrus. On June 16, 1909, an examination of a large bearing persimmon tree surrounded by citrus nursery trees and bearing citrus trees of different kinds showed that the first spring growth of the persimmon was much more attractive to the first brood of adults than were the citrus trees. The second brood of adults, however, found the persimmon comparatively unattractive and showed a marked preference for the citrus trees. The earliest citrus growth of the spring had become fully matured, and no new growth appeared until after the second brood of adults had practically disappeared. The comparative condition of infestation is shown by counts made on leaves picked at random from the persimmon tree and from the surrounding citrus trees, including the sweet orange, sour orange, tangerine, and grapefruit. The average infestation with first-generation forms of the citrus white fly on 25 leaves each of persimmon and citrus was in the ratio of 10.9 to 1.3, while that of the same number of leaves by the second generation was in the ratio of no forms on the persimmon leaves as compared with 191 on the citrus, thus showing the great preference of the second generation of adults for citrus growth.

Neither the Japanese nor the wild persimmons are usually infested by the citrus white fly to the extent of causing noticeable blackening from sooty mold. The infestation, however, might be between from five to ten times as great as on the leaves from the trees referred to above without producing this result. Small wild persimmon bushes have been observed in a growing condition at the time the adults of the second brood are on the wing, and at such times they sometimes appear to be very attractive as food plants. Mr. W. W. Yothers has observed near Hawthorn, Fla., on April 29, 1909, the citrus white fly on wild persimmon bushes growing in pine woods at distances upward to one-fourth of a mile from any citrus grove, and the junior author has made similar observations along roadsides near Orlando, Fla., in June, 1909, the insects being in the adult stage only in this latter case. On the other hand, the senior author noted on June 18, 1909, that wild persimmon bushes growing in a vacant lot with China trees and abandoned citrus trees were only very slightly infested, although the citrus trees and the China trees were heavily infested. The wild persimmon had made vigorous growth, but its white-fly infestation consisted of less than 100 eggs per leaf and an occasional adult. The examination of leaves of the China tree showed hundreds of pupæ and pupa cases per leaf, with a few adults and newly deposited eggs. The old citrus leaves bore many larvæ, pupæ, and pupa cases, and the new leaves bore hundreds of unhatched eggs. The wild persimmon bush was as favorably located with respect to citrus trees as was the China tree. Notwithstanding the exceptions noted in degree of attractiveness, the Japanese and the wild persimmons very evidently rank well below citrus trees, China trees, and umbrella China trees.

In so far as observed the persimmons have little effect on the control of the citrus white fly, but in special cases they may rank as important food plants. The fact that the Japanese persimmon is a producer of fruit of some commercial value makes its ordinary lightness of infestation a matter of gratification. The wild persimmon, on the other hand, is of practically no value either for shade or fruit, and can easily be destroyed where advisable.

LILAC.

Lilac is not commonly grown in the citrus-growing regions of the Gulf States, and on this account, so far as observed, presents no element of menace to orange groves. In company with all of the ornamental plants listed as preferred food plants this one must be considered, however, as undesirable for introduction and growing in citrus-growing regions.

PRICKLY ASH.

Belonging to the family Rutaceæ, to which the genus Citrus also belongs, it is not strange that the prickly ash is a favorite food plant of the citrus white fly. This plant seems to be highly attractive to the adult flies, frequently being observed infested with more adults than many near-by citrus trees combined. The prickly ash is common in Florida and in some localities, where growing in abundance along roadsides, it constitutes a distinct menace to citrus groves through its connection with the spread of the white fly from city and town to country and from grove to grove.

COFFEE.

Dr. E. W. Berger has reported having observed a coffee tree thoroughly infested with as many eggs on its leaves as citrus leaves may have. This food plant is too rarely grown in the Gulf States in orange-growing regions to be of any importance economically as a white-fly food plant.

OCCASIONALLY INFESTED FOOD PLANTS.

The plants listed in Class II as a whole are of very little importance as regards their bearing on white-fly control. Banana shrub, cherry laurel, and cultivated pear might well be considered in a third class for rarely infested plants. Although not uncommon, their attraction for the citrus white fly is so slight as to make it safe to ignore them except in the matter of introducing the fly on them into noninfested districts. In unpublished notes Dr. Berger has recorded the wild olive as a food plant. He has observed the wild olive infested in comparatively isolated places. The junior author has observed wild olive heavily infested in Charleston, S. C., and in several places in Orange County, Fla. The wild olive, being an evergreen, if neglected may prove to be of considerable importance as a food plant when growing in abundance near a fumigated grove or when citrus trees have been defoliated by cold.

Dr. Berger has recorded pomegranate, allamanda, and smilax as food plants, and has verified Prof. Gossard's record of *Viburnum nudum* as a food plant of the citrus white fly. The positions of these plants as regards their attractiveness to the citrus white fly has not been fully determined, and further observations will perhaps show one or more of them to be of fully as high if not of higher rank in this respect than the persimmons. In general, however, like the coffee and lilac of Class I, they are not of sufficiently common occurrence in the Gulf coast citrus-growing regions to be of much economic importance as citrus white-fly food plants.

SPREAD IN THE UNITED STATES.

There is seldom positive evidence in regard to the means by which the citrus white fly has become established in a previously noninfested grove or locality. Such direct observations, however, as it is possible to make, aided by strong circumstantial evidence, give us a sufficient knowledge of the methods of spread to show the advisability of certain restrictive measures.

Checks on Successful Establishments.

Fortunately the chances are greatly against the successful establishment of the citrus white fly in a previously uninfested locality, which is outside the limits affected by large numbers of migrating adults. If this were not so the pest would have become established in every grove of the State long before the present time. Except for spread by direct flight and on nursery trees and ornamental plants, the chances are against more than a few insects being introduced into a particular grove by any of the other methods discussed hereafter.

In the case of a single adult there are two chances in three that it would be of the reproductive sex. If, as would be probable, the specimen were a female, there would be about one chance in three that it would not have been fertilized. In this case the second generation of adults would all be males, as shown by the observations recorded under the subject of Parthenogenesis. This would, of course, end the infestation directly due to the single specimen introduced, as the original female would have died several weeks before the first male matured. In case the originally introduced specimen were a female and fertile the chances of a male appearing among the second generation are not definitely known, but are with little doubt only small. The chances of such a male appearing at a favorable time to meet with and to fertilize a female of the same parentage are practically negligible, though possible as a result of the great variation in the length of the life cycle as recorded under life history. The third generation would, therefore, in all probability, be all males, and the infestation ended. The chances that a single adult specimen introduced into an isolated grove or into a previously noninfested community would successfully establish a permanent infestation are extremely small. The chances are only slightly increased by an increase to 5 or even 10 in the number of adults originally introduced into a single grove.

From the foregoing considerations it is evident that two or more distinct introductions of even a few individuals at proper intervals during a single season might greatly increase the chances for the successful establishment of the pest.

Flight of Adults.

The flight of adults is the most important method of local distribution and is also an important element in its association with spread by means of winds and vehicles, railroad trains, and boats.

The distance to which the insect is capable of flying.—It would be almost impossible to obtain positive records on the distance the adult citrus white fly is capable of flying. Mr. W. W. Yothers, on April 29, 1908, found on wild persimmon first and second generations of this species of fly at a distance of one-fourth of a mile from the nearest orange grove, which was also the nearest point of the occurrence of a food plant upon which the insect could have passed the winter. The infested persimmons were in pine woods and the insects were in such numbers that it was evident that spread through pine woods might easily greatly exceed one-fourth of a mile. Mr. W. C. Temple, of Winter Park, Fla., states that he has observed adults migrating into one of his groves on Lake Maitland under circumstances plainly indicating that they had traveled over the water for $1\frac{3}{4}$ miles. Dr. Berger has recorded an instance which presents strong evidence that adult white flies have heavily infested citrus trees through flights of a mile or more. On the other hand, there are orange groves within three-fourths of a mile of the city limits of Orlando, Fla., and within 2 miles of the courthouse which have only so recently become infested that no blackening of the foliage has taken place, although the citrus white fly has occurred at Orlando for more than 10 years with migrating adults in summer about as abundant as in any town in the State. As regards the capability of flight of the citrus white fly, it may be said to be undoubtedly more than a mile and perhaps several miles when aided by a gentle breeze. Distances of even a mile, however, are not usually attained except under certain circumstances which are largely preventable and which are discussed in the following paragraph.

Cause of extensive migrations by flight.—Overpopulation of food plants, usually associated with the emergence of adults in large numbers at seasons when the new and attractive growth is scarce or entirely wanting, is the main cause for migrations from citrus, cape jessamine, and privet. Migrations from China trees and umbrella trees, probably the most potent factors in the spread of the pest, are not due directly to overpopulation, so far as observed, since leaves are never overcrowded in a manner comparable to the overcrowding on citrus leaves. An average of 25 live larvæ or pupæ and pupa cases per square inch of lower leaf surface would represent an unusually heavy infestation of a China or umbrella tree and is rarely exceeded, whereas an average of 50 or 60 per square inch is not unusual for citrus leaves. In the case of China and umbrella trees, migrations are evidently due to lack of attractiveness of the foliage to the adult white flies at the times when the migrations occur. There are comparatively few live larvæ and pupæ on the foliage after the middle of August at Orlando. The greater part of these represent delayed emergence from the second generation of white flies and not the result of eggs deposited by the third brood of adults. This supports direct observations to the effect that the third brood of adults, which is concerned in the most extensive migrations, deposits practically no eggs on the China and umbrella trees.

China and umbrella trees as a factor in dissemination.—Umbrella and China trees are extensively grown throughout the Gulf coast citrus-growing regions, and they are almost entirely responsible for the hundreds of millions of adults which in midsummer appear on the wing throughout most of the towns where the citrus white fly occurs. That these are principally those which have bred upon China and umbrella trees is shown clearly by the fact that at Gainesville, Lake City, Tallahassee, and other points in the northern part of Florida, where other food plants are too few to produce noticeable numbers of migrating adults, the numbers are apparently not less than where both citrus trees and China and umbrella trees are extensively grown, as at Orlando. On this point, Dr. Berger states:[1] "The principal food plants in Gainesville and north Florida are China and umbrella trees, there being only enough citrus, privet, and other evergreen food plants to bring about the restocking of the deciduous trees every spring." These considerations indicate very positively the main source of the enormous number of migrating adult flies on trees in midsummer, sometimes observed between the middle of May and the middle of June. These adults are the second brood of the season and the first to mature on the food plants mentioned. The newer growth of these trees is, as has been shown, very attractive to the adult flies, and if there is an abundance of it comparatively few migrate. The third brood, composed mainly of individuals of the second and third generations, matures over a more extended period, in general covering the months of July and August in different sections of Florida.

Estimates of the number of adult citrus white flies breeding on umbrella trees and on citrus trees as given under the subject of food plants have shown that a single umbrella tree of medium size may produce as many adult white flies by midsummer as could be produced on 7 acres of orange trees. The maturity of so many adults on single trees, and their migration therefrom in search of a more desirable food supply than China and umbrella trees afford in midsummer, cause the rapid spread of the pest throughout the towns, directly by flight of the adults and by mediums hereinafter discussed into the surrounding country and from town to town along railway lines and watercourses.

Dissemination by flight when citrus trees only are concerned.—It has been shown under the subject of food plants that the citrus white fly does not ordinarily increase to the point of overcrowding on grapefruit. Migrations of adults in noticeable numbers from solid blocks of these trees probably never occur under ordinary circumstances, and spread through such blocks or groves from the first point of infestation is very slow if no other food plants are concerned. The spread in groves of orange or tangerine trees or of both is more rapid, but not as much so as ordinarily considered. The white fly is rarely observed during its first year's appearance in a citrus grove. Attention is usually first attracted to its presence through the blackening of foliage on one or a few trees. This blackening of foliage in itself

[1] Press Bulletin 108, Florida Agriculture Experimental Station, February 13, 1909.

is almost positive evidence of the presence of the fly in the grove during at least the preceding two years unless the infestation is due to migrations from China or umbrella trees or from overstocked neighboring citrus groves. In such cases infestation may become quite general throughout several acres in one season and extensive blackening of the foliage may result early in the next season, or in about one year after the first introduction. In the case of new infestation in any locality, however, the beginning doubtless is usually the introduction of a few insects by some one of the means hereinafter discussed. In a mixed grove of tangerine and orange the pest is discovered first as a rule on tangerine, and in a grove of seedling trees with a few budded trees intermixed usually the latter are first discovered to be infested. Many citrus growers who have groves, such as those mentioned, and who have watched carefully for the appearance of the pest in their groves, have finally found it well established on a single tangerine or budded orange tree before any evidence of the presence of the insect was observed elsewhere. Through the hindrances to successful establishment and the checks on multiplication, principally those discussed in connection with parthenogenesis and natural mortality, the white fly frequently develops so slowly after its first introduction that it may not increase to the point where it is usually first observed for three or four years. It is a common error to consider that the first discovery of the white fly in a grove is an indication of its very recent introduction. This may or may not be the case. Usually it is not the case. It should be borne in mind in this connection that in the most careful inspection, even by a competent entomologist, the failure to discover a single specimen of the white fly is not positive proof that it is not present. The foregoing generalizations are based upon many observations by the agents of this bureau who have been engaged in these investigations, more particularly the authors of this bulletin and Mr. W. W. Yothers.

The rapidity of spread into a citrus grove from neighboring infested groves is a subject which becomes temporarily important when a nonisolated grove becomes infested for the first time. It is a subject of more far-reaching importance in connection with fumigation, and it is in this connection that the most extensive studies in this line have been made. The result of these studies will be published in a final report on fumigation.

The slowness with which the citrus white fly increases in numbers and spreads from the first point of infestation has been noted by many citrus growers who have been observant enough to discover the white fly soon after its introduction into their groves. When the rate of spread of the white fly through the grove is affected by the presence of migrating adults from China or umbrella trees, the difficulties in effectively utilizing artificial checks, spraying and fumigation, are greatly increased. As the infested area in a newly infested grove or locality becomes larger the rate of spread by flight increases, aided by secondary centers of infestation which become established by various means.

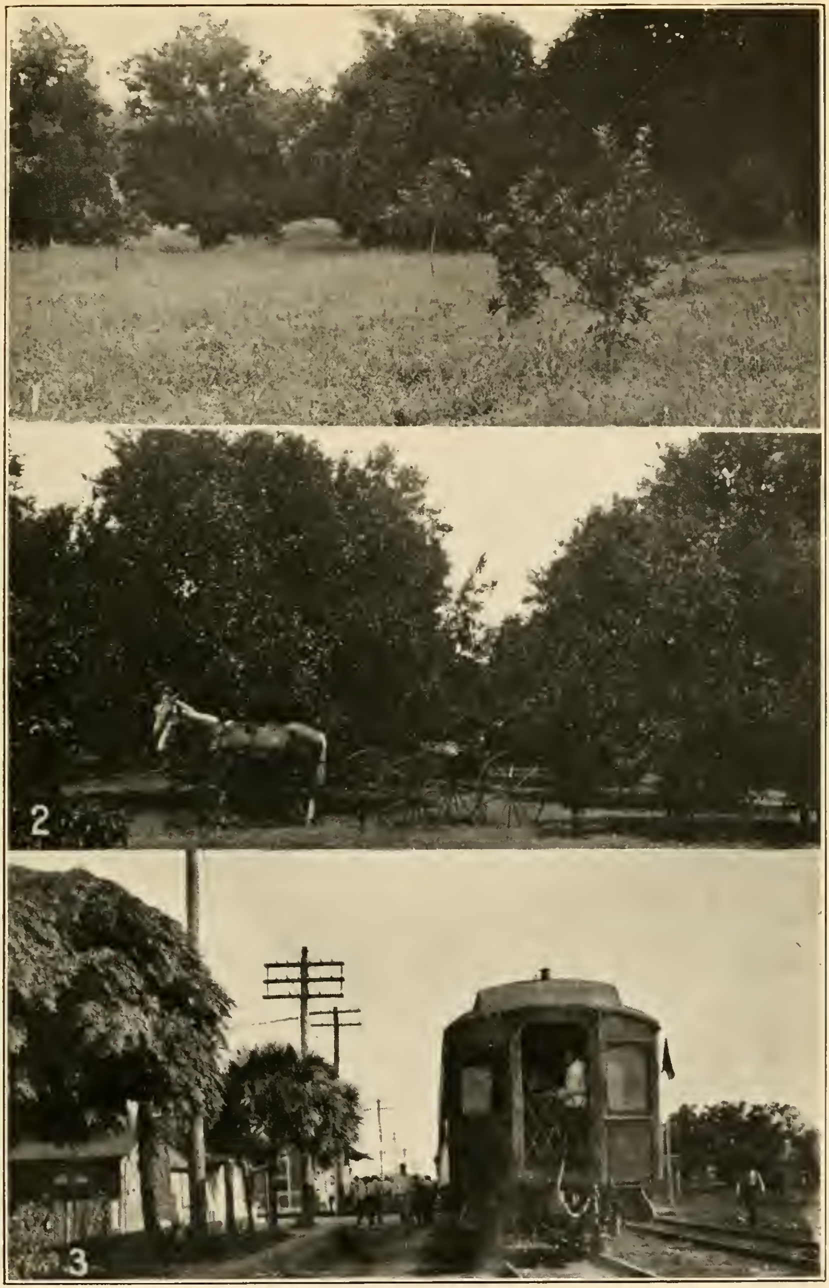
WINDS.

Light winds are an important adjunct to flight in the local distribution of adult white flies, but strong winds are ordinarily of slight consequence. The effect of light winds is shown by the influence of almost imperceptible movements of the air on the direction of migrations. This is especially noticeable in the vicinity of China and umbrella trees during a season when adults are emerging in abundance. The principal effect of the movement of the air under such conditions is not in carrying the insects, but in causing the flight energy of the insect to be expended in one general direction rather than to be wasted in zigzag lines with comparatively little real progression. Other conditions being equal, the adult white flies migrate in greatest abundance when the atmosphere is calmest, and conversely show the least tendency to migrate in strong winds. It is possible that isolated infestations may sometimes result from spread of adults by strong winds, but it is seldom that there is not a more plausible explanation obtainable. With the white fly present in abundance for many years in Orlando, Fla., and other towns and cities in important orange-growing sections of Florida, the fact that there are still many noninfested citrus groves within a radius of 5 miles of nearly all such centers of infestation is in itself an indication of the minor influence of winds in this connection. Strong breezes or winds exert some check on the spread of adults by causing them to cling tenaciously to their support, as pointed out by Prof. H. A. Gossard.[1]

VEHICLES, RAILROAD TRAINS, AND BOATS.

In towns in Florida where the citrus white fly occurs and China trees and umbrella trees are abundant it is a matter of common observation that during the periods of migration large numbers of adults alight upon automobiles, carriages, wagons, and railroad coaches. The authors have seen covered carriages with more than 100 adults resting on the inside of the top and sides. In driving through a heavily infested citrus grove in late afternoon at certain seasons, hundreds of adults may be observed on the carriage (Pl. VI, fig. 2). Newly infested groves show the first infestation so frequently on trees close to a driveway or road that conveyance of the citrus white fly by means of carriages, wagons, and automobiles must be considered one of the most important methods of spread from town to surrounding

[1] Bulletin 67, Florida Agricultural Experiment Station, p. 13.



DISSEMINATION OF WHITE FLIES.

Fig. 1.—Nursery citrus trees infested with white flies set out in an isolated noninfested grove without having leaves removed. Fig. 2.—Buggy in an orange grove; buggy top full of adult white flies ready to be carried to other groves. Fig. 3.—Train at station; adult citrus white flies swarming from near-by umbrella China trees into coaches ready to be carried for miles down the Florida east coast. (Original.)

country or from grove to grove. At Orlando, in July, 1906, adult citrus white flies were observed late in the afternoon alighting on the sides of coaches and flying into the windows and doors of coaches of a passenger train standing at a railroad station (Pl. VI, fig. 3). Hundreds of adults were carried west toward Wildwood through points which, so far as known, were not infested at the time. The presence of China, umbrella, or citrus trees near railroad stations increases the chances for successful introduction by railroad trains. In this connection the recent action of the Atlantic Coast Line Railroad and Seaboard Air Line Railway in destroying such trees along their right of way is to be commended. A map of Florida showing the distribution of the citrus white fly plainly indicates the relation between the railroads and the main lines of dissemination. This is shown in an incomplete way by figure 2, in which are given the points infested by the citrus white fly in Florida according to the records made in connection with the present investigation and such other records as are undoubtedly correct or which have been verified. The infestation at Arcadia, Fla., first discovered in January, 1907, but which probably resulted from an introduction of citrus white flies in 1905, was with little doubt due to the introduction of adult flies by means of railroad trains. An examination of the situation in February, 1907, by the senior author showed the center of infestation to be located near railroad stations, and careful inquiry concerning other possible sources showed that railroad trains were the most likely means of introduction. North of Arcadia no nearer infested point was known than Bartow and toward the south no nearer infested point than Fort Myers. The distance in each case was about 40 miles. So far as known there were at that time no intermediate points infested between Arcadia and the two points mentioned. Here again the factors unfavorable to the successful establishment of the pest in a previously uninfested locality play an important rôle, as shown by the fact that even at the present writing the citrus white fly is not generally distributed between Bartow and Fort Myers. As we have no record and have heard no report of the occurrence of the fly at any other point than Arcadia, it is unlikely that other infested points exist.

Steamboats are used quite extensively on the rivers and along the coast of Florida in transporting citrus fruits and have in a degree a similar status to railroad trains in transporting the citrus white fly.

Citrus Nursery Stock and Ornamental Plants.

The carriage of the citrus white fly in its egg, larval, and pupal stages by means of citrus nursery stock (Pl. VI, fig. 1) and ornamental plants has always been an important factor in the spread of the insect. The citrus white fly was without doubt introduced into the United States and distributed to the most important centers of infestation by this means. In Florida the white fly was probably introduced first on citrus nursery stock into some citrus grove on the St. Johns River in St. Johns County, and later by the same means into Manatee and Fort Myers. Gainesville, Ocala, Orlando, and Bartow were probably among the points to which the white fly was introduced on nursery stock. The distribution of the citrus white fly along the Gulf coast citrus-growing regions west of Florida has been largely due to shipments of infested citrus nursery stock, umbrella trees, privets, and cape jessamines. Of all methods of spread which are operative over greater distances than the flight of adults, introductions of live immature stages on trees or shrubs for transplanting purposes are by far the most certain to result in the successful establishment of the species. Fortunately it is practicable to prevent spread by this method by defoliating the trees as they leave the nursery. Much has been accomplished in the past by individual citrus growers, but more attention should be given to this matter in communities not now infested by both of the white flies treated in this bulletin.

Accidental Spread by Man.

Carriage of the adult white flies on human beings.—Man is doubtless responsible to a limited extent for the spread of adult white flies. During migrating periods, when in heavily infested orange groves or in towns where there are infested China and umbrella trees, adults are frequently observed on the clothing. Prof. H. A. Gossard states that he has carried adult white flies for nearly half a mile on his clothing after standing beneath a heavily infested tree.

Introduction in pickers' outfits.—In some instances the citrus white fly is believed to have been introduced into previously uninfested localities by orange pickers. In this case the principal danger lies in introducing live pupæ on citrus leaves accidentally brought in with picking sacks and field boxes. The authors consider that there is practically no danger of the carriage of adults of the citrus white fly by pickers' outfits between December 1 and March 1. The few adults present in citrus groves during this period would rarely result in their transference to uninfested groves by such means, and the unfavorable factors heretofore discussed would almost certainly prevent the successful establishment of the pest. It would be almost impossible to conceive of any likely method by which a successful introduction of the citrus white fly into a noninfested grove could be accomplished by the carrying of leaves infested by eggs or larvæ. Leaves infested with live pupæ, however, particularly about the time of the beginning of emergence of the first spring brood, might readily produce a sufficient number of adults to successfully establish the pest. Such leaves, after introduction, would need to have a favored location, for exposure to much sunlight or to too much moisture would soon destroy the insects.

Introduction on leaves infested with parasitic fungi.—The matter of spread of the white fly in connection with the attempt to introduce parasitic fungi is a subject of considerable importance. The danger here is due to the failure to recognize the distinction between the citrus white fly (*Aleyrodes citri*) and the cloudy-winged white fly (*Aleyrodes nubifera*). The owner of a grove infested by the latter species only, would provide a very favorable opportunity for the introduction of the first and most destructive species if in introducing parasitic fungi he should obtain his supply of leaves from certain sections of Florida. The spread of the cloudy-winged white fly has been encouraged in a similar manner. The tree-planting method of introducing the fungi, especially the brown fungus, is the most dangerous practice in this connection. Of somewhat less danger in the individual cases, but of far greater danger on account of the more frequent opportunities presented, is the introduction of fungus-infected leaves for pinning or for spraying the spores. The pinning of leaves as a means of introducing the parasitic fungi has little more to recommend it than the tree-planting method, but it has without doubt been the means of introducing the citrus white fly on many occasions. Leaves introduced for the spore-spraying method of spreading the fungus parasites are an element of much danger under certain conditions. Some sections of Florida in which only the cloudy-winged white fly occurs are in more danger of having the citrus white fly introduced by some uninformed person in this way than they are of its introduction in any other manner. Specific examples might be cited where the introduction of either *A. citri* or *A. nubifera* was with little doubt due to introducing fungus-infected leaves or trees, but the danger is too obvious to require further discussion in this place.

LIFE HISTORY AND HABITS.

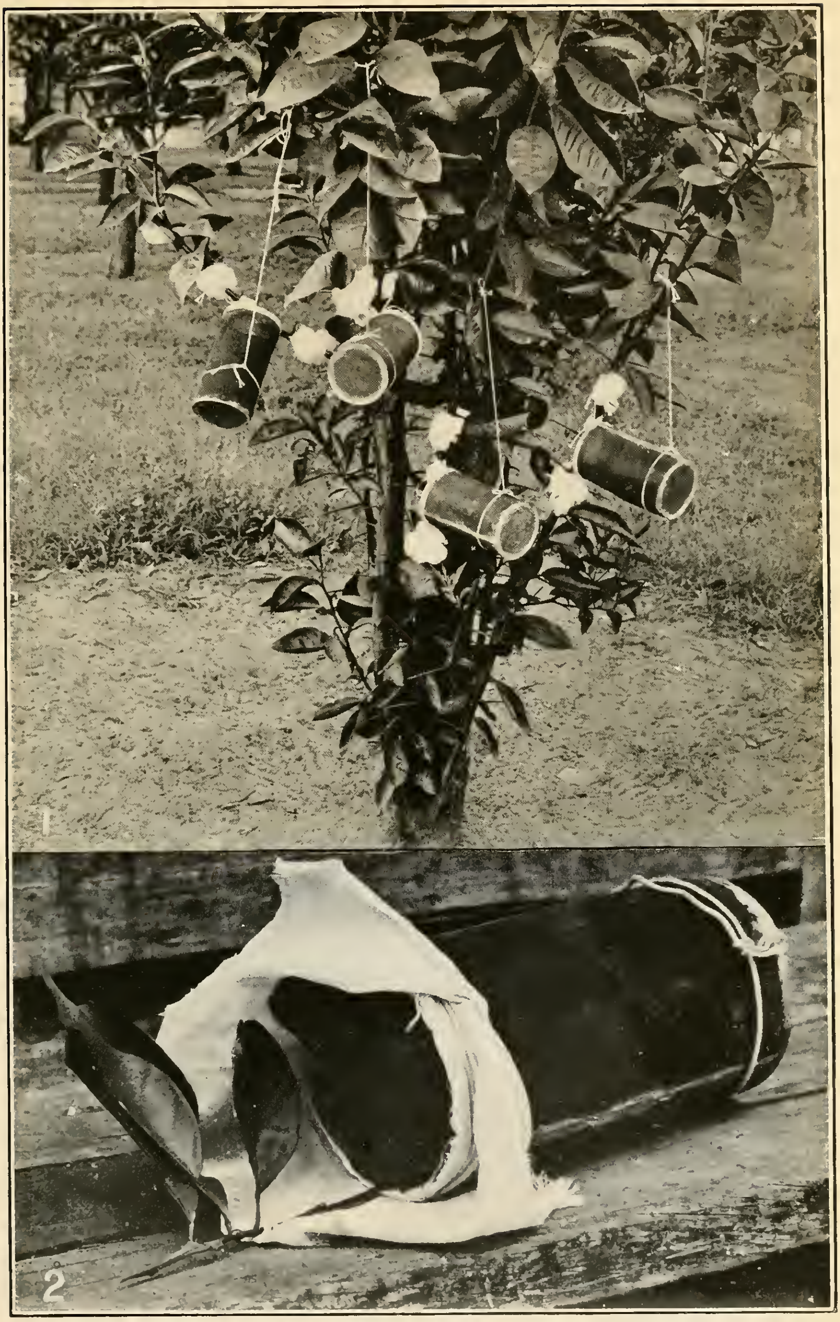
SUMMARY.

The eggs of the citrus white fly (fig. 3) are laid scatteringly, with few exceptions, on the underside of the leaves of the various food plants, and hatch in from 8 to 24 days, according to the season. During ordinary summer weather from 75 to 100 per cent hatch on the tenth to twelfth day. Infertile eggs hatch as readily as fertile eggs and produce adults of the male sex only. After hatching, the young larva (figs. 4–6) actively crawls about for several hours, when it ceases to crawl, settles upon the underside of the leaf, and begins to feed by sucking the plant juices. It molts three times before becoming a pupa. After the first molt (see fig. 7) the legs become vestigial; hence thereafter it is impossible for it to materially change its location upon the leaf. Larval life averages in length from 23 to 30 days. The pupa (fig. 9) closely resembles the grown larva (fig. 8) and requires from 13 to 304 days for development. The adult fly (fig. 10) has an average life of about 10 days, although several females have been known to live 27 days. Females may begin depositing eggs as soon as 6 hours after emergence and continue ovipositing throughout life. The maximum egg-laying capacity is about 250 eggs, although 150 more nearly represents the number laid under grove conditions. Unfertilized females deposit as many eggs as fertile females.

The entire life cycle from egg to adult requires from 41 to 333 days; the variation in the number of days required from eggs laid on the same leaf on the same day is very remarkable. During the course of the year the fly may pass through a minimum of two generations and a maximum of six generations. The generation started by the few adults that emerge during the winter is entirely dependent upon weather conditions and may or may not occur. Each generation except those started after the middle of August is more or less distinctly two-brooded.

Methods of Study.

As it is impossible to rear citrus white flies through their entire life cycle on detached leaves, a gauze-wire cage was devised by the senior author which has proved of great value and convenience in carrying on life-history studies under conditions as nearly normal as it is possible to get them. This cage (Pl. VII), which is cylindrical in shape and open at one end, may be made any size, but one 6½ inches long by 3½ inches in diameter has proved most convenient. It can easily be made by fashioning two rings of heavy wire to which is soldered the wire gauze, as shown in the illustration. To the open end is attached a piece of closely woven cheesecloth long enough to extend about 4 inches beyond the cage. After the leaf, or leaves, to be caged have been cleaned of all stages of the white fly by means of a hand lens and cloth, the cage is slipped over the foliage. The adult flies are then introduced, if desired, and the cloth attached to the cage wrapped around the stem of the shoot or petiole of the leaf, as the case may be, in such a manner that the flies can not escape nor the ants and other predaceous insects enter. To keep the entire weight of the cage from falling on the petiole of the leaf or its short stem, and to regulate the position of the leaf within the cage, a cord is tied around the outer end of the cage and attached by the loose end to a convenient branch.



CAGES FOR REARING WHITE FLIES.

Fig. 1.—Rearing cages in position on orange trees. Fig. 2.—Enlarged rearing cage. (Original.)

A very satisfactory method of definitely marking larvæ in order that no mistake may be made in identifying field notes with the individual larvæ to which they refer, is to scratch lightly on the epidermis of the leaf, with a thorn or pin, a bracket or other mark and outside this a number that shall correspond with that used in the note book. In marking larvæ care should be taken in scratching the leaf to allow for the future growth of the insect and not to injure the epidermis of the leaf too severely. In this manner a large number of larvæ were marked as soon as they settled and their growth noted by daily observations.

In determining the sums of effective temperature, 43° F. has been taken as a basis in accordance with Dr. Merriam's general law although this has led to certain inaccuracies of which the authors are aware. The determination of the effective temperature in the case of the white fly would require a special study which it has been impracticable to undertake.

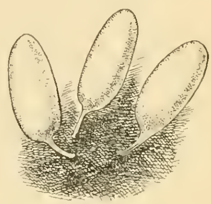


FIG. 3.—The citrus white fly (*Aleyrodes citri*): Eggs. Greatly enlarged. (Original.)

THE EGG.

DESCRIPTION.

The eggs of the citrus white fly (fig. 3) are so small that they appear to the unaided eye as fine particles of whitish dust on the under surface of the leaves. Their minute size is emphasized by the fact that 118 placed end to end would measure but an inch, while about 35,164 could be placed side by side in one square inch. Under the magnifying lens they appear as smooth, polished, greenish-yellow objects shaped much like a kernel of wheat. Following is a more minute description:

Length, 0.2–0.23 mm.; width, 0.08–0.09 mm. Surface highly polished, without sculpturing, color pale yellow with faint greenish tinge when first deposited, paler than the under surface of the leaf. Egg elongate, subellipsoid, slightly wider beyond the middle or at about the point where the eyes of the embryo subsequently appear; borne at end of a comparatively slender brownish petiole or footstalk, slightly shorter than the width of the egg, and somewhat knobbed at base.

As the embroyo approaches maturity its purple eyes may be seen showing distinctly through the egg membranes at a point beyond the middle of the egg. At about this time, also, the hitherto uniformly colored egg contents become orange or golden at the proximal end and whitish translucent on the distal three-fourths. The egg surface sometimes assumes a white pruinose appearance, due to the presence of wax rubbed from the bodies of the adults while crawling over the eggs. Eggs deposited on leaves from which the adults have been excluded after egg deposition do not show this pruinose condition.

Eggs in which the embryonic development is normal do not turn dark in color, but those killed through attack by thrips or by other agency frequently become bronze colored, thus resembling the eggs of *A. nubifera* from which the waxy sculpturings have been rubbed.

DURATION OF EGG STAGE.

That no doubt might arise concerning the exact age of the eggs used in obtaining the data incorporated into Table VIII, suitable leaves were selected from which all eggs previously deposited were carefully removed by the aid of the hand lens and a cloth. Similar attention was given the leaf petiole and the stalk, and wads of cotton were tied about the latter both above and below the leaf to prevent crawling young from reaching the leaf along the petiole (Pl. VII, fig. 1). These preliminary steps completed, a rearing cage containing adult white flies was placed over the leaf and allowed to remain the length of time desired, usually from 1 to 24 hours, with preference shown the latter number. The cage was then removed and an empty one put in its place. By this method all doubt was removed as to the period of time over which deposition took place. As there is scarcely a leaf in a grove infested with the citrus white fly that does not bear from a few to many eggs, this becomes an important point and failure in its recognition has led in the past to statements greatly underestimating the minimum duration of the egg stage during the warmer months.

TABLE VIII.—*Duration of egg stage of the citrus white fly.*

Record number.	Date deposited.	Eggs under observation.	First egg hatched.	Last egg hatched.	Least number of days.	Largest number of days.	Daily rate of hatching in percentages with degrees of accumulative effective temperatures.													
							8 days.	°F.	9 days.	°F.	10 days.	°F.	11 days.	°F.	12 days.	°F.	13 days.	°F.	14 days.	°F.
	1909		1909	1909																
1	Feb. 23	163	Mar. 13	......	18	......	0	......	0	......	0	......	0	......	0	......	0	......	0	......
2	Mar. 3	305	Mar. 17	Mar. 24	14	21	0	......	0	......	0	......	0	......	0	......	0	......	0	......
3	Apr. 20	452	May 1	May 6	11	16	0	......	0	......	0	......	.5	401	0	422	96.2	442	.5	470
4	June 16	360	June 26	June 30	11	15	0	0	0	......	0	......	5.4	383	60.6	424	14.7	462	14.8	496
	1907		1907	1907																
5	July 17	927	July 26	Aug. 5	9	19	0	......	0.1	371	24.3	409	75.5	449	0	......	0	......	0	......
6	July 19	1,225	July 30	July 31	11	12	0	......	0	......	0	......	49.	454	51.0	497	0	......	0	......
7	Aug. 1	448	Aug. 11	......	10	......	0	......	0	......	8.	393	90.	429	......	......	......	......	......	......
	1908		1908	1908																
8	Sep. 18–21	260	Sept. 26	Oct. 2	8	11–15	1.2	282	1.9	318	1.9	355	15.	389	45.4	424	30.4	460	4.2	493
9	Sept. 21	314	Oct. 2	Oct. 8	11	17	0	......	0	......	0	......	14.0	385	65.9	415	6.1	445	9.5	477

Record number.	Daily rate of hatching in percentages with degrees of accumulative effective temperatures.																			
	15 days.	°F.	16 days.	°F.	17 days.	°F.	18 days.	°F.	19 days.	°F.	20 days.	°F.	21 days.	°F.	22 days.	°F.	23 days.	°F.	24 days.	°F.
1	0	......	0	......	0	......	3.0	583	1.5	626	[1]0	......	......	......	......	......	......	......	......	......
2	0	......	0	......	0	......	0	......	.3	518	0.7	544	......	575	[2]93.4	611	......	655	[2]5.6	695
3	1.5	500	1.3	531	0	......	0	......	0	......	0	......	0	......	......	......	......	......	......	......
4	4.5	532	.0	......	0	......	0	......	0	......	......	......	......	......	......	......	......	......	......	......
5	0	......	0	......	0	......	0	......	.1	770	0	......	0	......	......	......	......	......	......	......
6	0	......	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
8	0	......	0	......	0	......	0	......	......	......	......	......	......	......	......	......	......	......	......	......
9	2.5	507	1.0	538	1.0	570	0	......	......	......	......	......	......	......	......	......	......	......	......	......

[1] The thrips *Aleurodothrips fasciapennis* Franklin is responsible for death of 95.5 per cent of the eggs.

[2] Records include eggs hatching on previous day.

The conclusions presented herewith are drawn from the data presented in Table VIII, based upon daily observations of over 5,000 eggs deposited at intervals from February to October. From these and other data not included, it can be stated that the eggs hatch during a period of from 8 to 24 days after deposition, according to the season of the year. While there are no data regarding the length of the incubation period for eggs deposited by the few female flies occasionally seen during the winter months, as noted under seasonal history, it is probable that hatching extends over even a greater number of days during the winter season. The deposition of such eggs is, however, a comparatively rare occurrence and will receive no further mention here. In no instance have eggs been seen to hatch before the eighth day from deposition, even during the months July and August, 1907, when the average mean temperatures were slightly above normal, while under the most favorable summer weather conditions from 75 to 100 per cent of the eggs hatch during the period from the tenth day to the twelfth day from deposition.

In general, the warmer the season the shorter and more nearly uniform is the period of egg development or incubation. During the months of July and August, when the normal monthly temperatures at Orlando range from about 72° F. as the mean of the minimums to about 93° F. as the mean of the maximum records, practically all the eggs hatch from the tenth day to the twelfth day. Even at this most favorable season, in one instance hatching was delayed for 19 days. During the somewhat cooler weather of late September and early October and the decidedly cooler months of February, March, and April, hatching is more or less delayed according to the prevailing temperature and is scattered over a larger number of days. This same result is brought about, only in a less degree, by a cool period occurring in an otherwise warm season, as shown under record 4 (Table VIII).

Reference to the daily rate of hatching in Table VIII, and to the accompanying degrees of accumulated effective temperatures, shows that regardless of the time of year deposited and the number of days required for incubation, over 90 per cent of the eggs, on an average, hatch between the accumulation of from 375° to 475° of effective temperature.

Exception to this statement must be taken in records 1 and 2 (Table VIII). The number of degrees of effective temperature required seems to be greater at this season, although this might not prove to be the case if, as is probable, an error has arisen from using 43° F. as the basis for calculating the effective temperature.

Reference to the two preceding tables shows that considerable variation exists in the length of the egg stage among eggs deposited on the same day, or even within the same hour, and subsequently subjected to identical conditions of heat and moisture. Even when hatching was most concentrated during the heat of summer and 99.8 per cent of the eggs hatched on the tenth and eleventh days from date of deposition, hatching extended over a period of from 9 to 19 days. Hatching over a period of from 6 to 7 days after the first crawling young appears is an ordinary occurrence during the cooler portions of the season of activity. In this respect, white-fly eggs are markedly different from the eggs of most other insects deposited in batches which usually hatch within one or, at the most, a few hours of each other.

PARTHENOGENESIS.

The existence of parthenogenesis among aleyrodids was first recognized by the senior author [1] in connection with his investigations of the greenhouse white fly (*A. vaporariorum*). His prediction at that time that this method of reproduction would ultimately be proved to occur among many if not all the species of Aleyrodes has been strengthened by the results of the present investigations. While there are no definite data to the effect that parthenogenetic eggs are deposited under natural conditions, there is practically no doubt that such deposition does occur, especially by females not yet mated or by females appearing at unseasonable times or when males are decidedly in the minority. Scattered females emerging during the winter, or resulting from the comparatively few pupæ surviving fumigation, either never have the opportunity to mate or deposit many of their eggs before such opportunity presents itself.

That virgin females of *A. citri*, emerging from pupæ kept separately in vials, and later confined in rearing cages under normal grove conditions, except for the exclusion of males, will readily deposit the normal number of eggs, and that these eggs will develop normally and will produce adults of the male sex, has been thoroughly demonstrated. Of the five separate cage experiments started with parthenogenetic eggs, all of 111 adults emerging in four of the cages were males, while of 208 more adults emerging from the fifth cage, all but 4 individuals were males; the 4 females emerging under such conditions as to lead to the supposition that they came from fertile eggs overlooked in preparing the leaf for the experiment.

HATCHING.

In hatching, the egg membranes rupture at the end opposite the pedicel, and then split down each side sufficiently to permit the young larva to crawl out. The glistening eggshell, somewhat resembling in appearance a bivalve shell, eventually becomes shriveled and loses its original form.

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[1] Notes on Some Aleyrodes from Massachusetts, with Descriptions of New Species. Psyche, April, 1903, p. 81. Technical Bulletin No. 1, Mass. Agr. Exp. Sta., pp. 31–33.

Proportion of eggs that hatch.—Observations covering many thousands of eggs, both in the cage experiments and in the grove, have demonstrated that the number of eggs that fail to hatch is too insignificant and has too little practical bearing to warrant the collection of data on this point. It is safe to say that considerably less than 1 per cent do not hatch. In fact, it seems evident that no egg would fail to hatch except owing to the dropping of the leaf or unless subjected to attack from without. In many instances failure to hatch can be directly traced to attack by several species of insects and a fungous parasite.

Effect of drying of leaves on hatching.—In 10 instances leaves bearing many thousand eggs were so placed that the eggs were exposed to direct sunlight or to partial shade, and although frequent observations were made none of the eggs were known to hatch. In general the drying of leaves to which eggs are attached prevents hatching of all except those eggs containing nearly mature embryos. This feature is probably common to all aleyrodids, since the senior author has noted a similar occurrence in the case of the greenhouse white fly (*A. vaporariorum*).

The Larval and Pupal Stages.

DESCRIPTION OF STAGES.

THE LARVA.

The larvæ [1] are thin, translucent, elliptical, scalelike objects, found usually on the underside of the leaves, though more rarely upon the upper surface. When normally attached to the leaf they are so nearly transparent as to be seen with difficulty. They readily become visible, however, by either bending or rubbing the fingers along the opposite side of the leaf, thus loosening them and allowing the air to get beneath them. They then appear whitish (Pl. X, fig. 2). So very inconspicuous are the live larvæ and their attack so unaccompanied by any visible effects on the leaves, aside from the blackening of the foliage, that their presence is very frequently overlooked by the casual observer. A detailed description follows:

First instar larva (figs. 4–6). Length, 0.3 to 0.37 mm.; width, 0.182 to 0.22 mm. Body flat, scalelike, somewhat swollen ventrally, especially in the cephalothoracic region; margin entire, with 30 small tubercles, each bearing a horizontally directed spine of which 6 cephalic and 4 anal are proportionately longer. Spines of second pair, counting from anterior end of body, arising from tubercles not on, but slightly posterior to, margin on ventral surface. Relative lengths of the 15 pairs of spines as follows:

Pair	1	2	3	4	5	6	7	10	11	12	13	14	15
Spaces	11'	9.8'	11'	6.5'	5.4'	5.5'	6'	4'	4'	4'	18'	5.4'	18.5.

[1] The larvæ and pupæ are frequently called by many growers the "egg" of the white fly. This misapplication of terms should be discouraged as it leads to undesirable confusion when referring to the various stages through which the white fly passes during its growth from egg to adult.

No marginal wax fringe appears before or after crawling young settles. Cephalothoracic and thoracic articulations invisible; 8 or possibly 9 abdominal segments are seen with little difficulty. Segments at posterior end of body modified by vasiform orifice. Latter nearly semicircular in outline, somewhat longer than wide, bordered laterally by chitinous thickenings which do not meet posteriorly; operculum semicircular, nearly equaling in size the vasiform orifice itself, covering the ligula and bearing on its median posterior margin what appear to be two pairs of small spines, the penultimate pair of which is about twice as long as the ultimate. Ligula darker in color and broadly crescentic in shape. On either side of, and slightly anterior to, the vasiform orifice is a short backwardly directed spine arising from a small tubercle. The two pairs of rounded, simple, reddish-brown eyes, less than 0.01 mm. in diameter and 0.096 mm. apart—a dorsal pair and a ventral pair—are situated mesad and slightly anterior to the fifth pair of marginal spines, the dorsal pair being nearer the margin and slightly anterior to the ventral pair.

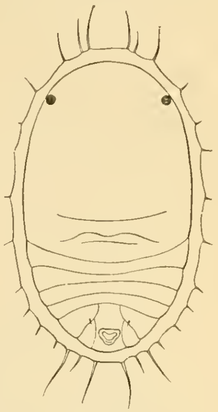


FIG. 4.—The citrus white fly: Crawling young; first instar, dorsal view. Greatly enlarged. (Original.)

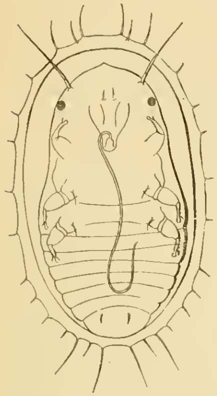


FIG. 5.—The citrus white fly: Crawling young; first instar, ventral view. Greatly enlarged. (Original.)

Antennæ, legs, and mouth-parts on the venter. Antennæ anterior and mesad to the anterior pair of legs, 0.1 mm. long, very slender; apparently 4-segmented, articulations between the segments seen with difficulty and frequently that between the third and fourth entirely wanting, while in a few specimens the second segment appears to be divided into two parts: Segment 1 short, stout, fleshy; segment 2 one-half as wide and twice as long as segment 1; segment 3 narrower than segment 2 and about four times as long; segment 4 very slender, less than one-half as long as segment 3, and bearing on its proximal posterior side a minute spine, and distally a long spine. Legs short, moderately stout, where extended about one-third the width of the body; coxæ very short and stout, the two posterior pairs on the posterior inner side with a moderately stout spine about equal in length to the diameter of the coxæ and directed backward and inward; trochanters distinguished with difficulty, about one-third as long as wide and collar-shaped; femora more elongate, slightly tapering distally, about four times as long as trochanters; tibiæ much narrower, somewhat longer than the femora, with numerous short bristles, two on the outer proximal portion longer and more easily seen, on the outer distal portion with a long bristle forwardly directed and curving inward toward the tip of the tarsi; tarsi short, ending distally in an enlarged disk-like process.

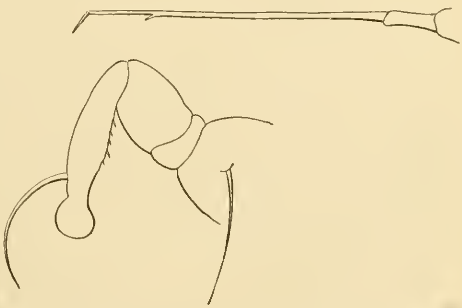


FIG. 6.—The citrus white fly: Antennæ and left hind leg, first instar. Highly magnified. (Original.)

Midway between the anterior pairs of legs in the middle of the body is the fleshy mouth papilla from which arise the mouth setæ, at first when bent backward reaching only to slightly beyond the posterior coxæ, but later becoming more elongate. Anterior to the mouth papilla is the semiovate prostomal plate, extending anteriorly as far as a line connecting the antennæ, and divided longitudinally by two curved sutures into one elongate median and two shorter lateral pieces. At the anterior end of the prostomal plate is a pair of small papillæ, each papilla bearing a small forwardly directed spine.

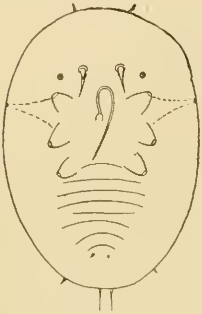


FIG. 7.—The citrus white fly: Second larval instar, ventral view. Greatly enlarged. (Original.)

On the venter beneath and to the side of the vasiform orifice is a pair of spines arising from small tubercles, normally directed backward and outward, equal in length to the distal tibial spine.

Second instar larva (fig. 7).—Length, 0.37 to 0.43 mm.; width, 0.24 to 0.29 mm. Broadly ovate, dorsum densely rugose, all marginal tubercles and spines wanting except 2 cephalic and 4 anal, the three pairs, counting from the cephalic region, giving the relative lengths: $\frac{1}{9.5}$, $\frac{2}{4.5}$, $\frac{3}{10.5}$. Eyes smaller and less regular in outline than in the first instar, but distinctly evident. Antennæ greatly reduced, unsegmented, directed backward and slightly outward, tapering, reaching nearly to base of first pair of legs; on inside near base with a distinct spinelike projection, and on basal portion with numerous roughenings; legs almost rudimentary, reduced to short, stout, fleshy processes without distinct segments, composed of a very stout, tapering basal portion, and a comparatively small, rounded, thick terminal disc; the second and third pairs of legs on the inner side at the base with a minute spine. Mouth parts as in previous stage; prostomal plate anteriorly indistinct and its pair of spines wanting. Spines on either side of vasiform orifice, both on dorsum and venter, as in first instar. A marginal pore, on either side of body opposite base of first pair of legs, and formed by an upward fold of the integument, becomes very evident in this instar.

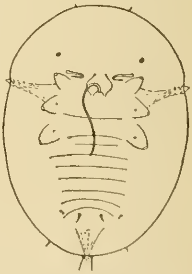


FIG. 8.—The citrus white fly: Third larval instar, ventral view. Greatly enlarged. (Original.)

Third instar larva (fig. 8).—Length, 0.62 to 0.78 mm.; width, 0.43 to 0.58 mm. Very similar to second instar but larger; the most striking difference presented by the antennæ, which have migrated backward so as to arise from a tubercle slightly anterior to base of first pair of legs. Antennæ immovable, directed mesad for about two-thirds of their length, and then suddenly doubled backward so that the distal third lies in the same plane as the basal portion. Legs smaller in proportion than in second instar and prostomal plate less developed, but the marginal pores and anal cleft more fully developed. A waxen rod is seen often protruding from the marginal pores. Relative lengths of the marginal spines: $\frac{1}{3.4}$, $\frac{2}{2.5}$, $\frac{3}{4.5}$.

THE PUPA.

The introductory remarks regarding the general appearance of the larva apply with equal force to the young pupa (fig. 9, *a*, *b*, and *c*), with the exception that the pupa is larger, being nearly one-sixteenth of an inch long, is more easily seen, and on either side of the thoracic region 3 distinct curved lines representing the outlines of the legs are very distinct. As the pupa becomes older it becomes thicker, more rounded and opaque, and the outlines of the legs are obscured by the contents of the body. At the approach of maturity a bright red or orange spot develops on the back, and from three to eight days before emergence the eyes of the adult become visible. A detailed description is as follows:

Length, 1.10 mm to 1.40 mm; width, 0.60 mm to 1.0 mm. Body broadly elliptical, thin, not raised from leaf on vertical wax fringe, color pale yellowish-green, becoming more yellowish and thicker on approaching maturity; thoracic lobes, representing outlines of the three pairs of legs, and a line extending from between first two pairs of legs and from the vasiform orifice to edge of body distinctly more yellowish, as are also the lines representing the union of the body segments although these last are prominent. As body thickens thoracic lobes become less distinct due to body contents, a bright orange or red medio-dorsal spot develops at anterior end of abdomen, and later, a few days before emergence, the purple eyes of adult become very distinct, as also do the white developing wing pads; rim of vasiform orifice brown or yellowish. All marginal bristles lost except one anterior and one posterior pair of minute bristles. A low medio-dorsal ridge or carina and corresponding depressions on each side extend from the head to the anal ring, traversed by short transverse ridges on the thorax and abdomen, terminating in a low subdorsal ridge hardly perceptible; from these last numerous very fine granulated striæ radiate all around the body to the lateral margin. A short transverse ridge appears near posterior margin of head with a curved impressed line in front. A minute brown tubercle at the anterior end of the subdorsal carina is sometimes to be seen. From a pore at the edge of the body, between head and thorax and top of anal slit, issues a very fine, glistening-white, curled thread of waxen secretion. These so-called "pores" in margin of the cephalo-thoracic region are formed by a slight upfolding of the body which extends from margin to cephalo-thoracic spiracle and forms an outlet for secretions from same. Location of spiracles and respiratory system as already described for aleyrodids. Legs and antennæ easily seen with high-power lens. Antennæ located as shown in fig. 9, partially concealing front pair of legs, apparently 3-segmented but division into segments not distinct; last segment as long as other two combined, with quite a number of irregular annulations; tip provided with a stout spine. Legs short, very stout, especially the two posterior pairs; front legs projected forward; all without distinct segmentation; tarsus very short, stout, and rounded. Vasiform orifice nearly semicircular (for details and shape see fig. 9, *b*).

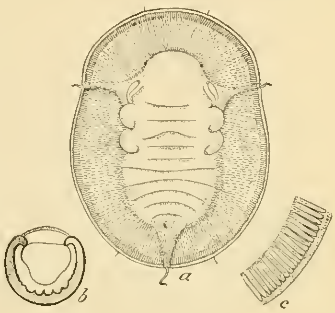


FIG. 9.—The citrus white fly: *a*, ventral aspect of pupa; *b*, vasiform orifice of same; *c*, margin of body of same. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

Pupa case.—White, firm, retaining definite shape, and remains firmly attached to leaf unless forcibly detached. (See Pl. VIII, fig. 1.)

DURATION OF STAGES

LARVAL INSTARS.

Data upon the duration of the larval instars nave been secured by daily observations of over 300 specimens marked as soon as the young larvæ had settled, supplemented by frequent counts of several thousand specimens in various life-history cages.

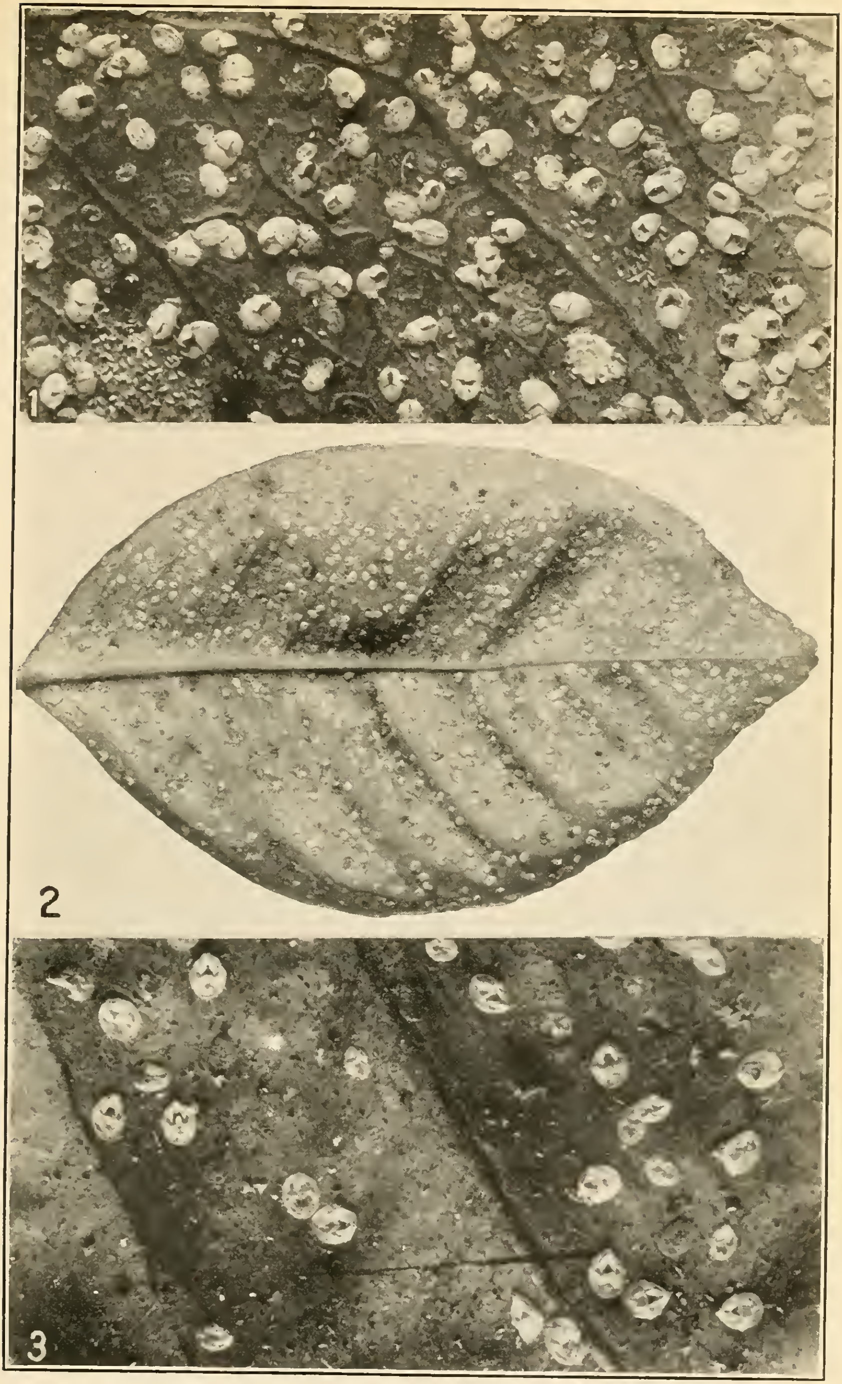
From these records those included in Table IX have been chosen as representative. A study of these will give a very accurate knowledge of this subject, and will impress upon one the considerable variation in the duration of the several instars of larvæ hatching at the same time, feeding upon the same leaf, and consequently subject to the same weather conditions. The data also emphasize the retarding effect of cool spring and fall weather upon the length of larval life, although this has not been found to be as great as many have thought. The period of larval growth ranges from an average of 23 days during the warmest months to an average of 30 days during the cooler months.

Table IX.—*Duration of larval instars of the citrus white fly.*

Specimen No.	Period of growth.	Number of days in—			Sum of effective temperatures.	Specimen No.	Period of growth.	Number of days in—			Sum of effective temperatures.
		Instar 1.	Instar 2.	Instar 3.				Instar 1.	Instar 2.	Instar 3.	
1	Mar. 22–Apr. 26...	13	10	12	1,044	33	Oct. 3–Oct. 27....	7	5	12	736
2	.....do............	11	.....	......	....	34	Oct. 3–Oct. 30....	5	8	14	811
3	.....do............	9	.....	......	....	35	Oct. 3–Nov. 11....	7	15	17	1,102
4	.....do............	10	.....	......	....	36	Oct. 3–Oct. 29....	7	8	11	792
5	.....do............	11	.....	......	....	37	Oct. 3–Dec. 4.....	31	14	17	1,644
6	.....do............	9	.....	......	....	38	Oct. 3–Nov. 4.....	12	7	13	922
7	.....do............	9	.....	......	....	39	Oct. 3–Nov. 1.....	8	8	13	843
8	June 26–July 18...	8	7	7	898	40	Oct. 3–Nov. 2.....	8	7	15	868
9	June 26–July 19...	8	5	10	938	41	Oct. 3–Nov. 3.....	9	7	15	894
10	June 26–July 16...	8	5	7	813	42	.....do............	11	7	13	894
11	June 26–July 18...	7	6	9	898	43	Oct. 3–Nov. 1.....	8	8	13	843
12	June 26–July 20...	8	4	12	978	44	Oct. 3–Nov. 10....	7	4	17	1,060
13	June 26–July 18...	8	5	9	898	45	Oct. 3–Oct. 31....	8	8	12	828
14	June 26–July 29...	8	5	20	1,365	46	Oct. 3–Nov. 4.....	10	7	15	922
15	June 26–July 18...	8	5	9	898	47	Oct. 3–Nov. 8.....	7	7	22	1,012
16	June 26–July 21...	8	5	12	1,015	48	.....do............	7	10	19	1,012
17	June 26–July 18...	8	5	9	898	49	Oct. 3–Nov. 2.....	7	9	14	868
18	June 26–July 16...	7	5	8	813	50	Oct. 5–Nov. 1.....	7	7	13	783
19	June 26–July 18...	8	5	9	898	51	Oct. 5–Nov. 7.....	5	17	11	932
20	June 27–July 19...	7	5	10	902	52	Oct. 5–Oct. 31....	5	8	13	768
21	June 27–July 20...	8	5	10	942	53	Oct. 5–Nov. 8.....	8	8	18	952
22	.....do............	7	8	8	942	54	Oct. 5–Nov. 5.....	9	8	14	883
23	June 27–July 16...	7	5	7	777	55	Oct. 5–Nov. 1.....	8	6	13	783
24	June 28–July 21...	6	6	11	938	56	Oct. 5–Nov. 3.....	9	8	12	834
25	June 28–July 28...	7	9	14	1,220	57	Oct. 5–Nov. 5.....	8	9	14	883
26	June 28–July 18...	6	5	9	821	58	Oct. 5–Nov. 1.....	10	6	11	783
27	June 29–July 27...	5	4	19	1,141	59	Oct. 5–Nov. 19....	11	34	died.	....
28	July 28–Aug. 18...	5	4	12	866	60	Oct. 5–Oct. 31....	6	8	13	767
29	Sept. 28–Nov. 14..	7	10	30	1,365						
30	Sept. 30–Oct. 25...	7	6	12	780	Average..	June 26–Aug. 18...	7.2	5.4	10.5	945.7
31	Sept. 30–Oct. 23...	6	7	10	727		Sept. 28–Dec. 4...	[1] 7.8	[2] 8.3	14.3	903.4
32	Oct. 1–Oct. 21.....	7	9	7	635						

[1] Does not include No. 37.

[2] Does not include No. 59.



PUPA CASES OF THE CITRUS AND THE CLOUDY-WINGED WHITE FLIES.

Fig. 1.—Leaf showing pupa cases of *Aleyrodes citri;* also a few pupæ and eggs. Fig. 2.—Under surface of orange leaf, showing heavy infestation by citrus white fly. Fig. 3.—Leaf showing pupa cases of *A. nubifera.* Note delicate structure as compared with those of *A. citri.* (Original.)

PUPAL STAGE.

One of the most interesting phases of life-history studies has been the wide range in the duration of the pupal stage; a range of from 13 to 304 days. Considering the relatively slight variation in the length of the larval life, this range among specimens passing into the pupal stage at practically the same time is remarkable. In view of the fact that the effect of this variation upon the duration of life and number of annual generations will be fully discussed under those headings and brought out in Tables XV and XVII and figure 12, only a few of the large number of records on file are given in Table X to illustrate this range in pupal life during different parts of the year.

TABLE X.—*Duration of pupal stage of the citrus white fly.*

Specimen No.	Period of growth.	Number of days.	Sum of effective temperatures.	Specimen No.	Period of growth.	Number of days.	Sum of effective temperatures.
1	Apr. 30–May 13	13	410	11	Aug. 15–Sept. 6	22	885
2	Apr. 30–June 20	51	1,833	12	Aug. 16–Mar. 18	214	5,414
3	Apr. 30–Aug. 3	64	2,564	13	Aug. 16–Mar. 20	216	5,479
4	May 18–June 5	18	664	14	Aug. 17–Mar. 25	220	5,574
5	May 18–July 31	74	2,866	15	Aug. 18–Sept. 10	23	931
6	May 18–Mar. 18	304	....	16	Aug. 18–Apr. 1	226	5,752
7	July 15–July 30	15	602	17	Sept. 30–Mar. 31	182	4,473
8	July 15–Aug. 4	20	808	18	Oct. 28–Apr. 19	173	4,167
9	Aug. 15–Aug. 27	12	479	19	Nov. 1–Apr. 17	167	4,069
10	Aug. 15–Aug. 28	13	521	20	Nov. 8–Mar. 25	137	3,256

It will be noticed that pupæ pass either a comparatively few or a comparatively large number of days in this stage and that ordinary temperatures and humidity do not have the power to determine which it shall be.

LOCOMOTION.

On hatching from the egg the young larva is provided with well-developed legs, as shown in figure 5, by the aid of which it crawls about the leaf for several hours and then settles and begins to feed. Because of the aimless way in which it crawls, frequently doubling on its own course and turning aside for the least obstacle, it travels over a very limited area. It is therefore improbable that the crawling larvæ ever leave the leaf upon which they were hatched, unless carried on the feet of birds or insects or blown or dropped from one leaf to another. After settling, the larva does not change its position on the leaf, while with the first molt its legs become vestigial (see fig. 7) and unfit for locomotion. Larvæ frequently move slightly, especially directly after or during molting when they merely describe an arc of 180°, using their mouth parts as a pivot. The larva passes into the pupal stage without materially changing its position on the leaf. The only time, then, during the life cycle when the white fly is capable of moving about from place to place is during the winged adult stage and the crawling larval stage.

GROWTH.

Pronounced and striking growth in size occurs only at molting, when the soft flexible skin of the larva or pupa is able to stretch before assuming its normal rigid condition. With each successive molt the larva greatly increases its horizontal dimensions, until by the time it reaches the pupal stage these are about eighteen times as great as in the newly hatched larva. When first settled after molting the larva is very thin, papery, and transparent, being seen with difficulty except with the aid of a lens, but after feeding several days it slowly becomes thickened until, from two to five days, sometimes longer, before molting into the next instar, it is decidedly plump and whitish opaque in color. Oftentimes before molting the larva becomes very much swollen as though gorged with liquid. This appears to be an abnormal condition, since many that become thus unduly enlarged either fall or die without molting. During the increase in thickness following feeding, there is no increase in the horizontal dimensions. On the contrary, increase in the former is secured at a slight expense of the latter.

MOLTS.

Daily observations on over 300 marked individuals from time of settling to emergence of adult have conclusively demonstrated that the larva passes through but three instars [1] before reaching the pupal stage, instead of four as has been previously supposed. Each larva, then, molts or casts its skin three times before becoming a pupa. The process of molting was first described by Riley and Howard [2] and as observed by the authors is as follows:

> In preparing for a molt the insect curves the abdomen upwards at considerably more than a right angle, moving it also occasionally up and down. The margin of the abdomen has at the same time a slightly undulating motion. During these movements the insect is shrinking away from the lateral margin until it eventually occupies only about one-third of the original lateral space, causing a distinct dorsal and ventral median ridge. The skin then splits, not on the dorsum, as would be expected, but either at the anterior end or underneath the head. The head and prothorax are then pushed out and the skin is gradually worked backwards by means of the abdominal motions, the portion already out swelling as soon as it is free.

As the insect flattens after molting it appears milky white, the head, thoracic lobes, and abdominal segments being more greenish. At this time the legs, which resemble much the prolegs of a caterpillar, are very active, and there appears a pair of fleshy protuberances more or less movable, not as large as the legs, but apparently of the same

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[1] This agrees with the senior author's observations on the greenhouse white fly (*A. vaporariorum*) and the strawberry white fly (*A. packardi*), which are the two species of the genus which have previously been studied in greatest detail. Tech. Bul. 1, Mass. Exp. Sta. and Can. Ent., vol. 35, pp. 25–35.

[2] Insect Life, vol. 5, p. 223, 1893.

structure, which act as sucking disks to aid the insect in reattaching itself. These protuberances are later withdrawn so that no trace of them remains. While becoming attached to the leaf the insect may be seen occasionally to rotate itself through an arc of 270°, in the meanwhile frequently raising and lowering the abdomen. The cast skins are usually blown away by the breeze or fall from the leaf as soon as molted, but not infrequently are found partially pinioned beneath the body of the insects. Molting occurs most actively during hours of high humidity. Newly molted larvæ are abundant during the early morning when the humidity ranges between 100° and 90°.

FEEDING HABITS OF LARVÆ AND PUPÆ.

As the white flies, or Aleyrodidæ, belong to the Hemiptera, or sucking insects, the larvæ and pupæ do not eat the tissue of the leaf, but insert their thread-like mouthparts and suck the plant juices by the aid of a suction apparatus located in the head. Their ravages are not accompanied by any visible effect upon the leaf itself, but may be detected by means of the sooty mold which develops after the fly becomes very abundant. Our only means of estimating the amount of sap taken up by the insect is by the amount of waste material, or honeydew, ejected by it. A first-instar larva, on being watched under the compound miscroscope for 20 consecutive minutes with the temperature at 90° F., was seen to eject honeydew 48 times, or an average of about 10 times every 5 minutes. A pupa with well-developed eyespots, in March, with the temperature at 85° F., ejected honeydew 4 times in 5 minutes. This difference in the amount of honeydew secreted is due in part to the different temperatures at which the observations were made as well as to the difference in the degree of development.

A very interesting observation on the amount of sap extracted by larvæ and pupæ of the white fly has been made by Dr. Berger [1] Leaves with live larvæ and pupæ were placed between glass plates so that the ejected honeydew was collected on the glass. By weighing it was found that each live insect had excreted about 0.0005 gram in 48 hours. At this rate a tree infested with 1,000,000 white-fly larvæ and pupæ would lose one-half pound of sap per day.

THE ADULT.

The adult citrus white fly is very small, measuring only about one-sixteenth of an inch in length, and with a wing expanse of less than one-eighth of an inch. The natural color of the body, antennæ, legs, and wings is entirely obscured by secretions of delicate white wax particles, so that the insect appears snowy white (Pl. IX; text fig. 10, *a–i*)

[1] Bulletin 97, Florida Agricultural Experiment Station, pp. 63–64, 1909.

without spots or traces of darker shades upon the wings. Only the purple eyes are free from the white wax, and are in sharp contrast to the color of the rest of the body. A detailed description of the adult, by Riley and Howard, follows:

DESCRIPTION.[1]

♀.—Length, 1.4 mm.; expanse, 2.8 mm.; four-jointed rostrum about as stout as legs; joint 1 shortest, joint 2 longest, and about as long as 3 and 4 together; joint 3 somewhat longer than joint 1 and a little shorter than 4. Joint 1 of the 7-jointed antennæ very short, as broad as long, subcylindrical, slightly wider distally; joint 2 twice as long as 1, strongly clavate, and at tip somewhat broader than 1, bearing 3 or 4 short hairs arising from small tubercles; joint 3 longest, about twice as long as 2, slenderer than this and with a very narrow insertion, rather abruptly stouter at apical third, corrugated and terminating above in a small callosity resembling a similar organ in Phylloxera; joints 4

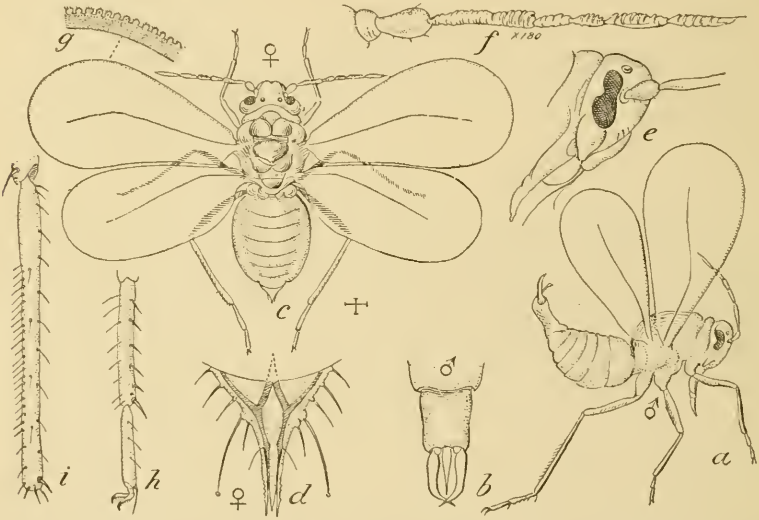

FIG. 10.—The citrus white fly. Adult. *a*, Male; *b*, claspers of male; *c*, female; *d*, ovipositor of female; *e*, side view of head of female; *f*, antenna; *g*, enlarged margin of wing; *h*, tarsus and claws; *i*, tibia. *a*, *c*, Greatly enlarged; *b*, *d–i*, more enlarged. (Adapted from Riley and Howard.)

and 5 subequal in length, each nearly as long as 2, joint 5 bearing a short spine anteriorly near apex; joints 6 and 7 subequal in length, each somewhat longer than 2, 7 with a stout spine at tip; joints 4 and 7 somewhat corrugate or annulate but less so than apical third of 3. The 2-jointed tarsi about half the length of the tibia, joint 1 of the hind tarsus bearing 6 rather stout spines on each side; joint 2 supporting at base 3 rather prominent claws, the middle one longest. Ovipositor short, acute, and retractile. Eyes divided into two by a curved pointed projection from middle of cheek, the upper portion being smaller than the lower portion. Wings clear, colorless; costa delicately serrate. General color, light orange yellow, tip of rostrum black, tarsi and part of tibia orange.

♂.—The male resembles the female in all important respects except in being smaller. Claspers about as long as preceding abdominal joint, or one-fifth the length

[1] Riley and Howard, Insect Life, vol. 5, p. 222, 1893.

ADULTS OF THE CITRUS WHITE FLY ON FOLIAGE OF ORANGE.

Fig. 1.—Tender growth swarming with adults. Fig. 2.—Leaf of same enlarged. (Original.)

of the abdomen, curved gently upward and inward, each bearing 4 or 5 equidistant minute cylindrical piliferous tubercles on upper and outer edge; style almost as long as claspers, rather stouter at base, more slender toward tip, terminating in a stout spine at upper end. Head and abdomen with heavy tufts of wax soon after issuing from pupa.

Examination of a large number of antennæ shows that the relative length of the antennal segments is subject to slight variations. The average relative lengths are about as follows:

Segment	1	2	3	4	5	6	7	Spine.
spaces [1]	10,	24,	43,	16,	16,	18,	22,	3

Although they have examined thousands of males both at and for some time after emergence and as they occur at all times throughout the grove, the authors have never been able to observe males with the tufts of wax on head and abdomen mentioned in the above description and illustrated in connection with its original publication.

EMERGENCE.

DESCRIPTION OF THE PROCESS.

The emergence of the adult occurs soon after its purple eyes and folded whitish wings can be seen distinctly through the pupal skin. About 20 minutes before the pupal skin is ruptured the body of the adult shrinks gradually away from it and assumes its natural shape. This gradual shrinking away from the edges of the pupa, and the accompanying thickening of the body, brings a pressure to bear on the pupal skin which causes it to split from margin to margin between the thorax and abdomen and along the median line from this rupture to the anterior margin. Through the T-shaped opening thus formed the insect first pushes its thorax, then its head, with little apparent exertion. The body now projects almost perpendicularly from the pupa case, as the pupal skin is called, with the antennæ, legs, and abdomen still in their pupal envelopes. By a series of backward and forward movements the antennæ and legs are freed from their membranes and are in constant motion. The abdomen is now so nearly out of the pupal case that the fly is practically free, holding on only by means of the end of the abdomen. With a sudden forward bend of the body the legs are brought in contact with the leaf, and with their aid the fly frees the rest of its abdomen and crawls away rapidly.

The period covered between the time the insect ruptures the pupal skin and the time it becomes entirely free from the case and is crawling is from 7 to 10 minutes. Not infrequently flies die during emergence.

[1] These represent the spaces read on eyepiece micrometer when 1-inch eyepiece and $\frac{1}{6}$-inch objective are used, and the miscroscope tube is drawn to 160.

CHANGES AFTER EMERGENCE.

Immediately after emergence from the pupa case the adult differs from the more mature individuals in that the lemon-yellow color of the body is not obscured by the white waxy secretion that subsequently appears. Also the wings, which appeared as crumpled whitish pads when the thorax was first protruded from the pupa case, have had time only to partially expand. As the fly crawls away from the case the wings are held perpendicularly above the back, but as the wings gradually unfold and assume their normal shape they are lowered to their natural position. It requires about 7 minutes for the wings to become straightened after the fly leaves the case, and from about 14 to 17 minutes from the time they first begin to expand. When fully expanded, the wings are colorless and transparent, with the costa pale yellowish. The powdery whiteness so characteristic of the flies as seen in the grove gradually appears as the wax glands secrete their particles of wax. In about one and three-fourths hours the wings and body have become perfectly white.

CONDITIONS AFFECTING EMERGENCE.

Aside from that inherent influence affecting the development of the citrus white fly and determining whether the adult shall emerge during the first or second general emergence period, as hereinafter described under "Seasonal history," many field observations made at all seasons during the past three years, supplemented by laboratory experiments, have emphasized the great influence which temperature has on emergence. While a normal amount of humidity is necessary for emergence to occur, it is not so controlling a factor as temperature during ordinary Florida weather, as will be shown later. Light also seems to affect emergence under certain conditions.

EFFECT OF TEMPERATURE ON EMERGENCE.

Conclusions drawn from field notes, supplemented by laboratory experiments, show that emergence seldom occurs outside the range of 62° F. to 85° F., with preference to temperatures ranging from 70° to 85°. During the winter months of December, January, and February, when the average monthly mean is about 60° F., no emergence occurs except to a slight degree during warm spells of several days' duration. In January, 1906, when the average monthly mean temperature was 59.6°, or practically normal, no flies were noted on wing at Orlando, Fla., except in small trees beneath pinery sheds where the temperatures averaged several degrees higher than outside. During late December, 1908, and early January, 1909, the temperature had been sufficiently high to cause a limited amount of new growth to appear on some trees in Orlando, and on January 4 a comparatively large number of adult white flies were seen feeding and depositing eggs on new growth in a very sheltered place. The average mean temperature of the 6 days preceding this observation was 66° F., while, for the 6 days preceding these, when no white flies were on wing, the average mean was about 58.5° F. Adult white flies were not seen in the laboratory grove in February, 1909, until about the 20th, or until the temperature records for the grove showed an average daily mean of about 64.5°. It is from the above facts that the lowest temperature at which emergence occurs has been determined to be about 62° F. This conclusion, drawn from general field observations, is strengthened by emergence records kept in connection with cage life-history work during the period of active spring emergence of March, 1908, when the monthly mean was 71°. Reference to the data contained in Table XI brings out the fact that while

TABLE XI.—*Relation of temperature to emergence of the citrus white fly.*

Date.	Range in temperature.	Average mean temperature.	Emergence records.			
			No. 1.	No. 2.	No. 3.	No. 4.
1908.	°*F.*	°*F.*				
Mar. 19	62–89	75.5	4	....	6	2
Mar. 20	63–90	76.5	5	18	78	4
Mar. 21	54–65	59.5	0	0	1	1
Mar. 22	60–80	70.0	10	15	69	15
Mar. 23	66–90	78.0	17	35	71	4

emergence had been going on actively two days before and after March 21, when the average mean temperature was about 75° F., a drop in the mean temperature on the 21st to 59.5° F. practically prevented any white flies from emerging. The 1 white fly that is recorded under Nos. 3 and 4 may have emerged on the 20th after the daily record had been taken. Such emergences are not rare at this season of the year, as will be shown later. Of 2 lots of about 100 pupæ each, from which adults were nearly ready to emerge, 1 was placed in a refrigerator at about 56° F, and the other kept at room temperature which ranged between 70° F. and 80° F. while emergence was taking place. Of those kept on ice, but 1 white fly emerged during the first 12 hours, as compared with 17 from pupæ kept at room temperature. White flies continued to emerge on 3 consecutive days from pupæ kept at the latter temperature. No more emerged from the refrigerated pupæ. It is therefore evident that emergence may occur at as low a temperature as 56° F., though very rarely.

That white flies seldom emerge after the temperature reaches 85° F. may be concluded from the following facts: During the months of July and August, when the average daily mean is about 82° F., a newly emerged adult is rarely seen in the grove after 8 a. m. Practically all adults at this season emerge between 4 and 7 a. m. This is true both in the laboratory and in the grove. Of 233 white flies emerging separately in vials in the laboratory during August, 1907, 212 emerged between 3.30 and 8 a. m., and the remaining 21, with one exception, emerged between 8 and 9.30 a. m. In the grove over 95 per cent of the white flies emerge before 7 a. m. At this time of day the temperature ranges between 70° F. and 85° F. During the early spring, when the daily maximum temperature does not usually exceed 85°, emergence is not restricted to the early morning as during the heat of summer, but occurs at all times of the day. It may also be added that like conditions exist in October and November, but because of difference in seasonal history, they affect chiefly the spotted-wing white fly.

EFFECT OF HUMIDITY ON EMERGENCE.

Under normal Florida conditions at Orlando, at any season of the year, the relative humidity rises to nearly or quite 100 per cent by from 6 to 10 p. m., and there remains until about 6 a. m., when it normally drops rapidly, sometimes to as low as 19 per cent, though more often to from 35 to 60 per cent. It has already been stated that over 95 per cent of the white flies will have emerged before 7 a. m. or before the humidity has fallen far from the saturation point. That temperature and not humidity is the more important factor governing emergence in Florida, can be inferred by a comparison of the humidity and temperature records of Table XIII. It so happened that the cold wave of March 21, 1908, was accompanied by a higher average humidity, but the temperature and not the humidity prevented adults from emerging. Again, during the spring, when the daily maximum temperature is seldom above 85°—usually less—emergence goes on even at midday when the humidity has dropped to as low as 33°. In this connection attention should be called to the fact that the humidity in the corked vials mentioned under the preceding heading remained at about 100 per cent throughout the greater part of the experiment.

There are, however, times of abnormal weather conditions when lack of humidity seems to play an important part in preventing emergence. During the month of March there sometimes occur dry winds of several days' duration, accompanied by more or less heat, which seriously check emergence, and, as far as can be determined, cause many pupæ from which adults are about to emerge to die.

Two such periods occurred during March, 1909, from the 3d to the 6th, and from the 25th to the 27th, respectively. During these periods the relative humidity was extremely low, on one day dropping to 19 per cent. For 42 hours during the latter period the humidity ranged below 50 per cent and for 36 hours above 50 per cent. During these periods emergence was noted to be seriously checked and at the end of the latter upward of 30 per cent of the pupæ were dead, apparently from no other cause.

EFFECT OF LIGHT ON EMERGENCE.

During the summer months light seems to have an influence on emergence. At this season emergence in the laboratory and grove begins at about daybreak. Observations made at hourly intervals on the emergence of 233 adults, from 3.30 and 4 a. m. show that white flies rarely emerge before this time. In one instance only about one-third as many white flies emerged from pupæ kept in the dark as from those kept in the open, and their emergence was noticeably delayed. During the cooler months the low morning temperatures prevent the white flies from responding to this apparent stimulation due to light, and they emerge at various times after the temperature has risen sufficiently high.

DURATION OF LIFE.

Without food.—In none of the experiments conducted to determine the length of adult life without food have white flies lived longer than 30 hours, and a very large percentage has died before the end of 24 hours. When confined on leaves of plants other than those recognized as food plants, life is usually longer than this, but never approaches the normal length. White flies confined on crape myrtle in July died as soon as those kept in empty cages, but flies caged on oak, in March, lived as long as 4 days; those on fig, in August, 3 days; and on banana shrub, in July, 2 to 3 days. In all these tests flies were placed only on the tenderest growth.

With food.—Adult life under normal outdoor conditions averages about 10 days, although individual white flies kept in cages have been known to live as long as 27 days. Adults are so fragile and so easily killed by winds and heavy showers and by numerous species of spiders and ants that their duration of life is at most very uncertain. Cage experiments during March, April, July, August, and September show that, in the cages at least, there is little difference in the length of life at various times of the year.

MATING.

The courtship of the citrus white fly has been observed to begin within 2 hours after emergence, and in one instance even before the wings of either male or female had become whitened. There is no time in the day when the males can not be seen courting the females. The male appears unable to locate the female at a distance much greater than one-fourth of an inch, according to Prof. H. A. Gossard. Observations made during the present investigations show that when males and females are placed in separate receptacles and separated only by a very porous cheesecloth they show absolutely no attraction to each other. Mating, therefore, is not so likely to occur when the adults are scarce, as it seems to be the result of chance meeting upon the leaves rather than to such a definite attraction as exists between males and females of many moths.

Upon detecting the female, the male approaches her nervously, stopping at intervals, especially as the distance lessens, and swinging his body about excitedly in a semicircle, the head being used as a pivot, his wings in the meanwhile opening and closing spasmodically. While no movement is made by the female, she is repeatedly approached from many directions before coition occurs. More often the male lies alongside the female and courts her in this position, raising and lowering his wings as above described, and raising and swinging his abdomen from side to side. During these antics of the male the female remains quiet, only occasionally flittering her wings. While males may be seen courting females at all times of the day, it is seldom that one sees a pair in coitu except late in the afternoon and evening. Because of the uniformity of color and the ease with which adults are disturbed and made restless the duration of copulation can not be stated with certainty, but it probably lasts but a short time. Experiments to determine the duration of fertility have thus far proved unsuccessful.

OVIPOSITION.

AGE AT BEGINNING OVIPOSITION.

Virgin females in confinement have deposited eggs within 6 hours after emergence. In one instance 35 virgins deposited 58 eggs between 5 and 9½ hours after emergence during summer weather, with the temperature ranging from 80° to 92° F. However, even at this temperature single females occasionally did not deposit eggs for over 24 hours. Prof. H. A. Gossard[1] states that egg laying begins at from 18 to 30 hours after the emergence when the temperature ranges from 65° to 75° F. Laboratory tests have shown that lack of fertilization does not prevent a female from depositing eggs, but that she will readily deposit infertile eggs until opportunity for mating presents itself.

PORTION OF PLANT SELECTED.

If not numerous, the females deposit almost exclusively on the under surface of the leaves, laying over 75 per cent of their eggs on the half of the leaf bordering the midrib. It is only when very abundant and pressed for room that they deposit eggs thickly over the entire lower surface and more sparingly on the upper surface, the petioles, and the stems of twigs. Next to the portion bordering the midrib, the natural depressions and the curled margins of the leaf, especially

[1] Bul. 67, Fla. Agr. Exp. Sta., p. 609, 1903.

of the tender growth, are favorite places for oviposition, and not infrequently as high as 40 per cent of the eggs are there laid, even when the adults are not very abundant. Although eggs may be deposited along the leaf margin, it is seldom that they are laid on the margin itself, as is the case with the cloudy-winged white fly. Even when not crowded for leaf space, the adults sometimes settle upon the under side of young fruit, where they deposit eggs freely and apparently feed.

DAILY RATE OF OVIPOSITION.

Previous to these investigations no data have been published on the daily rate of oviposition. In obtaining the data given in Table XII, the females recorded were collected at random throughout the grove, without regard to age, and, together with males not mentioned, were caged over leaves cleaned of all eggs and larvæ of the white fly and allowed to remain the recorded time, when the adults were removed and the eggs counted.

TABLE XII.—*Daily rate of oviposition of the citrus white fly.*

Record No.	Date deposited.	Number of females.	Duration of egg laying.	Number of eggs deposited.	Average number of eggs per female per 24 hours.	Average mean temperature.
			Hours.			° *F.*
1	Feb. 23–24, 1909	14	26	197	13	74.5
2	Apr. 11–15, 1907	3	103	98	7.6	68.2
3	Apr. 20–21, 1909	50	24	454	9.1	77.2
4	Apr. 21–22, 1909	40	24	405	10.1	78.2
5	June 16–17, 1909	30	24	360	12	82
6	July 17–18, 1907	255	21	2,533	11.3	82
7	July 22–23, 1907	105	24	1,216	11.6	85
8	July 24–26, 1907	50	46	1,331	13.8	84
9	Aug. 17–18, 1907	70	24	805	11.5	81
10	Sept. 21–22, 1908	35	24	405	11.6	79

Number eggs per day per female, grand average, 11.2.

The generally uniform results obtained in the nine records when the average mean temperature was about 75° F. or above, together with the grand average daily rate of oviposition for individual females whose age was definitely known, as shown in Table XIII, indicate that each female normally deposits on an average 10 or 11 eggs a day. Varying degrees of temperature above a daily mean of 75° F. do not correspondingly increase the number of eggs deposited. However, temperatures below an average mean of 72° F. (estimated) have a distinct checking effect upon oviposition, as shown by record No. 2.

Notwithstanding the general average number of eggs per day deposited by the females of all ages in Table XII, and the same for the females of known ages for the total number of days they lived, in Table XIII, reference to the daily oviposition records in the latter shows that as many as 14, 19, 27, or even 33 eggs may be deposited by a single female in one day. It will also be noted that much variation exists between the number of eggs deposited by several different females on the same day and by the same female on successive days without any apparent reason, and that there exists no appreciable difference between the rate of deposition by virgin and by fertilized females.

TABLE XIII.—*Number of eggs deposited by single females of the citrus white fly.*

Fly No.	Date of first daily record.	Condition of female.	Daily rate of oviposition by individual females.											
			1	2	3	4	5	6	7	8	9	10	11	12
1	Aug. 8, 1907	♀+males 12 hours old	8	19	9	22	11	2	15	6	(1)	...	...	...
2	....do	....do	5	19	14	12	12	15	13	14	(1)	...	...	...
3	....do	....do	3	9	13	5	13	9	16	8	1	15	19	14
4	....do	Virgin 12 hours old	5	12	17	4	3	20	5	1	0	6	3	6
5	Aug. 15, 1907	Virgin 8 hours old	5	13	15	14	12	12	15	13	14	10	9	9
6	....do	....do	6	16	17	5	33	13	23	16	15	14	10	3
7	....do	♀+males 8 hours old	8	8	16	14	17	11	16	7	1	4	2	4
8	....do	....do	2	18	16	14	9	2	13	15	6	9	9	1

Fly No	Daily rate of oviposition by individual females.												Total number of eggs laid.	Number of days lived.	Average number of eggs per day.
	13	14	15	16	17	18	19	20	21	22	23	24			
1	...	...	...	...	...	...	...	...	...	...	...	...	92	8	11.5
2	...	...	...	...	...	...	...	...	...	...	...	...	104	8	13
3	13	9	5	14	10	8	6	9	6	1	(1)	...	206	22	9.4
4	5	10	2	2	3	0	8	(2)	...	...	...	...	112	19	6.0
5	5	20	11	2	(3)	...	...	...	...	...	...	...	179	16	11.2
6	19	...	11	6	4	(4)	...	...	...	...	...	...	211	17	12.4
7	8	3	14	12	2	(1)	...	...	...	...	...	...	146	17	8.6
8	1	27	3	(5)	...	...	...	...	...	...	...	...	144	14	10.3

[1] Dead.
[2] Dead; 13 eggs in abdomen.
[3] Dead; 18 eggs in abdomen.
[4] Dead; 11 eggs in abdomen.
[5] Dead; 7 eggs in abdomen.

Number of eggs per day per female, grand average, 10.3.

The eight records in Table XIII are selected from about forty similar records on file and are considered as representing an average condition of oviposition. Although the general average of 10.3 eggs per day throughout life for the 8 females recorded in Table XIII agrees very closely with the similar average obtained in Table XII, there is sufficient evidence in the data in Table XIII to warrant the statement that the daily rate of oviposition for individual females is usually greater during the early part of the insect's life and decreases with each successive week of existence. Leaving out of consideration the first day, when the flies had not reached their normal egg-laying capacity, a little calculation shows that the average daily deposition for the three successive weeks is 12.8, 8.5, and 6.1, respectively. This same decrease in the number of eggs deposited with increase in age is perhaps better brought out by a study of the number of eggs deposited by the individual females over 5-day periods. Thus No. 6 averaged 16.2 eggs per day for the first 10 days, but for the next 5 dropped to an average of 7.8; Nos. 4 and 7 showed a sharp falling off during the second 5 days. No. 3 is an exception to the above statement, maintaining an average of from 9.8 to 11.8 eggs per day for the first three periods of 5 days each, and during the fourth period of 5 days deposited as many eggs as during the first 5 days. It will be noticed, however, that No. 3 deposited comparatively few eggs during the early part of her life. In view of the fact that the average adult life is only about 10 days, the higher rate of deposition during early life has an influence on multiplication.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES.

First mention of the egg-laying capacity of the citrus white fly was made by Riley and Howard,[1] who based their conclusions on the number of eggs that could be counted in the abdomen of the females when mounted in balsam, and not upon daily counts of eggs deposited by the females throughout life. Their estimate of about 25 eggs as the probable total number of eggs deposited by a single female during life has been generally accepted by subsequent writers, none of whom has ever placed the maximum number deposited above this figure. The present investigations, however, have demonstrated that this estimate is far too low and that the number of well-developed eggs to be found in the abdomen of the female at any one time is not indicative of the number of eggs deposited throughout her life. Females have been known to deposit more than this number of eggs in a single day. As will be seen by reference to Table XIII, as many as 211 eggs have been actually deposited by one female, and should the 11 well-developed eggs found in her abdomen at death be added a total of 222 eggs would be obtained. As this female, No. 6, lived but 17 days and others have been known to live 28 days, it is even probable that as many as 250 eggs more nearly represent the maximum egg-laying capacity under most favorable conditions. However, it is seldom that a female lives sufficiently long to deposit her full quota of eggs. With the average length of adult life curtailed to about 10 days, the average of 149.2 eggs per female, as shown in Table XIII, is beyond doubt high. An average of 125 eggs per female is nearer the number of eggs deposited during life in the grove.

ACTIVITY IN OVIPOSITION DURING DIFFERENT PARTS OF THE DAY.

In order to determine that portion of the day when eggs are most freely deposited by females during summer weather, adults were inclosed in a rearing cage over leaves from which all previously deposited eggs had been removed, and allowed to remain for a period of two hours, when the cage with adults was removed to another leaf and the deposited eggs counted, with results shown in Table XIV.

[1] Insect Life, vol. 5, p. 222, 1893.

TABLE XIV.—*Activity of the citrus white fly in oviposition during different parts of the day.*

Time of day.	Mean temperature for period.	Number of eggs deposited.	Per cent of total eggs deposited.
	° F.		
6 a. m.–8 a. m....	82	20	2.6
8 a. m.–10 a. m...	89	55	7.3
10 a. m.–12 m.....	91	35	4.7
12 m.–2 p. m.....	92	65	8.7
2 p. m.–4 p. m....	90	30	4
4 p. m.–6 p. m....	85	197	26.1
6 p. m.–8 p. m....	81	248	32.9
8 p. m.–6 a. m....	74	103	13.7
6 a. m.–6. a. m...	[1] 81.6	753	100

[1] Average temperature for entire day of 24 hours; not the average of the 8 periods.

From the data it will be seen that while oviposition occurs at all times of the day, nearly 60 per cent of the eggs are deposited between 4 p. m. and 8 p. m., and that oviposition does not cease on the approach of darkness. The variation in the number of eggs deposited during the periods from 6 a. m. to 4 p. m. has little significance. It was noted that the least number of eggs were deposited when the bright sun fell directly upon the cage.

In further evidence of the greater activity of oviposition during the latter part of the day, two other cages were started on August 1, 1909. One cage placed repeatedly over the tenderest growth resulted in 698 eggs being laid between 10.15 a. m. and 4.15 p. m., as compared with 895 eggs laid between 4.30 p. m. and 7.30 p. m. The second cage, covering spring growth, gave 115 as compared with 786 eggs deposited during the same periods.

Relation between oviposition and food supply.—As the egg-laying capacity of a single female is close to 250 eggs and but 25 well-developed eggs have ever been seen in her abdomen at any one time, it is necessary that she obtain nourishment sufficient to mature her numerous "potential" eggs. There remain many interesting observations and experiments to be made on the relation between oviposition and food supply. That females deposit fewer eggs when feeding upon many of the recognized food plants other than citrus than they do on the latter is a subject of considerable interest. While adults feed apparently as contentedly upon new growth of China trees and umbrella China trees, they do not appear to deposit as many eggs per female on these host plants as on citrus. The extremely small number of eggs laid by females swarming over new growth of wild persimmon in June at Orlando is even more astonishing considering the marked preference shown by the females for this growth over the spring growth of orange. Even on citrus itself oviposition is influenced by the ages and corresponding toughness of the leaves, though not as markedly as is that of the cloudy-winged white fly. In one instance equal numbers of adults were confined on a tender and an old leaf of orange for two hours, when the adults were removed and 576 eggs were found to have been laid on the tender leaf and but 25 on the old leaf. Again, under practically the same conditions, 364 eggs were deposited upon tender growth and but 2 on very old growth. The difference between oviposition on tender August growth and spring growth is not as great as this, though very marked, as about 90 per cent of the third-brood adults fly to the new growth put on by the trees late in July and early in August.

From the foregoing it is evident that the number of eggs deposited is strongly influenced by the nature of the insect's food. Females confined in empty cages never deposit eggs, neither do those resting upon thick bark, ladders, or picking boxes, and, as has been stated under "Food plants," oviposition is entirely checked[1] when females are confined with leaves of nonfood plants. This difference in the number of eggs deposited on various plants may prove of value from the standpoint of trap foods, and become a factor in the control of this pest.

PROPORTION OF SEXES.

Examination of thousands of adult citrus white flies at all seasons of the year has shown that after a grove has become well infested an equilibrium between the proportion of males and females is established from which there is under ordinary conditions little variation. In such groves it has been found that from 60 to 75 per cent of the adults are females. Of the records on file, about 66 per cent give percentages of 60 and over for females, while 66 to 76 per cent are more frequent percentages where adults are abundant.

In groves where the progress of the white fly has been very seriously and suddenly checked by natural or artificial causes, the proportion of sexes is subject to a much wider variation and there follow for a time fluctuations between a predominance of males and females. In one such grove where the white fly had been greatly reduced in numbers because of the scarcity of adults of the first brood, there was a very large percentage of males appearing with the second brood, which in turn resulted in the third brood of 90.5 per cent females. In a second grove, where over 99 per cent of the white fly were killed by fumigation, the few females of the first brood, because of their isolation due to scarcity in numbers, were forced to deposit mostly infertile eggs, which resulted, in the second brood, in a reduction of females to 18.6 per cent.

Dependence of sex upon parthenogenesis.—The proportion between the sexes is largely and evidently entirely dependent upon parthenogenesis. It has been shown that infertile females deposit eggs in as

[1] Three hundred adults of *A. citri* confined on the tenderest spring growth of oak for three days deposited 1 egg.

large numbers and as frequently when males are not given access to them as do fertile females, and that the adults developing from these eggs are all males. Whether the adults from fertile eggs are invariably females has not been proved, although the evidence leaves little doubt that they are. If otherwise, it would be difficult to account for the fluctuations in sexes mentioned under the preceding heading, or to explain the great predominance of females over males after the species has become well established.

INFLUENCE OF WEATHER CONDITIONS ON ACTIVITY OF ADULTS.

During the cooler portions of the year, when adults are present on the trees, very few are seen flying about from tree to tree unless abundant. The morning and evening temperatures easily chill them; hence their activities are confined to the warmer part of the day.

However, after summer weather has become established the white flies rest very quietly on the under surface of the leaves during the greater part of the day. They shun the bright sunshine and prefer leaves in shaded places. When exposed to the sun without protection they soon die. As the temperature falls during the late afternoon, and especially after afternoon showers when the humidity has risen to 90° or even to 100°, they become very active, and about 4 o'clock begin to fly about from leaf to leaf and from tree to tree, and, when very abundant, swarm in such large numbers about the groves and town streets as to arrest the attention of pedestrians, to whom they become at times a source of much aggravation, becoming entangled in the hair, crushed upon the clothing, breathed in with the air and causing choking, and flying into the eyes.

FEEDING HABITS OF ADULTS.

The adult insects, having well-developed sucking mouth parts, feed upon the plant juices in the same manner as do the larvæ and pupæ, but with the advantages of not being confined to the same location. They do not leave any external evidence of the feeding except on very young growth, when the feeding of a large number of adults frequently produces a crinkling of the foliage.

It is difficult to determine positively whether or not an adult citrus white fly is feeding when it is resting on a leaf or stem. Adults rest contentedly during the warm portions of the day upon the underside of leaves of plants upon which they have never been known to deposit eggs. Under these circumstances they even appear to mate, and it seems probable that they feed to a limited extent. When on one of the principal food plants of the species, however, it is safe to consider that adults feed wherever eggs are deposited in noticeable numbers. It is because of this indiscriminate settling upon vegetation upon which they are not able to subsist, and upon which they never breed, that the belief has received such an unfortunately wide circulation among orange growers that the citrus white fly breeds on all kinds of hammock trees, shrubs, and grasses. Regardless of the food plant, the adults feed almost exclusively upon the under surface of the leaves, more rarely upon the fruit, and never upon the woody portions of the tree. When new growth is very young and the leaves have not expanded, adults often feed upon both surfaces of the leaf, the petiole, and even the tender shoots, but this lasts only for a short time. At all seasons the newest growth is preferred, as indicated by the data under the caption of the relation of food supply to oviposition, and the portion of the plant selected coincides with that already discussed for oviposition. It should be noted here that the decided preference of the adults for the new growth has a checking effect, as noted elsewhere, upon multiplication, as they are entirely lacking in instincts preventing over-oviposition

Multiplication.

The relation of multiplication to food supply and the restrictions upon multiplication due to overcrowding, natural mortality, dropping of leaves after freezes, parthenogenesis, and attacks by insects and other predaceous enemies and fungi will be found treated elsewhere. It has been estimated that not more than 5 per cent, at the most, of the eggs deposited throughout the State result in the development of mature insects. If each female deposited her full number of eggs and all the forms lived, it has been estimated, the progeny of a single pair of white flies emerging in January would amount to about 55,000,000,000 in one year.

Length of Life Cycle.

Data concerning the duration of the egg, larval, and pupal instars of the citrus white fly have already been given, but not in a form readily showing the relation to the complete life cycle. From some of the more important and complete of the life-history studies the data in Table XV have been arranged to illustrate the important points in this connection:

Table XV.—*Length of life cycle of the citrus white fly at Orlando, Fla.*

Lot No.	Eggs deposited.	First fly emerged.	Last fly emerged in fall.	First fly emerged in spring.	Last fly emerged.
No. 1	Feb. 23	Apr. 30	....	....	....
No. 2	Mar. 3	May 9	....	....	....
No. 3	Apr. 3	May 30	....	....	....
No. 4	Apr. 20	June 7	....	....	Mar. 18
No. 5	June 16	July 30	....	....	....
No. 6	July 17	Aug. 27	Sept. 10	Mar. 16	Apr. 16
No. 7	...do.....	Sept. 4	Sept. 17	Mar. 17	May 4
No. 8	July 19	Sept. 2	Sept. 21	...do.....	May 1
No. 9	July 26	Sept. 6	Sept. 20	Mar. 18	May 10
No. 10	Aug. 1	Sept. 19	Sept. 26	Mar. 24	Apr. 6
No. 11	Aug. 3	Sept. 25	...do.....	Mar. 23	Apr. 15
No. 12	Aug. 8	Sept. 19	Sept. 27	....	....
No. 13	Aug. 9	Mar. 30	0	Mar. 20	May 12
No. 14	Sept. 18	Mar. 16	0	Mar. 16	Apr. 28
No. 15	Sept. 21	Mar. 12	0	Mar. 12	May 10

Lot No.	Least number of days for development.	Largest number of days for development.	Per cent emerging before winter.	Per cent wintering over to emerge in spring.	Smallest number degrees effective temperature for development.	Degrees accumulating before spring emergence.	Degrees accumulating before last fly emerged.
No. 1	67	....	100.0	0	1,783	....	....
No. 2	67	....	100.0	0	1,885	....	....
No. 3	57	....	100.0	0	1,888	....	....
No. 4	48	333	....	....	1,712	....	....
No. 5	44	....	....	....	1,725	....	....
No. 6	41	273	56.9	43.1	1,641	6,632	7,619
No. 7	49	291	30.8	69.2	1,972	6,665	8,253
No. 8	45	286	12.7	87.3	1,815	6,504	8,059
No. 9	42	288	29.8	70.2	1,703	6,322	7,981
No. 10	49	248	5.5	94.5	2,015	6,255	6,654
No. 11	53	255	3.6	96.4	2,153	6,107	6,858
No. 12	42	....	2.7	97.3	1,735	....	....
No. 13	223	276	0	100.0	5,825	5,825	7,545
No. 14	179	222	0	100.0	4,552	4,552	5,836
No. 15	172	231	0	100.0	4,289	4,289	6,100

From this table it will be seen that the period of development for individuals hatching from eggs laid upon the same leaf within a few hours of each other is subject to an astonishing variation, ranging from 41 to 333 days. This variation is absolutely independent of both temperature and humidity influences. It will be noted that the sums of effective temperatures required for the minimum duration of immature stages for individuals developing from eggs deposited between February 23 and August 8 vary from 1,641° to 2,153°, with an average of 1,846°, which may be regarded as very nearly the normal for minimum development up to the time when all individuals winter over as pupæ. It should also be noted that the number of maximum degrees of effective temperature is more strongly influenced by the time of year the eggs are deposited—the nearer the winter months deposition takes place the fewer the degrees accumulating before the last fly emerges. This is due to the equalizing effect of the cooler winter temperatures.

This same equalizing effect of the winter temperatures upon the length of the life cycle for individuals developing from eggs laid on September 20 is brought out in Table XVI:

TABLE XVI.—*Duration of instars of the citrus white fly.*

Specimen No.	Instar.								Total number of days.
	First.		Second.		Third.		Pupal.		
	Duration of instar.	Number of days.	Duration of instar.	Number of days.	Duration of instar.	Number of days.	Duration of instar.	Number of days.	
	1908.		1908.		1908.		1908.		
1	Oct. 3-10	8	Oct. 10-15	5	Oct. 15-27	12	Oct. 27-Apr. 28	173	198
2	Oct. 3-10	8	Oct. 10-24	14	Oct. 24-Nov. 10	17	Nov. 10-Apr. 17	158	197
3	Oct. 3-15	13	Oct. 15-22	7	Oct. 22-Nov. 4	13	Nov. 4-Apr. 8	155	188
4	Oct. 3-Nov. 2	31	Nov. 2-16	14	Nov. 16-Dec. 3	17	Dec. 3-Apr. 6	128	190
5	Oct. 3-10	8	Oct. 10-18	8	Oct. 18-29	11	Oct. 29-Mar. 26	148	175

From this table it will be seen that retardation in growth during any one instar does not affect materially or show a corresponding increase in the total number of days required for development when the individual passes the winter in the pupal stage. Also, that an unusually large number of days spent in one instar does not necessarily mean that the individual insect will be equally backward in the next instar. These records of daily observation on individual specimens from hatching to adult are only 5 of 85 similar observations for the same period. Nos. 2–5 were insects on the same leaf.

SEASONAL HISTORY.

GENERATIONS OF THE CITRUS WHITE FLY.

It has been generally understood in the past that there are three generations annually of the citrus white fly, although Prof. H. A. Gossard,[1] states that "four generations a year doubtless often occur, but not in sufficient numbers to obscure three well-defined broods as the rule." In the greenhouses at Washington, Riley and Howard[2] found that there were but two generations annually. The life-history work of the present investigations has shown that while the general

[1] Bul. 67, Fla. Agr. Exp. Sta., p. 612, 1903.

[2] Insect Life, vol. 5, p. 224, 1893.

observations of the past leading to the statement of three more or less distinct periods of emergence are correct, the number of generations annually ranges from two to five, or, under unusually favorable conditions, from three to six. In figure 11 the maximum and minimum number of generations as actually known to occur in groves at Orlando during 1907–9 has been plotted. Figure 11 is based upon the development of individuals in rearing experiments. The generation between January and March may or may not occur, according to whether the winter weather is warm or cold, but when present is numerically insignificant. The other generations are more confused than can be indicated diagrammatically. As may

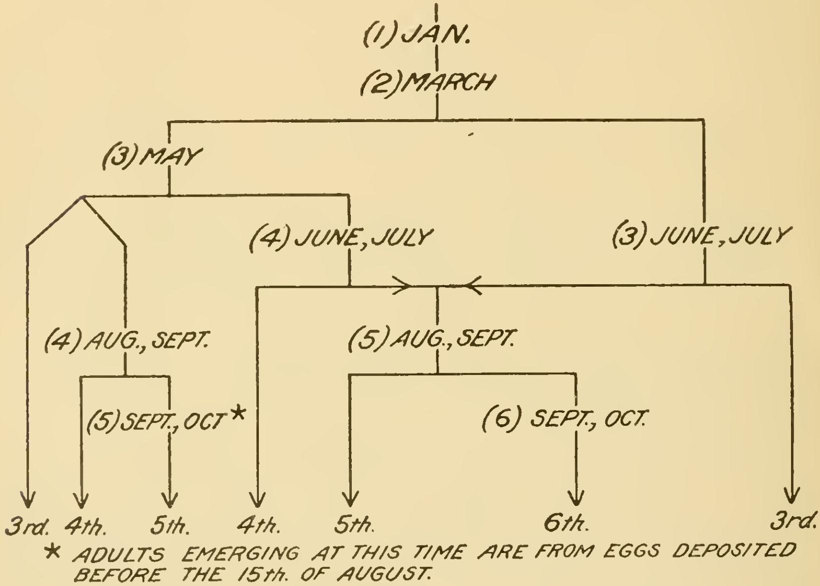

FIG 11.—Diagram showing generations of the citrus white fly. (Original.)

have been inferred from data in Tables XV and XVII, the variation in the number of generations is due almost entirely to the length of the pupal stage, which, as has already been pointed out, is subject to wide variation, the cause of which can not be traced to food, temperature, humidity, or location on the tree. The most striking variation in the length of life cycle, with its effect upon the possible number of annual generations, is found among individuals developing from eggs deposited in April and May. In one instance eggs deposited on April 20 produced adults on June 5, July 31, and in the following March. In the main, each generation has two more or less distinct periods of emergence, as reference to the data in Tables XV and XVII will show.

TABLE XVII.—*Emergence of adult citrus white flies at Orlando, Fla.*[1]

Record No.	Eggs deposited.	April. 1–15	April. 16–30	May. 1–15	May. 16–31	June. 1–15	June. 16–30	July. 1–15	July. 16–31	August. 1–15	August. 16–31
1	Feb. 22	0	1	85	....	....	....	....	....	....	....
2	Mar. 3	0	0	44	44	....	....	....	....	....	....
3	Mar. 18–25	0	0	1	51	30.3	2.9	0	4.9	9.9	0
4	Apr. 20	0	0	0	0	50.1	28.6	0	8.2	0	0
5	June 16	0	0	0	0	0	0	0	(3)	....	....
6	July 17	0	0	0	0	0	0	0	0	0	32.1
7	July 17	0	0	0	0	0	0	0	0	0	0
8	July 19	0	0	0	0	0	0	0	0	0	0
9	July 26	0	0	0	0	0	0	0	0	0	0
10	Aug. 1	0	0	0	0	0	0	0	0	0	0
11	Aug. 8	0	0	0	0	0	0	0	0	0	0
12	Aug. 9	0	0	0	0	0	0	0	0	0	0
13	Sept. 18	0	0	0	0	0	0	0	0	0	0
14	Sept. 21	0	0	0	0	0	0	0	0	0	0

Record No.	Eggs deposited.	September. 1–15	September. 16–30	October to March.	March. 1–15	March. 16–31	April. 1–15	April. 16–30	May. 1–15	May. 16–30
1	Feb. 22	....	....	....	....	....	....	....	....	....
2	Mar. 3	....	....	....	....	....	....	....	....	....
3	Mar. 18–25	0	0	0	0	0	0	0	0	0
4	Apr. 20	0	(2)	0	0	0	0	0	0	0
5	June 16	....	....	....	....	....	....	....	....	....
6	July 17	24.4	0.4	0	0	43.1	0	0	0	0
7	July 17	23.9	6.9	0	0	67.3	1.9	0	0	0
8	July 19	8.7	1.7	0	0	89.2	.4	0	0	0
9	July 26	23.8	6.5	0	0	64.3	5.4	0	0	0
10	Aug. 1	0	3.3	0	0	85.6	11.1	0	0	0
11	Aug. 8	0	2.7	0	0	....	....	....	....	....
12	Aug. 9	0	0	0	0	98.7	1.3	0	0	0
13	Sept. 18	0	0	0	0	38.3	46.8	14.9	0	0
14	Sept. 21	0	0	0	0	38.6	47	14.7	0	0

[1] This table is introduced to demonstrate the two emergence periods for individuals developing from eggs deposited at the same time. It is not intended to represent the abundance of adults at different times of the year. Figures represent percentages.

[2] Only one fly survived to winter over.

[3] One fly emerged July 30. Leaf was broken off on same day. Development of flies indicated that at least 50 per cent would have emerged during August.

This makes it possible for adults emerging during the first period to deposit eggs for a second generation, a portion of the adults of which (first brood) will emerge at the time of the second emergence period (second brood) for the first generation, while a large proportion of the remaining individuals on the leaf to all appearances remain stationary in their development, though actively secreting honeydew, until the approach of the first emergence period of the second generation started by the second brood of the first generation, when they rapidly mature and emerge with this brood. However, this double-brooded character of each generation up to and including generations started in early August does not obscure the three well-defined "broods" of adults, to be discussed under "Seasonal fluctuations in the numbers of adults or so-called 'broods,'" but shows that the adults appearing during the three general emergence periods do not, strictly speaking, represent a single brood of one generation, but different broods of different generations. By far the greater number of wintering-over pupæ belong to the fourth, fifth, and sixth generations, with the last two most abundantly represented. The number of third-generation pupæ—or second generation should the first generation in figure 11 not occur—to winter over is insignificant.

SEASONAL FLUCTUATIONS IN THE NUMBERS OF ADULTS OR SO-CALLED "BROODS."

During winters of unusual mildness there is a tendency for continuous breeding, and adults in varying numbers can be found on the wing at different times, but these are as a rule too few in number to be of importance in effecting the general seasonal history of the citrus white fly. With the exception of the limited number of larvæ developing from eggs deposited by these unseasonal adults, the white fly passes the winter in the pupal stage. The first general spring emergence of adults begins after the daily mean temperatures have risen to about 65° F., which at Orlando in 1909 was about February 20.

There are three periods throughout the year when adult citrus white flies are so much more abundant than at other seasons that it is generally said there are three broods of white flies each year,

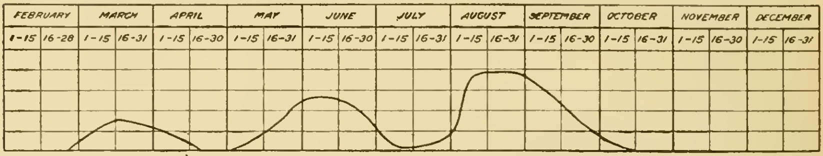

FIG. 12.—Diagram showing abundance of adults of the citrus white fly at Orlando, Fla., throughout 1909. (Original.)

although, as already noted under the subject of generations, the term brood in this case is somewhat misleading. The dates at which these adults appear is subject to such variation in groves in the same county, town, or even on individual trees of the same grove, that no accurate statement of the dates between which the broods occur throughout the State as a whole can be made. The authors, therefore, have chosen to follow the history of the white fly in a single grove at Orlando during the season of 1909 as a specific example, as a basis, and present in figure 12 a curve representing the abundance of adults throughout that season. In all its essential features the curve is regarded as representing the appearance of adults in any grove, when it is remembered that variations of from one to three or four weeks may occur in the appearance of the broods.

While it is generally believed that adults appear earlier in the spring throughout southern Florida, it is a fact that there is very little difference in time of emergence between that and the central portion. Emergence throughout the northern portion of the State is, according to the season, from one to four weeks later than in the central and southern portions. Prof. H. A. Gossard has stated that at Lake City in 1902 white flies began to appear no earlier than April 14, and continued to appear until late in May, although the majority of them emerged during the latter half of April, while in 1903 the same trees produced adults as early as March 12, or but one week later than groves at Orlando and Palmetto. While the spring brood of adults at Orlando in 1909 had begun to emerge as early as February 20 and had reached their height and begun to decline by March 27, on the latter date in St. Augustine only 5 per cent of the pupæ had developed the eyes of the adult and practically no adults had emerged. Professor Gossard also is authority for the statement that at "Tampa, 30 to 40 miles north of the Manatee section, the spring brood of white flies has in some seasons preceded their appearance about Bradentown and Manatee by two weeks." By June 18, 1909, more than twice as many adults of the second brood had emerged at Manatee as at Island Grove about 125 miles north in Alachua County, while by July 7 of the same year the white fly in a grove at Alva in Lee County was no further advanced than at Orlando.

From the curve in figure 12 it will be noticed that there are two periods of about three weeks during the summer between the broods when adults are comparatively very scarce. While reference to Table XVII shows that a few wintering-over individuals continue to emerge as late as early May, the period between the first and second broods of adults is exceptionally free from adults of the citrus white fly. This, however, is not true of the like period between the second and third broods as before this time the generations of the white fly have become somewhat confused, due to variation in life cycle, and adults continue to emerge in appreciable numbers throughout the period.

In speaking of the entire citrus belt, including Florida and the Gulf States, the greater part of the spring brood may be said to emerge during March and April; the second brood to emerge during late May, June, and July, and the third brood during August and September. It should be noted here that the greater part of the adult white flies appearing in October and November in the central and southern part of Florida are the cloudy-winged white fly, *A. nubifera*, although in the northern part adult specimens of *A. citri* have been seen in small numbers on the wing in St. Augustine as late as November 15.

THE CLOUDY-WINGED WHITE FLY.

(*Aleyrodes nubifera* Berger.)

HISTORY.

Specimens of the cloudy-winged white fly (eggs, larvæ, and pupæ) in the collection of the Bureau of Entomology show that this species occurred on oranges in the United States as early as 1889. The records in connection with the specimens show that it was collected in Mississippi and North Carolina in 1889, in Louisiana in 1890, and in Florida in 1895. Outside of the United States it is known to occur only in Cuba. Its introduction into the United States from Cuba does not seem as probable as its introduction into Cuba from the United States. At present there is no evidence concerning the probable origin of the insect except in the absence, so far as is known, of other food plants than citrus, which would seem to indicate the introduction of the insect with its only known food plant.[1]

Several writings on the citrus white fly (*Aleyrodes citri*) have in part included the cloudy-winged white fly (*A. nubifera*). Prof. H. A. Morgan,[2] in 1893, previous to the publication of the original description of *Aleyrodes citri*, briefly described the egg of *Aleyrodes nubifera* and figured it, the description of the pupa and adult given at the same time evidently being based on specimens of *A. citri*. The species to which Prof. Morgan referred the specimens was *Aleyrodes citrifolii* Riley MS. The original description of the citrus white fly,[3] while unquestionably defining the species generally recognized as *A. citri*, included in part reference to what is probably the spotted-wing white fly. In the text the description of the first stage or instar of the larva was evidently based on a specimen of the spotted-wing white fly and the illustration of the first instar[4] was also based on this species with little doubt. One figure of the pupa[5] and one of the pupa case[6] evidently were based upon specimens of the same species. In the writings of Prof. Gossard there are no references in the text which evidently refer to the cloudy-winged white fly, but what is probably this species is represented in an illustration of the first stage.[7]

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[1] Its recent discovery on *Ficus nitida*, rubber tree, in greenhouses at Audubon Park, New Orleans, La., points to its possible introduction from India.

[2] The Orange and Other Citrus Fruits. Special Bulletin Louisiana Agricultural Experiment Station, p. 72, 1893.

[3] Insect Life, vol. 5, pp. 220–222, 1893.

[4] Id., vol. 5, p. 219, fig. 23, *d*.

[5] Id., vol. 5, p. 219, fig. 23, *h*.

[6] Id., vol. 5, p. 219, fig. 23, *i*.

[7] Bulletin 67, Florida Agricultural Experiment Station, pl. 2, fig. 1. See also Bulletin 88, pl. 2, fig. 1, and Bulletin 97, fig. 11, Florida Agricultural Experiment Station, and Circular 30, California Agricultural Experiment Station, pl. 2, fig. 1.

The white fly known as the cloudy-winged white fly was first determined as specifically distinct from the citrus white fly by Dr. E. W. Berger in 1908. Dr. Berger has recently given this species its scientific name in connection with a synopsis of the principal distinctive characters and illustrations of egg and larval and pupal stages.[1]

AMOUNT OF INJURY BY THE CLOUDY-WINGED WHITE FLY.

The injury caused by the cloudy-winged white fly is at present much restricted by several factors. In Florida the distribution of this species is limited as compared with that of the citrus white fly. Its food-plant differences and adaptations are such that orange trees[2] are not as a rule subject to as heavy infestations as by the citrus white fly, although with grapefruit trees this situation is usually reversed. Most important as a factor limiting the injury from the cloudy winged white fly is that when both occur in an orange grove the citrus white fly almost invariably predominates and the cloudy-winged white fly assumes a position of comparative insignificance. Owing to the difference in the seasonal history of the two species of white fly this latter point is not always apparent to the casual observer. An observation made between the broods of adults of the citrus white fly, or at any time after the middle of September up to December 1, may result in noting a great preponderance of the cloudy-winged white fly, leading one to conclude, perhaps, that it is this latter species which is causing the most injury. An examination of the leaves during the winter months, when there are practically no adults of either species, will probably show an entirely different situation. In many groves near Orlando and Winter Park in Orange County, Fla., both species of white fly are well established and practically have assumed their normal relative positions in point of numbers. Examinations of leaves varying in number from 85 to 400 pinched at random in 11 of such groves furnish data which illustrate the general situation as regards the importance of the two species of white fly under the conditions mentioned. (See Table XVIII.) All the examinations were made during the winter months, using pupa cases and live pupæ as the basis of the comparison.

[1] Bulletin 97, Florida Agricultural Experiment Station pp. 68–70, figs. 12, 14, 16, 18, 19.

[2] According to the latest statistics available (Ninth Biennial Report of Commissioner of Agriculture, State of Florida) there were more than five times as many orange trees as grapefruit in Florida, 1,786,944 orange trees being reported for 1905 as against 373,008 grapefruit trees.

TABLE XVIII.—*Comparative abundance of Aleyrodes citri and Aleyrodes nubifera in groves infested by both species.*

Grove Nos.	Tangerine.		Grapefruit.		Orange.		Grapefruit and orange.	
	Citri per leaf.	Nubifera per leaf.	Citri per leaf.	Nubifera per leaf.	Citri per leaf.	Nubifera per leaf.	Citri per leaf.	Nubifera per leaf.
1	44.2	7.5	1.6	1.4				
2					33.2	0.5		
3					4	1.2		
4					14.5	.4		
5					4.6	.2		
6			8.8	2.4				
7							11.2	1.1
8							21.	1.6
9					33	.56		
10					30	7.		
11	.9	.2	.8	3.7				
Average	22.5	3.6	3.7	2.5	19.9	.59	16.1	1.3
Per cent	86.7	13.3	59.6	40.3	97.7	2.3	92.6	7.4

Owing to the great attraction of new growth for the cloudy-winged white fly, which is discussed elsewhere, the scarcity of new citrus growth at certain seasons which causes concentration on water shoots, and other factors, this species, when it occurs by itself in a tangerine or orange grove, does not as frequently as the citrus white fly cause noticeable blackening of the foliage before the middle of June. At the end of the season the cloudy-winged white fly by itself may cause tangerine and orange trees to become as heavily blackened with sooty mold as the citrus white fly when the latter is at its greatest abundance. As has been stated, the cloudy-winged white fly is more likely to heavily infest grapefruit trees than is the citrus white fly. The cloudy-winged white fly seems to be subject to more extensive fluctuations from year to year, aside from the effects of fungus parasites, than is the citrus white fly, and frequently after infesting an orange grove for several years fails to cause enough injury to make washing of the fruit necessary or to make necessary the washing of more than one-fourth or one-third of the crop each year.

As a whole, the injury is not as extensive in groves where the cloudy-winged white fly occurs alone as in groves where the citrus white fly occurs alone. When the two species become well established, the former does comparatively little damage except to grapefruit. The authors would estimate that there are about 5 per cent of the orange and tangerine groves in the State infested by the cloudy-winged white fly that are not also infested by the citrus white fly, and that there are in addition 1 per cent of orange and tangerine groves infested by both species but in which the citrus white fly has not as yet attained injurious abundance. The average damage from the cloudy-winged white fly is estimated at about 10 to 15 per cent lower for oranges where that species alone infests the grove than where the citrus white fly is the species concerned. For injury to grapefruit the authors consider 25 per cent a fair estimate of the injury by the cloudy-winged white fly as compared with about 10 or 15 per cent by the citrus white fly. The total loss in Florida due to the cloudy-winged white fly is estimated by the authors at between $100,000 and $125,000 per annum at the present time.

DISTRIBUTION.

So far as known at the present writing the cloudy-winged white fly occurs in 12 counties in Florida. The locality list is given below:[1]

Brevard County: Mims, Sharpes, Titusville.
Dade County: Miami.
Hillsboro County: Riverview, Thonotosassa, Ybor City, Clearwater, Dunedin, Largo, Ozona, Safety Harbor, Saint Petersburg, Sutherland.
Manatee County: Bradentown, Oneco, Palmetto.
Monroe County: Key West.
Orange County: Geneva, Maitland, Ocoee, Orlando, Oviedo, Waco, Winter Park.
Palm Beach County: Palm Beach, West Palmbeach.
Polk County: Auburndale, Bartow, Lakeland, Winterhaven.
St. Lucie County: Fort Pierce.
Sumter County: Wildwood.
Volusia County: Haw Creek, Holly Hill, Port Orange, Pierson.

Outside of the State of Florida the only available records of the occurrence of the cloudy-winged white fly are those of the Bureau of Entomology in connection with specimens in the collection. Mr. A. L. Quaintance has identified as this species specimens from New Orleans (1890) and Baton Rouge, La. (1891), Pass Christian, Miss. (1889), and Raleigh, N. C. (1889). In a brief examination at Audubon Park, New Orleans, in August, 1909, the senior author was unable to find any evidence of the presence of this species, although the citrus white fly was prevalent on citrus trees, privets, and other food plants.

As stated in the footnote on page 27, the species occurring at Bakersfield, Cal., in 1907 was the cloudy-winged white-fly. Owing to the fact that the insect is, so far as known, confined to citrus as a food plant and only a limited number of these in an isolated location were infested, the thorough measures adopted by the agents of the State commissioner of horticulture met with complete success, and there is no record of this species occurring at present in this State.

Its occurrence in Cuba has already been noted, specimens having been received from Santiago de las Vegas in 1905.

The distribution of the cloudy-winged white fly in Florida, so far as now known, is shown in figure 13. The territory included in the

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[1] The authors have determined as *Aleyrodes nubifera* specimens from all of the localities listed above except the following, which are listed upon the authority of Dr. E. W. Berger: Holly Hill, Ybor City, Bartow, Clearwater, and Safety Harbor.

infested area is not generally infested, and the same precautions should be observed within this area as outside of it to avoid unnecessary spread of the pest.

FOOD PLANTS.

The cloudy-winged white fly is not known in Florida to breed upon any other food plant than citrus. It has recently been discovered infesting the rubber trees (*Ficus nitida*) growing in the greenhouses in Audubon Park, New Orleans. Extensive examinations for possible food plants have been made by the authors and by Dr. Berger, and it is reasonably certain that no important food plant will be found in Florida citrus-growing sections which will interfere with the control of this species.

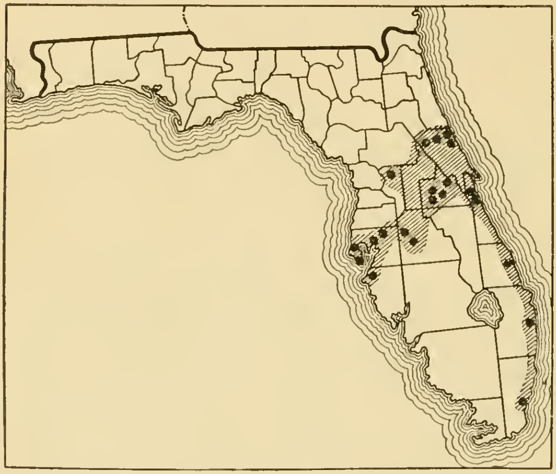


Fig. 13.—Map showing distribution of the cloudy-winged white fly (*Aleyrodes nubifera*) in Florida. (Original.)

Examinations of prickly ash (*Xanthoxylum clava-herculis*), the most common representative of the family Rutaceæ to which the citrus belongs, indicate that this species of white fly never breeds on this plant, regardless of the condition of infestation of neighboring citrus trees. Reports of blackening of the foliage of prickly ash by the white fly in sections where only the cloudy-winged white fly of the two herein treated occurs, are doubtless erroneous and probably based upon the blackening due to an aphis or to some other insect. In addition the following plants have been examined under favorable conditions to determine if subject to attack by the cloudy-winged white fly, but so far without results:

China trees and umbrella China trees, cape jessamine, privets, Japan and wild persimmons, oaks, wild cherry, guava, fig, grape, cherry laurel, blackberry, and magnolia.

SPREAD.

The dissemination of the cloudy-winged white fly is limited by the same factors which have been discussed as unfavorable to the successful establishment of the citrus white fly. Aside from these factors its chief limitation is in its lack of important food plants other than citrus. Migrations of adults are not an important factor in the spread of this white fly except between adjoining groves. Its spread throughout a newly infested grove and to adjoining groves is perhaps favored by its greater degree of attraction to new growth. It has been observed frequently in newly infested groves that it is found to be present in very small numbers over a considerable area, whereas the citrus white fly, when at a corresponding numerical status, would be expected to be more localized. Winds are doubtless concerned with the spread of the insect from local centers, but, as with the citrus white fly, they are evidently a factor of small consequence in spread to distant points.

Flying insects and birds as carriers of the crawling larvæ are necessarily of little or no consequence in the spread of the cloudy-winged white fly, as with the species previously discussed. Between groves vehicles of various kinds are of much importance in distributing this white fly, as is generally recognized. Without doubt infested citrus nursery stock has been the principal factor in the spread of the spotted-wing white fly. Nursery stock from Mims, Fla., is quite definitely known to have been the source of this white fly at Sharpes, Fla. At the present time it seems to be the most probable source of this white fly at Fort Pierce, Palm Beach, and Miami.

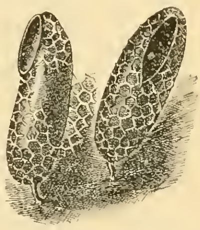


Fig. 14.—The cloudy-winged white fly: Eggs. Greatly enlarged. (Original.)

The species here considered are apparently as likely to be carried on the person from an infested grove as is the citrus white fly, the degree of infestation being equal. The same may be said of pickers' outfits. The introduction of fungus-infected leaves into groves infested only by the citrus white fly in connection with the introduction of fungus parasites has doubtless assisted in the spread of the cloudy-winged white fly, but not to the same extent that this has assisted in the spread of the former species.

LIFE HISTORY AND HABITS.

The Egg.

The egg (fig. 14) of the cloudy-winged white fly differs from that of the citrus white fly in that it is not greenish-yellow and highly polished, but bluish or grayish black and roughened by a film of wax arranged in an hexagonal pattern. To the unaided eye the eggs appear as fine particles of blackish dust scattered over the leaves (Pl. X, fig. 1). Because of their dark color they are more readily seen on the tender citrus growth by the average observer than are the eggs of the citrus white fly. When first deposited they are not blackish, but are dull white or cream colored and under the microscope the waxy coating appears tinged with red. The eggs remain pale for three days, when about 96 per cent turn black, the rest taking sometimes as long as seven or eight days to darken. Meanwhile the waxy coating has turned gray. Because of the dark color and much tougher chorion, the eyes of the embryo are not as easily seen as are those of the citrus white fly. The eggs are attached to the leaf by a pedicel arising from the proximal end similar to that of *A. citri*.

A study of the contents of Tables VIII and XIX will prove that what has been said of the duration of the egg stage, variability under identical temperature conditions, and effect of temperature in general, regarding the citrus white fly, applies almost equally well to this species.

TABLE XIX.—*Duration of egg stage of the cloudy-winged white fly.*

Record No.	Date deposited.	Eggs under observation.	First egg hatched.	Last egg hatched.	Least number days.	Largest number days.	Daily rate of hatching of eggs of the cloudy-winged white fly in percentages, with accumulative effective temperatures.									
							8 days.	° F.	9 days.	° F.	10 days.	° F.	11 days.	° F.	12 days.	° F.
1	Apr. 20, 1909.	345	May 2	May 7	12	17	0	....	0	....	0	....	0	....	4.1	422
2	June 16, 1909.	849	June 26	July 1	11	16	0	....	0	....	0	....	0.5	383	4.9	424
3	Aug. 23, 1909.	276	Sept. 3	Sept. 7	11	15	0	....	0	....	0	....	63.4	457	21.4	496
4	Sept. 4, 1907.	146	Sept. 14	Sept. 19	10	15	0	....	0	....	3.4	351	73.9	390	....	428
5	Sept. 18–21, 1908.	171	Sept. 26	Oct. 3	8	12–16	2.4	282	0	318	1.1	355	1.1	389	13.5	424
6	Sept. 21, 1908.	325	Oct. 1	Oct. 9	10	18	0	....	0	....	.3	349	1.5	385	40.7	415
7	Oct. 9–11, 1908.	898	Oct. 23	Oct. 29	14	18–20	0	....	0	....	0	....	0	....	0	....

Record No.	Daily rate of hatching of eggs of the cloudy-winged white fly in percentages, with accumulative effective temperatures.															
	13 days.	° F.	14 days.	° F.	15 days.	° F.	16 days.	° F.	17 days.	° F.	18 days.	° F.	19 days.	° F.	20 days.	° F.
1	32.8	442	48.0	470	7.7	500	5.0	531	2.4	564	0	....	0	....	....	....
2	45.5	462	44.9	496	4.0	532	.2	569	0	....	0	....	....	....	....	....
3	4.3	534	7.3	571	3.6	610	0	....	0	....	....	....	....	....	....	....
4	19.8	466	2.1	501	.8	539	0	....	0	....	0	....	....	....	....	....
5	35.1	460	43.3	493	3.5	523	0	....	0	....	0	....	0	....	....	....
6	34.3	445	15.4	477	3.2	507	2.8	538	1.2	570	0.6	601	0	....	0	....
7	0	....	.8	407	6.7	432	43.8	460	37.6	490	8.3	520	1.9	551	0.8	576

The duration of the egg stage, however, is in general slightly longer. As the bulk of the eggs hatch from 1 to 10 days later, a slightly higher number of degrees of accumulated effective temperature are necessary, and hatching is more evenly distributed though not always extending over a larger number of days.

The process of hatching, proportion of eggs that hatch, and the effect of drying of leaves in hatching do not appreciably differ from what has been stated of *A. citri;* in hatching, however, the egg membranes split only about one-third the length of the egg from the tip and on one side only, and on account of the tougher chorion do not shrivel, but retain their original form. Frequently, after the larva has escaped, the membranes spring back into their original position, thus causing the eggs to appear unhatched; as a rule, however, this does not occur, and the opening made by the escaping larva does not close. While no adults have yet been reared from larvæ hatching from infertile eggs, it has been proved that virgin females of the cloudy-winged white fly will deposit eggs and that these readily hatch and produce healthy larvæ, and the evidence in case of the citrus and greenhouse white flies leaves no doubt that adults resulting from infertile eggs will prove to be of the male sex.

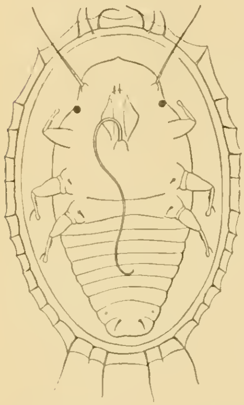


FIG. 15.—The cloudy-winged white fly: Ventral view of crawling larva of the first instar. Greatly enlarged. (Original.)

THE LARVAL AND PUPAL STAGES.

THE LARVA.

The larva of the cloudy-winged white fly does not differ in general appearance from that of the citrus white fly except that it is a trifle larger. With the aid of the microscope the first instar may be separated from that of *A. citri* by the possession of 36 instead of 30 marginal bristles. No structural differences between the second and third instars of the two species have been discovered. Following is a more detailed comparative description:

First larval instar (fig. 15).—Length, 0.29–0.32 mm.; width, 0.19–0.22 mm. Similar to the corresponding instar of *A. citri*, but differing in being proportionately broader, in possessing 18 instead of 15 pairs of marginal bristles, and in developing soon after settling a marginal irregular wax fringe eventually equaling in width the length of the marginal spines. Relative length of marginal spines as follows:

$$\frac{\text{Pair}}{\text{Spaces}}\ \frac{1}{10.5},\ \frac{2}{7.5},\ \frac{3}{10.5},\ \frac{4}{8.5},\ \frac{5}{7.0},\ \frac{6}{5.5},\ \frac{7}{6.0},\ \frac{8}{5.0},\ \frac{9}{6.0}$$

$$\frac{\text{Pair}}{\text{Spaces}}\ \frac{10}{5.0},\ \frac{11}{5.0},\ \frac{12}{5.0},\ \frac{13}{5.0},\ \frac{14}{5.0}\ \frac{15}{6.5},\ \frac{16}{15.5},\ \frac{17}{6.5},\ \frac{18}{15.5}.$$

The relative lengths and location of other spines of the body do not differ from similar spines on *A. citri*, neither do there appear differences in the structure of the antennæ, legs, vasiform orifice, or mouthparts when examined under a one-sixth inch objective. Particles of wax secretions are found in varying amounts on the ventral surface, sometimes in such abundance as to make microscopic examinations difficult.

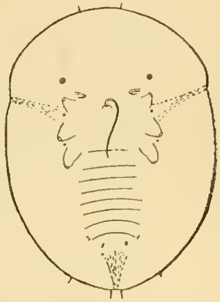


FIG. 16.—The cloudy-winged white fly: Ventral view of crawling larva of the third instar. Greatly enlarged. (Original.)

Second larval instar.—Length, 0.42–0.51 mm.; width 0.28–0.37 mm. Except in point of size no differences have been discovered between this and the corresponding instar of *A. citri.*

Third larval instar (fig. 16).—Length, 0.66–0.9 mm.; width, 0.48–0.68 mm. Except in size no differences have been discovered between this and the corresponding instar of *A. citri.*

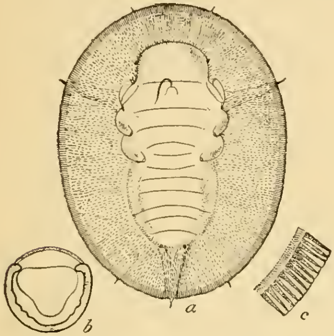


FIG. 17.—The cloudy-winged white fly. Pupa: *a*, Ventral view; *b*, enlarged vasiform orifice; *c*, enlarged margin. *a*, Greatly enlarged; *b, c*, highly magnified. (Original.)

THE PUPA.

In general appearance the pupa of the cloudy-winged white fly (fig. 17, *a, b, c*) resembles very closely that of the citrus white fly. No striking structural differences have been discovered between them. They are, however, very distinct, and one who has examined them carefully can readily separate them without the aid of a lens. The most important differences are in the larger size and thinner and flatter appearance of the pupa of the cloudy-winged white fly. The difference in outline is shown in figs. 9, *c*, and 17, *c*. Their skins are more membranous, making them more delicate and easily crumpled. Furthermore, after thickening before maturity they do not develop the bright red or orange spot on the middle of their backs, and the wing pads and body of the adult (fig. 18) are more easily seen. The pupa case (Pl. VIII, fig. 3) is much thinner, more membranous, and falls from the leaf more readily. Its walls do not remain rigid as do those of *A. citri*, but because of their more delicate structure collapse after the emergence of the adult and present the crinkled appearance shown in the illustration.

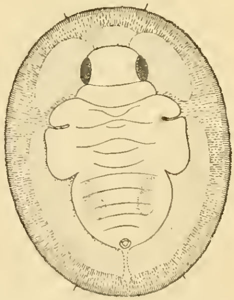


FIG. 18.—The cloudy-winged white-fly: Dorsal view of pupa, showing adult insect about to emerge. Greatly enlarged. (Original.)

DURATION OF INSTARS.

Larval instars.—By comparing the data in Tables IX and XX it will be found that the larvæ of *A. nubifera* are slower in maturing than those of *A. citri*. While this difference is not so pronounced during the warmer months of the year, the total average number of days being 25.9 and 23.1, respectively, during the cooler months it is very striking, the total average number of days then being 56.7 for *A. nubifera*, as compared with 30.4 for *A. citri*. In other respects the statements made on the duration of the larval instars for *A. citri* apply to *A. nubifera*.

TABLE XX.—*Duration of larval instars of cloudy-winged white fly.*

Specimen No.	Period of growth.	Number of days in— Instar 1.	Instar 2.	Instar 3.	Sum of effective temperature.	Specimen No.	Period of growth.	Number of days in— Instar 1.	Instar 2.	Instar 3.	Sum of effective temperature.
1	June 26–July 19...	9	6	8	938	33	Sept. 30–Nov. 20..	8	15	28	1,322
2	June 27–July 20...	6	6	11	942	34	Sept. 30–Nov. 23..	11	12	31	1,401
3	June 27–July 21...	8	6	10	979	35	Sept. 30–Dec. 20..	11	14	46	1,831
4	June 27–July 26...	9	7	13	1,179	36	Sept. 30–Dec. 3...	8	19	37	1,670
5	June 27–July 19...	9	7	6	902	37	Sept. 30–Nov. 23..	8	14	32	1,401
6	June 27–July 21...	8	8	8	979	38	Sept. 30–Dec. 3...	11	12	42	1,670
7	June 27–July 17...	7	6	7	820	39	Sept. 30–Nov. 27..	9	9	40	1,513
8	June 27–July 19...	5	7	10	902	40	......do...........	8	14	36	1,513
9	June 27–July 20...	7	6	10	942	41	Sept. 30–Dec. 3...	8	14	42	1,670
10	.....do............	7	6	10	942	42	Sept. 30–Nov. 23..	9	11	34	1,513
11	June 27–July 21...	7	6	11	979	43	Sept. 30–Dec. 10..	8	15	48	1,831
12	June 27–July 19...	7	6	9	902	44	Sept. 30–Dec. 3...	8	14	42	1,670
13	June 28–July 27...	14	8	7	1,179	45	Oct. 2–Dec. 7.....	10	9	47	1,704
14	June 28–July 29...	7	6	18	1,260	46	Oct. 2–Nov. 10....	7	9	21	1,060
15	June 28–July 24...	11	8	7	1,056	47	Oct. 2–Nov. 30....	8	23	26	1,524
16	June 28–July —...	9	21	......	....	48	Oct. 2–Nov. 19....	9	10	27	1,235
17	June 28–July 19...	6	6	9	861	49	.....do............	7	12	27	1,235
18	June 28–July 24...	7	9	10	1,056	50	Oct. 2–Nov. 23....	8	9	33	1,332
19	June 29–July 29...	6	15	9	1,222	51	Oct. 2–Nov. 19....	7	11	28	1,235
20	June 29–July 24...	7	7	11	1,018	52	Oct. 3–Nov. 27....	11	18	27	1,414
21	June 29–July 29...	8	8	14	1,222	53	Oct. 3–Dec. 3.....	10	17	35	1,561
22	June 30–July 30...	8	8	14	1,229	54	Oct. 3–Dec. 7.....	10	16	40	1,662
23	June 30–July 29...	12	7	10	1,188	55	Oct. 3–Dec. 2.....	10	23	28	1,536
24	Sept. 30–Nov. 1...	5	10	18	912	56	Oct. 3–Dec. 1.....	10	15	35	1,510
25	Sept. 30–Nov. 20..	8	16	28	1,322	57	Oct. 3–Dec. 3.....	11	20	33	1,561
26	Sept. 30–Nov. 30..	12	12	38	1,593	58	.....do............	11	20	31	1,561
27	.....do............	14	15	33	1,593	59	Oct. 5–Nov. 11....	9	11	18	1,000
28	Sept. 30–Dec. 3...	12	23	32	1,670	60	Oct. 5–Dec. 10....	66	died.	......	......
29	Sept. 30–Nov. 3...	8	10	17	963						
30	Sept. 30–Dec. 3...	8	21	35	1,670	Average	June 26–July 30...	8	7.8	10.1	1,031.7
31	Sept. 30–Nov. 30..	8	13	40	1,593		Sept. 30–Dec. 10..	9.1	14.4	33.2	1,475.6
32	Sept. 30–Dec. 3...	8	14	42	1,670						

Pupal instar.—That little difference exists between the length of the pupal stages of the two species of white fly in question is shown by a comparison of the data in Tables X and XXI. The minimum length of the pupal stage (17 days) will average but a trifle above that of *A. citri*. But the maximum length is so dependent upon the seasonal history that a direct comparison is difficult; this subject, therefore, is more profitably discussed under the caption of seasonal history. What has been said in connection with the maturing of specimens of *A. citri* passing into the pupal stage at practically the same time is equally true of the cloudy-winged white fly, *A. nubifera*.

TABLE XXI.—*Duration of pupal stage of cloudy-winged white fly.*

Specimen No.	Period of growth.	Number of days.	Sum of effective temperature.	Specimen No.	Period of growth.	Number of days.	Sum of effective temperature.
1	May 24–June 11	18	694	11	Oct. 12–Mar. 27	167	3,500
2	May 26–June 14	19	741	12	Oct. 31–Mar. 23	23	2,893
3	May 26–July 19	24	2,107	13	Nov. 1–Mar. 25	145	2,920
4	May 26			14	Nov. 14–May 29	196	5,102
5	July 16[1]–Aug. 2	17	689	15	Nov. 20–May 4	165	4,318
6	July 18–Aug. 5	18	714	16	Nov. 23–Mar. 28	125	2,981
7	Oct. 9–Oct. 26	17	466	17	Dec. 3–Mar. 27	114	2,702
8	Oct. 9–Oct. 28	18	519	18	Dec. 3–Apr. 29	147	3,662
9	Oct. 9–Oct. 30	21	562	19	Dec. 7–Mar. 28	111	2,681
10	Oct. 9–Oct. 26	17	466	20	Dec. 11–Mar. 24	104	2,476

[1] It is to be regretted that the falling of the leaf upon which Nos. 5 and 6 matured prevented gathering data on the maximum length of stage at this season of year.

GROWTH, MOLTS, LOCOMOTION, AND FEEDING HABITS.

Concerning growth, molts, locomotion, and feeding habits, there is little to add to that already stated in connection with the larvæ and pupæ of the citrus white fly. The two species are alike as regards the number of larval instars and in their crawling and sedentary habits. Their manner of feeding is similar also, with the exception that when crowded the larvæ of the cloudy-winged white fly settle freely upon the upper surfaces of shaded leaves, where they frequently reach maturity.

MORTALITY AMONG LARVÆ AND PUPÆ.

Remarks relating to mortality among the larvæ and pupæ of the citrus white fly apply with greater force to the cloudy-winged white fly. This mortality appears to result from the same causes in the latter as in the former species. Life-history work has shown that mortality due to spring droughts and dropping from leaves is practically the same for the two species, but that general mortality including "unexplained" mortality is about 3 per cent higher for *A. nubifera*. In this last respect, however, observations throughout groves where infestation is much heavier than on leaves used in the life-history work, and counts of forms on leaves infested with both species of fly, show that the comparative susceptibility to the influences producing mortality of all kinds is often at least twenty times greater for *A. nubifera*. This greater susceptibility appears to be due not only to the more delicate structure of the larvæ and pupæ and their need of more room for development because of their larger size, but also to the adults' habit of crowding the new growth with eggs far beyond its capacity for maturing the larvæ hatching therefrom.

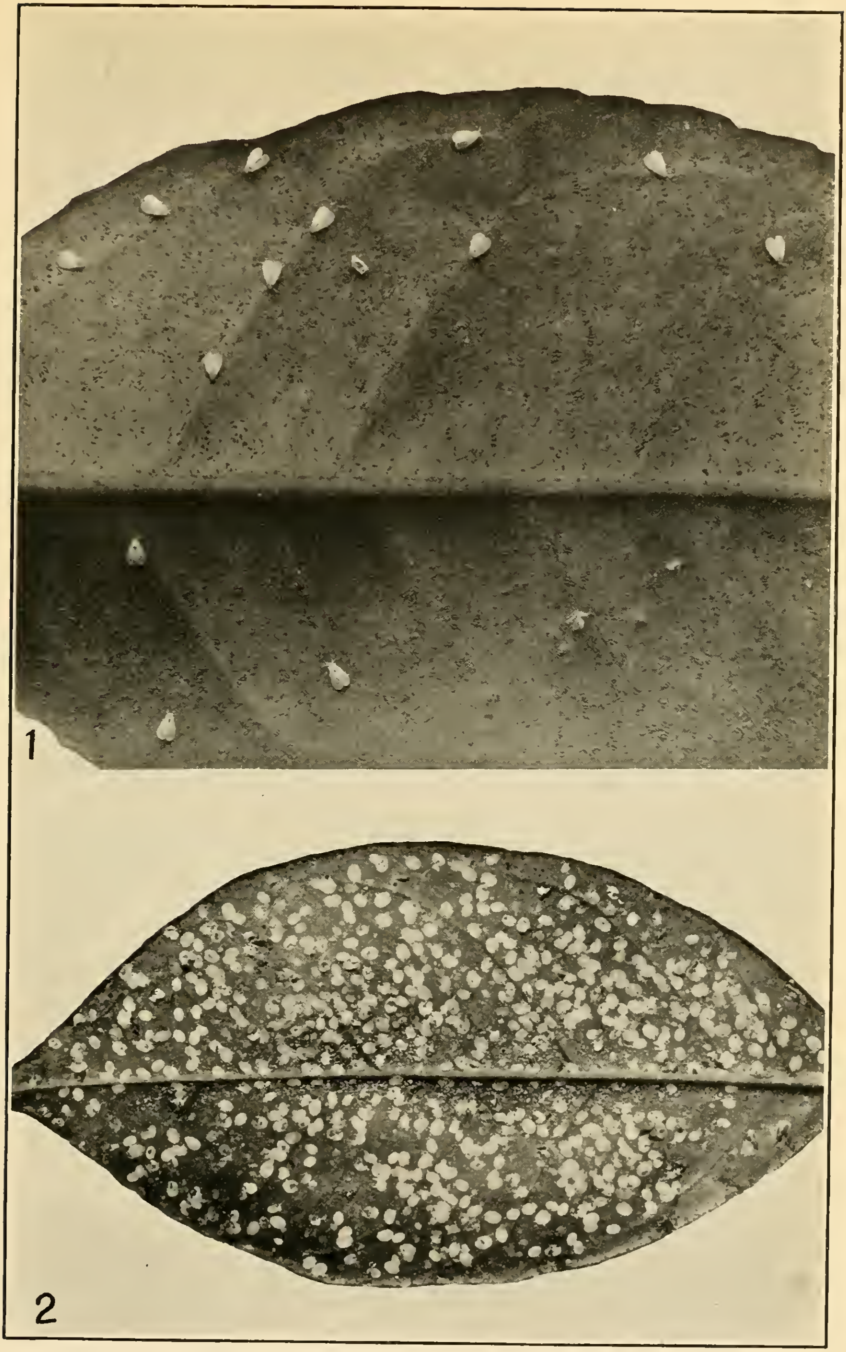
As may have been inferred already from statements upon the subject of oviposition, it is this insatiable desire of the adults for feeding and ovipositing on new growth that is a most powerful factor leading to the insect's control. While a large amount of data might here be presented illustrating the disastrous effect on the species resulting from overcrowding, the data itself would differ in no respect from that already presented under the general consideration of *A. citri*. Nevertheless, there is a great difference in the extent and practical bearing of this mortality among the immature forms of the two species.

The Adult.

The adult of the cloudy-winged white fly is similar to that of the citrus white fly, but is at once separated from it by the dark spot or shading on the outer portion of the upper wings (Pl. X, fig. 1). Except for the further fact that the female is appreciably more robust the adults of both species are structurally much alike. The antennæ of *A. nubifera* are not as highly corrugated as those of *A. citri*, but possess a terminal spine over three times as long as that of *A. citri*. The eyes of *A. nubifera* are more nearly divided in many instances than those of *A. citri*, although this is a character subject to variation in both species.

On nearly all features of life history and habits this species closely resembles the citrus white fly, and these subjects are therefore dealt with in a comparatively brief manner. The principal points wherein the cloudy-winged white fly differs from the citrus white fly may be stated summarily as follows: It is more closely restricted to citrus for its food supply as well as in oviposition; it shows a more strongly developed tendency to feed and deposit eggs on new growth; its arrangement of eggs and preferences for certain sections of leaves for ovipositing are characteristic, and it is slightly less prolific. Its apparent restriction to citrus as a food plant has been discussed under the subject of "Food plants." Its strong preference for new growth results in a situation which can be taken advantage of in the control of the pest by the pruning of water shoots.

The age at which oviposition begins and the activity in oviposition during different parts of the day are the same as for *A. citri*. The females, however, when not abundant deposit more readily along the outer margin of the under surface of the leaf and along the edge and upper surface, and not so freely along the midrib as is the case with *A. citri*. Not infrequently 90 per cent of the eggs will be deposited on the outer portion of the leaf while many are laid on the edge of the leaf itself, from which they often project perpendicularly. The depositing of eggs on the leaf margin and on the upper surface is peculiar to *A. nubifera* and is not the result of overcrowding. A count of 4,000 eggs on nine moderately infested leaves showed that 8.1 per cent of the eggs were laid on the edge of the leaf, 86.8 per cent on the lower surface, and 5.1 per cent on the upper surface. When adults are very numerous both surfaces of the leaves of tender growth and the petioles and shoot stems are thickly covered with



THE CLOUDY-WINGED AND CITRUS WHITE FLIES.

Fig. 1.—Adults of the cloudy-winged white fly, *A. nubifera*, showing cloud or spot at tip of wings, and many eggs scattered about. Fig. 2.—Larvæ and pupæ of both the citrus white fly and the cloudy-winged white fly killed by fumigation. During life they are nearly transparent and seen only with difficulty. Note eggs of *A. citri* along midrib. (Original.)

eggs. While the citrus white fly deposits her eggs without any definite arrangement, the cloudy-winged white fly, like many other species of Aleyrodes, very frequently lays hers in arcs of various sizes, and, as she is less restless while feeding, has a tendency to deposit her eggs in groups. This arrangement, together with the difference in color, makes easy the separation of the two species.

Reference to the data in Table XXII, especially when compared with that in Table XII, shows that the daily rate of oviposition for the cloudy-winged white fly is slightly less than for the citrus white fly. As much of the data in Table XXII was obtained before typical summer weather had set in, it is of more value as demonstrating the relative rate of oviposition between the two species.

TABLE XXII.—*Daily rate of oviposition of A. nubifera and A. citri compared.*

Record No.	Date eggs deposited.	Duration of egg laying.	Number of females of—		Number of eggs deposited by—		Average number eggs per female per 24 hours laid by—		Average mean temperature.
			Citri.	Nubifera.	Citri.	Nubifera.	Citri.	Nubifera.	
		Hours.							*°F.*
1	Apr. 20-21, 1909	23	50	45	454	345	9.4	8	76
2	Apr. 21-22, 1909	24	40	44	405	432	10.1	9.8	80
3	do	24	....	16	....	200	....	12.5	80
4	Apr. 22-24, 1909	48	....	36	....	662	....	9.2	78
5	Apr. 24-26, 1909	48	....	26	....	516	....	9.9	80
6	June 16-17, 1909	24	30	79	360	849	12	10.8	82
7	July 16-17, 1907	24	....	150	....	1,558	....	10.4	82

The number of eggs deposited by single females has not been definitely determined. However, as experiments have shown that adults of *A. nubifera* are capable of living as long as those of *A. citri* and have been known to maintain unimpaired an average of about 1 egg per day less than *A. citri* for at least seven days, it is safe to say that the maximum egg laying capacity is not far from 200.

When all food plants other than citrus are eliminated, the remarks covering the relation between oviposition and food supply for *A. citri* hold for *A. nubifera*, with the exception that oviposition with the latter species is far more dependent upon new growth. This last fact, as discussed under mortality of larvæ and pupæ due to overcrowding, has a most important bearing on the control of this species.

After a grove has been well infested with the cloudy-winged white fly there exists the same high percentage of females as recorded under the same topic for *A. citri*. In fact, the same proportions of sexes, and the same fluctuations and dependence of sex on parthenogenesis, are found to occur with *A. nubifera*. A typical example is the condition found in one grove infested entirely by this species. During the summer preceding winter fumigation the ratio between females and males was 71.4: 28.6 per cent. After fumigation, when over 99 per cent of the cloudy-winged white fly were killed, the females of the spring brood were so very few in number and so scattered that they deposited a very large percentage of infertile eggs, resulting in a second brood in September, 62.8 per cent of which were males. In other words, after the natural equilibrium between sexes had been disturbed by fumigation, there followed as the result of parthenogenesis a decided fluctuation between a predominance of females in one and of males in the following generations. Gradually this fluctuation diminishes until normal conditions obtain.

While less attention has been given the problems connected with the emergence of this species, observations have shown that the process and time required for emergence and the changes in color occurring thereafter are the same as for the citrus white fly, with the exception of the cloud at the tip of the wing already mentioned. Statements made concerning the conditions favorable and unfavorable for the emergence of the citrus white fly hold for this species. An examination of the extensive daily emergence records on file and summarized in Table XXIII show that even during October and early November emergence did not occur below an average daily mean temperature of 62° F. The emergence occurring later in the fall, and consequently during cooler weather, does not appear to be due to more resistance to cold, but to a difference in seasonal history.

Length of Life Cycle.

From a study of the length of the egg, larval, and pupal stages already given one can obtain an accurate knowledge of the length of the life cycle. A general summary of the data already presented in connection with these various stages is presented in Table XXIII.

TABLE XXIII.—*Length of life cycle of cloudy-winged white fly at Orlando, Fla.*

Lot.	Eggs deposited.	First fly emerged.	Last fly emerged in fall.	First fly emerged in spring.	Last fly emerged.	Least number of days for development.	Largest number of days for development.	Per cent emerging before winter.	Per cent wintering over to emerge in spring.	Least number degrees effective temperature for development.	Degrees accumulating before spring emergence.	Degrees accumulating before last fly emerged.
No. 1..	Apr. 20	June 10	....	....	....	51	334	......	......	1,890	......	......
No. 2..	June 16	Aug. 2	....	....	....	47	.....	......	......	1,849	......	......
No. 3..	Aug. 23	Oct. 14	Oct. 31	Mar. 20	May 16	52	266	64.7	35.3	1,899	5,205	7,062
No. 4..	Sept. 4	Oct. 23	Nov. 1	...do.....	Apr. 1	49	209	26.8	73.2	1,693	4,706	5,055
No. 5..	Sept. 18	Mar. 22	0	Mar. 22	May 5	185	229	0	100	4,650	4,650	5,915
No. 6..	Sept. 21	Mar. 25	0	Mar. 25	May 20	185	241	0	100	4,638	4,638	6,318
No. 7..	Oct. 2	Mar. 18	0	Mar. 18	....	167	.....	0	100	4,006	4,006	......
No. 8..	...do.....	Mar. 20	0	Mar. 20	....	169	.....	0	100	4,073	4,073	......
No. 9..	Oct. 22	Mar. 21	0	Mar. 21	Apr. 9	150	169	0	100	3,549	3,549	4,056

It will be noted that 47, the least number of days required for development, is but slightly higher than the minimum for *A. citri*, even during most favorable weather conditions. The greater average number of days required for development, shown especially by comparisons of lots 1, 3, 6, and 7 of Table XXIII and lots 4, 5, 14, and 15 of Table XV, is not the result of chance circumstances, but actually the result of slower general development under identical conditions. This fact is perhaps more forcibly brought out by the data in Table XXIV:

Table XXIV.—*Rate of development of A. citri and A. nubifera compared.*

Date.	Citri.				Nubifera.			
	Instar 1.	Instar 2.	Instar 3.	Instar 4.	Instar 1.	Instar 2.	Instar 3.	Instar 4.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
July 6	11.7	88.3	0	0	77.9	22.1	0	0
July 8	2.1	82.7	15.2	0	6.9	92.1	1.0	0
July 12	.7	10.5	89.8	0	1.4	30.8	67.8	0
July 16	0	4.8	86.1	9.0	0	8.1	91.1	0.8
July 21	0	2.9	20.6	76.7	0	5.9	62.2	31.9
July 25	0	0	6.1	93.9	0	.8	22.5	76.7
July 29	0	0	0	100.0	0	0	14.9	85.1
October 5	98.4	1.6	0	....	99.6	.4	0	0
October 11	8.0	92.0	0	0	35.8	64.2	0	0
October 15	.6	59.4	40.0	0	2.9	96.0	1.1	0
October 23	.6	4.3	90.7	0	2.8	48.8	48.3	0
October 31	0	2.4	17.2	4.4	1.8	20.9	75.4	1.8
November 11	0	.9	1.9	80.3	0	3.3	90.0	6.6
December 3	0	0	1.9	97.1	0	0	28.2	71.8
December 7	0	0	0	98.1	0	0	12.7	87.3
December 17	0	0	0	100.0	0	0	4.2	95.8
December 26	0	0	0	100.0	0	0	0	100.0

In this table is shown the corresponding progress of growth of both species on various dates after egg deposition. The data concerning development during July refer to larvæ hatching from eggs laid on June 16, 1909, and that during October, November, and December to larvæ hatching from eggs deposited on September 18, 1909. For these records, leaves on the same shoot were chosen for deposition of the eggs of each species; hence both species were subject to identical climatic and nutritive conditions.

A study of the data in Tables X and XXI will also prove that the same statements made for *A. citri* concerning the equalizing effect of winter on the length of the pupal stage for wintering-over pupæ are equally true for *A. nubifera*. The data show at a glance that eggs deposited in late October are capable of producing adults the following spring as early or even earlier than eggs deposited a month or, as sometimes occurs, five months earlier.

SEASONAL HISTORY.

Generations of the Cloudy-winged White Fly.

Aside from the fact that the adults of this species have never been seen by the authors on wing during January and early February, as have those of *A. citri*, there being therefore no winter generation corresponding to that of *A. citri*, the statements made regarding the number of annual generations of *A. citri* is true of *A. nubifera* when the additional statement is made that the height of the various emergence periods occurs usually about two or four weeks later than the corresponding periods for *A. citri*. The emergence of adults brings about the same complications in broods and generations described for *A. citri*, resulting from variation in length of life cycle, and the double-brooded character of each generation is also to be found in the life history of *A. nubifera*. Of eggs laid August 23, 1907, 1.5 per cent produced adults between October 1 and 15 and 63.2 per cent between October 16 and 31; of the remaining pupæ wintering over, 34.6 per cent emerged between March 16 and 30 and 0.7 per cent between April 1 and 15. From eggs laid September 4, 1907, 24 per cent of the adults emerged between October 16 and 31, 2.8 per cent between November 1 and 15, 71.8 per cent between March 16 and 30, and 1.4 per cent between April 1 and 15. From eggs laid September 18, 1908, 81.6 per cent of the adults emerged between March 16 and 30, 4.1 per cent between April 1 and 15, 10.2 per cent between April 16 and 30, and 4.1 per cent between May 1 and 15. From eggs deposited March 29, 1909, 44.5 per cent emerged between June 1 and 15, no further records being kept.

It might be inferred from the slower development of *A. nubifera* that it would pass through a less number of annual generations than *A. citri*. This, however, is not true, inasmuch as its slower development is offset by its seasonal history—it remaining active later in fall and early winter.

Seasonal Fluctuations in the Number of Adults or So-called "Broods."

Because the generations of the cloudy-winged white fly are of the same general double-brooded character as those of the citrus white fly, and are subject to the same unexplainable variation in the length of the life cycle, the seasonal history of *A. nubifera* is not unlike that of *A. citri* in nearly all essential features. In fact, the same three periods of general emergence of adults occur as with *A. citri*, but with the difference that the adults of each so-called "brood" reach their numerical maximum usually from two to four weeks later than the corresponding broods of *A. citri*. In figure 19 are given curves representing the abundance of adults of *A. citri* and *A. nubifera* at Orlando during 1909. As a result of this striking difference in the seasonal history of these two species, previous observations on this subject are considerably confused and should be disregarded unless one is positive of the species under consideration at the time. As with *A. citri*, no one definite statement can be made to cover the exact time when the emergence of various broods will begin. Emergence is strongly influenced by local weather conditions. While the curve in figure 19 represents the condition in one Orlando grove in 1909, it is not meant to represent the abundance of adults in any other grove in that city, much less in groves in various parts of the State. The same variation in neighboring groves in the same county and in a lesser degree in different trees in the same grove occurs with *A. nubifera*, and this statement apparently holds for infested groves in any part of the State. For example, groves at Dunedin and Sutherland, in 1909, showed a difference of at least 10 days in the beginning of the active spring emergence of adults.

The most striking difference in the seasonal history between *A. citri* and *A. nubifera* which perhaps attracts most general attention and leads to more confusion between the two species in the minds of many is the much later appearance of adults of *A. nubifera* in the fall of the year. The last large "hatching" of *A. citri* is on a rapid decline at Orlando by the middle of September at the latest, while that of *A. nubifera* at that time is only approaching its maximum and lasts well toward the 1st of November, when its decline is rapid, although adults can be found during moderately warm falls as late as the middle of December. Thus at Orlando in October 18, 1907, when adult

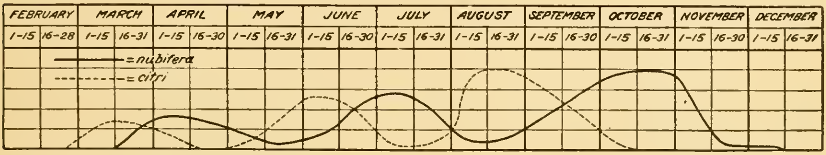


FIG. 19.—Diagram showing relative abundance of the adults of *Aleyrodes nubifera* and *A. citri*, throughout the year 1909, at Orlando, Fla. (Original.)

A. citri were practically off the wing and a large portion of the immature stages of *A. citri* had already reached the pupal stage, note was made that adults of *A. nubifera* were appearing in numbers and that pupæ of *A. nubifera* were rapidly developing eyespots on certain growths, and that new growth in places was crowded with ovipositing adults.

In consequence of the difference between the time of appearance of these fall broods, the immature stages of *A. citri* have largely reached the pupal stage and are prepared to winter over by the last of October. At this time females of *A. nubifera* are crowding the limited new growth with large numbers of eggs, and by far the larger proportion of this species will be found in the egg and larval stages up to the middle of December, and in a few instances third-instar larvæ may be found as late as the middle of February. It will be seen, therefore, from this and the foregoing data that there is no time during the season, except for about two months before spring emergence first sets in, that all stages can not be found in the grove in varying degrees of abundance.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 93.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE SUGAR-CANE INSECTS OF HAWAII.

BY

D. L. VAN DINE,

Special Field Agent.

ISSUED JUNE 15, 1911.

WASHINGTON:
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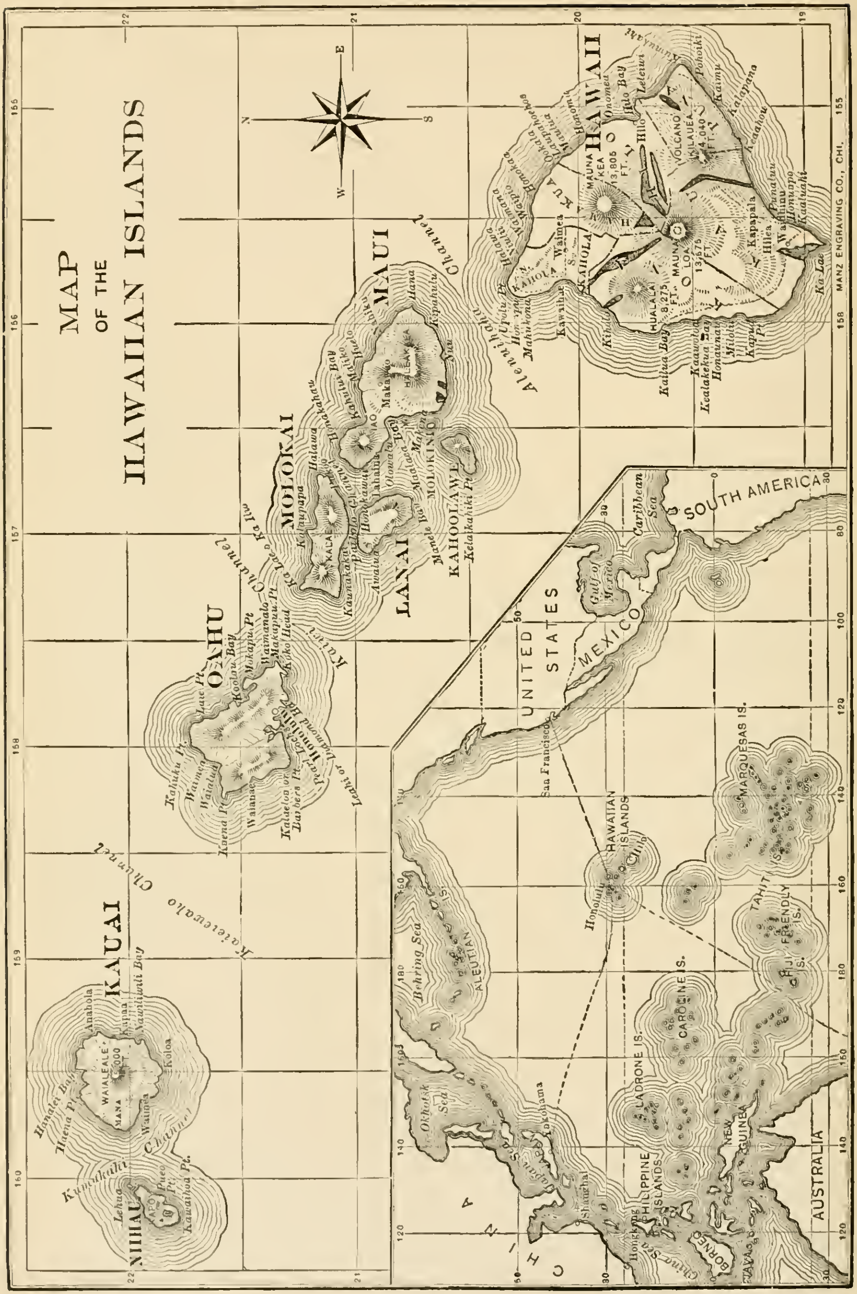
1911.

 PLATE I.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OF THE
HAWAIIAN ISLANDS
KAUAI
NIIHAU
OAHU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
MOLOKINI
HAWAII
MAUNA KEA 13,805 FT.
MAUNA LOA 13,675 FT.
HUALALAI 8,275 FT.
VOLCANO KILAUEA 4,040 FT.
Kaieiewaho Channel
Kaiwi Channel
Pailolo Channel
Alenuihaha Channel
UNITED STATES
MEXICO
SOUTH AMERICA
Gulf of Mexico
Caribbean Sea
San Francisco
HAWAIIAN ISLANDS
Honolulu
MARQUESAS IS.
TAHITI
FRIENDLY IS.
FIJI IS.
CAROLINE IS.
LADRONE IS.
PHILIPPINE ISLANDS
NEW GUINEA
BORNEO
AUSTRALIA
ALEUTIAN IS.
Behring Sea
Okhotsk Sea
Yokohama
Shanghai
Hongkong
CHINA
MANZ ENGRAVING CO., CHI.

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R. S. Clifton, *Executive Assistant.*
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D. L. Van Dine, Wilmon Newell, R. A. Cooley, A. F. Conradi, C. C. Krumbhaar, *collaborators.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 22, 1910.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "The Sugar-Cane Insects of Hawaii," by Mr. D. L. Van Dine, recently a special agent of this Bureau, and for several years entomologist of the Hawaii Agricultural Experiment Station. The manuscript includes a discussion of the present status of the sugar industry of the Hawaiian Islands and treats of the principal insect enemies to this important industry, which is rapidly assuming large proportions in our Southern States owing to the increased acreage which is being planted to cane. I would recommend its publication as Bulletin No. 93 of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The acreage devoted to sugar-cane culture in the southern United States has increased rapidly in recent years. Some of the cotton lands, abandoned because of the depredations of the cotton boll weevil, are being planted to cane. New lands are being planted to the crop in the Rio Grande valley and in the reclaimed areas in the lower Mississippi valley. It is stated that quite an area of land in process of reclamation in the State of Florida will be planted to sugar cane. It is desirable that the experience obtained through investigations of insects injurious to sugar cane in the Hawaiian Islands be placed at the disposal of the planters in our Southern States in order that the sugar industry in those States may receive practical benefit therefrom.

The Hawaiian planters are well provided with expert advice and have at hand numerous reports dealing with the subject, which latter, unfortunately, are not available for general distribution. This report is written primarily, therefore, for the information of our mainland planters.

Acknowledgment should be made of the courtesies extended to the writer by the members of the entomological staff of the Hawaiian Sugar Planters' Association Experiment Station during his return visit to the Hawaiian Islands in March and April, 1909.

D. L. Van Dine.

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THE SUGAR-CANE INSECTS OF HAWAII.

LOCATION AND CLIMATE OF THE HAWAIIAN ISLANDS.

The mid-Pacific Territory of Hawaii (see Plate I) is situated 2,100 miles to the southwest from San Francisco, the California coast being the nearest continental area. The islands are separated by channels varying from 20 to 58 miles in width. The 8 inhabitable islands, Hawaii, Maui, Oahu, Kauai, Molokai, Lanai, Kahoolawe, and Niihau, lie between 18° 54′ and 22° 15′ north latitude; that is, the northern limit of the islands is just within the Tropics. The climate of the entire group is, however, only subtropical, due largely to the prevailing northeasterly trade winds, the cool ocean currents from the north, and the relatively low humidity. The temperature varies according to the altitude and the location of the land as regards the higher mountains. The formation of the islands is of recent volcanic nature, with the exception of the low-lying coastal plains, which are of coral origin.

The annual maximum temperature ranges from 88° to 90° F., while the annual minimum temperature recorded ranges from 52° to 58° F. A temperature of 29° F. has been recorded at an altitude of 6,685 feet, and freezing temperatures are of frequent occurrence at these high altitudes. The rainfall varies in amount with the locality. Places within a few miles of each other are known to differ more than 100 inches in average annual rainfall. The sides of the islands exposed to the northeast trade winds have abundant rains, while the opposite sides have little and some localities hardly any.

The soils of the islands are exceedingly fertile and when properly cultivated yield abundant crops.

THE SUGAR INDUSTRY IN HAWAII.

The production of sugar is the leading industry in the Hawaiian Islands. Sugar cane is grown on four of the islands. The island of Hawaii has the largest acreage devoted to cane, Oahu, Maui, and Kauai coming next in importance in the order named. There are more than 200,000 acres planted to cane in the islands. In 1908 521,000 tons of raw sugar were produced, having a value of more than $40,000,000. The average yield of sugar per acre is 4½ tons.

The plant crop is taken off 20 to 22 months from the time of planting, and the first ratoon or stubble is harvested 18 to 20 months later. The second ratoon usually goes 18 months again before it is ground. Sometimes a "short ratoon" crop is made, in which case the cane runs about 14 months. The time given for growth depends on the maturity of the cane, which in turn is governed by the location and altitude of the land. To some extent also the time of harvest is governed by the labor supply, factory conveniences for taking off and grinding the crop, and the need of land for planting.

The sugar industry in Hawaii was placed on a basis to insure its becoming the leading industry by the reciprocity treaty of 1876 between the United States and the Hawaiian Government, the latter at that time being an independent monarchy. The effect of this treaty in removing the duty on raw sugar exported to the United States was to increase American influence in the islands and to strengthen the commercial relations between the two countries. A second great factor in the development of the sugar industry was the annexation of the islands as a Territory of the United States by an act of Congress passed July 7, 1898, by mutual agreement between the two countries, Hawaii at that time having overthrown the monarchy and become a republic. Annexation insured a free and protected market to the sugar output of the islands and gave confidence for the investment of capital. This is of prime importance, as the production of sugar in the islands is on a corporation basis and any disturbance in the market is felt at once by every plantation in the Territory.

Fundamental factors that have attended the development of the sugar industry are the equable climate of the islands, the natural productiveness of the soil, the resources of water for irrigation purposes, and the immunity from the more serious depredations by insects and diseases that retard the development of agricultural resources in less fortunate parts of the world. Further, there is to be found in Hawaii a class of progressive business men who have developed immense irrigation schemes, made use of the most modern agricultural and factory machinery, inaugurated advanced methods of cultivation, fertilization, and irrigation, and united their interests in a cooperative association.

This organization, the Hawaiian Sugar Planters' Association, has, since April, 1895, maintained a private experiment station, where important researches have been made and valuable results obtained. The work has applied to varieties and seedlings, propagation, cultivation, irrigation, the use of fertilizers, and the manufacture of sugar. These investigations, together with the perfection of factory methods and field machinery, have brought the sugar industry of the islands to the high standard it holds among the sugar-producing countries of the world.

SUGAR-CANE INSECTS.

The advent of a serious pest into the Hawaiian sugar-cane fields, the sugar-cane leafhopper (*Perkinsiella saccharicida* Kirk.), between 1900 and 1902 and the widespread injury of this insect throughout the sugar-cane districts in 1903 led to the establishment of an entomological division in the Sugar Planters' Experiment Station in September, 1904. In this division detailed studies have been made of the species of insects occurring in the Hawaiian cane fields, the investigations relating particularly to the leafhopper and its natural enemies.

Koebele[a] has earlier discussed the sugar-cane insects. Up to the time of the leafhopper invasion the sugar-cane borer ([*Sphenophorus*] *Rhabdocnemis obscurus* Boisd.) was the most injurious species. The sugar-cane aphis (*Aphis sacchari* Zehntner), the sugar-cane mealy-bug (*Pseudococcus calceolariæ* Maskell), the leaf-roller (*Omiodes accepta* Butler), cutworms, and certain other pests occurred locally, but up to this time no detailed study of their injury had been made.

An insect enemy of sugar cane has exceptional advantages for development in the Hawaiian Islands. Approximately only one-half the total area is harvested at any one time. Thus the great extent of the plant gives an abundant supply of food, while the system of cropping provides a continuous supply. These conditions, together with the even climate, favor the uninterrupted breeding of any enemy of the plant. A further factor in the undue increase of the cane-feeding insects is the impetus to development arising from the absence of the special parasitic and predaceous enemies of the plant-feeding species. The absence of natural enemies is understood when it is known that the islands are isolated from all continental areas and that the economic plants are introduced forms for which the native flora has made way, carrying with it the endemic species of insects, while the insect enemies of a cultivated plant are of foreign origin, introduced into the islands with their host plant but without their natural enemies. These very facts, together with the almost total absence of secondary parasites as a group and the opportunity of eliminating them when introductions are made, furnish ideal conditions for the introduction and establishment of special parasitic insects. The greatest factor in the successful establishment of a special parasite is the absence of the secondary parasites of which it is the host. One can understand why emphasis has been placed on the use of natural enemies in the control of injurious species in Hawaii and why also greater success has been

[a] Hawaiian Planters' Monthly, vol. 15, no. 12, pp. 590–598, December, 1896; vol. 17, nos. 5 and 6, pp. 208–219 and 258–269, May and June, 1898; vol. 18, no. 12, pp. 576–578, December, 1899; vol. 19, no. 11, pp. 519–524, November, 1900.

attained in Hawaii than in continental regions where investigations of this character are under way. From the above remarks it is apparent that the entomologists of the Hawaiian Sugar Planters' Experiment Station are justified in placing emphasis on this phase of insect control. Indeed, their work has been almost entirely along this line.

THE SUGAR-CANE LEAFHOPPER.

(*Perkinsiella saccharicida* Kirk.)

DISTRIBUTION.

The Hawaiian sugar-cane leafhopper (*Perkinsiella saccharicida* Kirkaldy) was introduced into the islands some time prior to 1900 from Queensland, Australia. The species occurs throughout the sugar-cane areas both in Australia and in Hawaii and has been recorded from Java.[a]

APPEARANCE OF THE LEAFHOPPER IN HAWAIIAN CANE FIELDS.

The first appearance of the leafhopper in Hawaii is recorded by Mr. Albert Koebele in January, 1902.[b] Koebele notes the species under the heading "Leafhopper (Fulgoridæ)," the species at that time not having been described. Regarding its appearance Mr. Koebele says:

According to Mr. Clark a small homopterous insect appeared upon the sugar cane at the experimental station some twelve months since, affecting the Demerara, and Rose Bamboô plants. Its presence is easily seen by the black and dirty appearance of the leaves and more or less red midribs.

The insect lives in company with its larva in large numbers behind leaf sheaths, which it punctures to imbibe the sap of the plant. When mature it is exceedingly active in its habits, springing with suddenness from its resting place at the least disturbance. The eggs are oviposited into the midrib over a large extent, most numerous near the base, in groups of about from four to seven, and large quantities are often present in a single leaf. The surroundings of the sting become red and in advanced stages the whole of the midrib becomes more or less of this color and brownish red.

That the species caused little alarm at this time is indicated by Mr. Koebele's further statement in this same article. He says:

Should this insect become numerous on any plantation, they could be kept in check by careful and repeated stripping and burning, immediately after, of the leaves containing the eggs. I do not anticipate any serious results from the above insect, which may have been present upon the island for many years.

In May, 1902, Dr. R. C. L. Perkins under the title "Leafhoppers (Fulgoridæ)," in a report to Mr. C. F. Eckart, director of the Hawaiian

---

[a] KIRKALDY, G. W.—A note on certain widely distributed leafhoppers. <Science, vol. 26, no. 659, p. 216, 1907.

[b] KOEBELE, A.—Report of the committee on diseases of cane. <Hawaiian Planters' Monthly, vol. 21, no. 1, pp. 20–26, January, 1902.

Sugar Planters' Experiment Station, mentions the doubtful origin and identity of the species.[a] Doctor Perkins again records the insect under the heading "The leaf-hopper of the cane" in December of the same year and says: "This small insect is highly injurious to cane and its destructiveness threatens to exceed that of the cane borer beetle."[b]

In response to repeated requests made to the department the writer was detailed early in May, 1903, to make a report on the pest. On May 11, 1903, specimens were forwarded by the writer to Dr. L. O. Howard, Chief of the Bureau of Entomology, Washington, D. C. Under date of June 1, 1903, Doctor Howard replied that the species was new to science and that there was in press a description of the insect under the name *Perkinsiella saccharicida* by Mr. G. W. Kirkaldy of the British Museum.

DESCRIPTION OF THE LEAFHOPPER.

The species was described by Mr. G. W. Kirkaldy in 1903 and represents a new genus which was named after Dr. R. C. L. Perkins. The description of the genus and species is taken from Mr. Kirkaldy's article in The Entomologist, London, for July, 1903, pages 179–180, and is as follows:

Perkinsiella, gen. nov.

Closely allied to *Aræopus* Spinola, but distinguished by the first segment of the antennæ being distinctly shorter than the second; distinguished from *Dicranotropis* Fieber, to which it bears some resemblance, by the form of the frons, and by the flattened apically dilated first segment of the antennæ. Type, *P. saccharicida* Kirkaldy.

Second segment of antennal peduncle about one-half longer than the first; flagellum about one-third longer than the entire peduncle, first peduncular segment much wider at apex than basally, flattened and explanate; second segment nearly as wide at base as the apex of the first segment [in *Aræopus* it is much narrower, while the first segment is more parallel-sided]. Exterior longitudinal nervure of corium forked near the base, and its exterior branch forked near its middle; interior longitudinal nervure forked near the apex. Membrane with six nervures, the fourth (commencing inwardly) forked; the first area has an incomplete nervure reaching only to the middle. Other characters as in *Aræopus*.

P. saccharicida, sp. nov.

Long-winged form ♂ ♀.—Tegmina elongate, narrow, extending far beyond apex of abdomen, interior half of clavus and corium more or less faintly smoky, a long dark smoky stripe on middle of membrane, three or four of nervures of the latter smoky at apex.

Short-winged form, ♀.—Tegmina reaching only to base of fifth segment, costa more arched, apex more rounded, neuration similar but shortened. Tegmina hyaline, colourless; nervures pale testaceous brownish, with blackish brown non-piligerous dots (in both forms).

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[a] ECKART, C. F.—Precautions to be observed with regard to cane importations. <Report to Hawaiian Sugar Planters' Association, May 9, 1902, p. 5.

[b] PERKINS, R. C. L.—Notes on the insects injurious to cane in the Hawaiian Islands. <Hawaiian Planters' Monthly, vol. 21, no. 12, pp. 593–596, December, 1902.

♂. Pallid yellowish testaceous. Abdomen above and beneath black, apical margins and laterally more or less widely pallid. Apical half of first segment and carinate edges of second segment of antennæ, flagellum, basal half of frons (except the pustules) and a cloudy transverse band near the apical margin of the same, longitudinal stripes on femora, coxæ spotted or banded near the base, a large spot on each pleuron, anterior and intermediate tibiæ with two or three annulations, apical segment of tarsi, etc., blackish or brownish. First genital segment large, deeply acute-angularly emarginate above.

♀. Like the male, but abdomen above and beneath stramineous, irregularly speckled with brownish. Ovipositor, etc., blackish. Sheath not extending apically so far as the "scheidenpolster." Long. ♂ ♀ 4½ mill.; to apex of elytra in long-winged form, 6¼ mill.

DISPERSION OF THE LEAFHOPPER.

The spread of the insect over the cane districts of the Hawaiian Islands was apparently very rapid, although it had undoubtedly occurred in the fields unnoticed by the planters for several years. By February, 1903, the species became generally abundant throughout the cane fields of the entire Hawaiian Territory.

The main factor in the distribution of the pest is the habit of the female of depositing her eggs beneath the epidermis of the internodes of the cane stalk. It seems probable that the pest was introduced into the islands and to a great extent distributed over the cane districts in seed cane. In local distribution other factors present themselves. The leafhopper is an insect readily attracted by light at night, as its presence about lamps in the factories and homes on the plantations testifies. Passengers and steamship officers of the interisland steamers have frequently stated to the writer on inquiry that in many instances, especially at night, great numbers of the insects have come aboard in certain ports or when offshore from certain plantation districts. These adults have undoubtedly traveled in this manner from one locality to another so that an uninfested district might easily have become infested by adults flying ashore from a passing steamer previously infested while stopping at or passing by an infested locality. Railway trains have been equally active in the spread of the insect on land.

Another mode of distribution, during the general outbreak of 1903, under conditions of heavy infestation, was the migration of the pest from one locality to another during the daytime. These migrations were observed by many of the planters. The manager of one plantation in the Hamakua district of the island of Hawaii stated to the writer that in the early evening of April 26, 1903, the atmosphere was "thick with hoppers" for a distance of 2 miles and that the "hoppers" were traveling with the prevailing wind, about southwest. Similar migrations, described by the observers as "clouds," were mentioned by other managers.

LIFE HISTORY AND HABITS.

The writer spent two months in the cane fields during the outbreak and in the early part of July, 1903, presented a report to the Hawaiian Sugar Planters' Association on the occurrence and injury of the species. Later an account of these investigations was published, from which a part of the information on the leafhopper presented herewith is taken.[a]

"Leafhopper" is a popular term applied to a certain group of plant-feeding insects of the order Hemiptera. The family Fulgoridæ, to which the Hawaiian sugar-cane leafhopper belongs, is included in this group. Common characteristics of these insects are their peculiar habit of springing or jumping when disturbed; their feeding upon plants by sucking from the tissue the plant juice or sap through a beak or proboscis, a piercing organ by means of which they puncture the epidermal layer of the plant; their incomplete development (that is, the young upon hatching from the eggs resembles the adult, except that it is smaller in size, wingless, and sexually immature and by a gradual process of development acquires the characteristics of the adult); and the fact that their eggs are deposited in the same plant upon which the young and adult appear and feed.

The eggs of the sugar-cane leafhopper (Plate II, figs. 1, 2) are deposited beneath the epidermis of the cane plant in situations along the midrib of the leaves, in the internodes of the stalk, or, in the case of young unstripped cane, in the leaf sheath of the lower leaves. When deposited in the leaves, the eggs are inserted from either side, but usually from the inside, the greater number being in the larger portion of the midrib down toward the leaf sheath. The place of incision is indicated at first by a whitish spot, this being a waxy covering over the opening. The female accomplishes the process of oviposition by puncturing the leaf or stem with her ovipositor, which organ (fig. 1, b) is plainly visible on the lower side of the abdomen, attached to the body at the center behind the last pair of legs and extending backward along the median line of the abdomen, reaching nearly to the end. By the aid of this structure the female pierces the epidermis of the cane stalk and through the one opening forms a cavity or chamber to receive the eggs. The number of eggs deposited in each cavity varies, the writer finding the average to be between four and six. That a single female is responsible for many of these clusters has been verified by the writer by observation. As the growth of the cane continues and the new leaves unfold toward the top of the plant, the infested leaves naturally occupy

[a] Van Dine, D. L.—A sugar-cane leaf-hopper in Hawaii, *Perkinsiella saccharicida*. <Hawaii Agr. Exp. Sta., Honolulu, Bul. 5, pp. 29, figs. 8, 1904.

the lower position on the stalk. The leafhopper, during a heavy infestation, will continue to puncture the midribs of the leaves as rapidly as the leaves unfold. The older egg chambers of the lower leaves are distinguished from the newly formed chambers of the upper leaves by a reddish discoloration.

Under laboratory conditions the writer found that the eggs deposited in cane growing in rearing cages hatched two weeks thereafter. The period of development of the young to the adult required 34 additional days, making the life cycle 48 days in length.

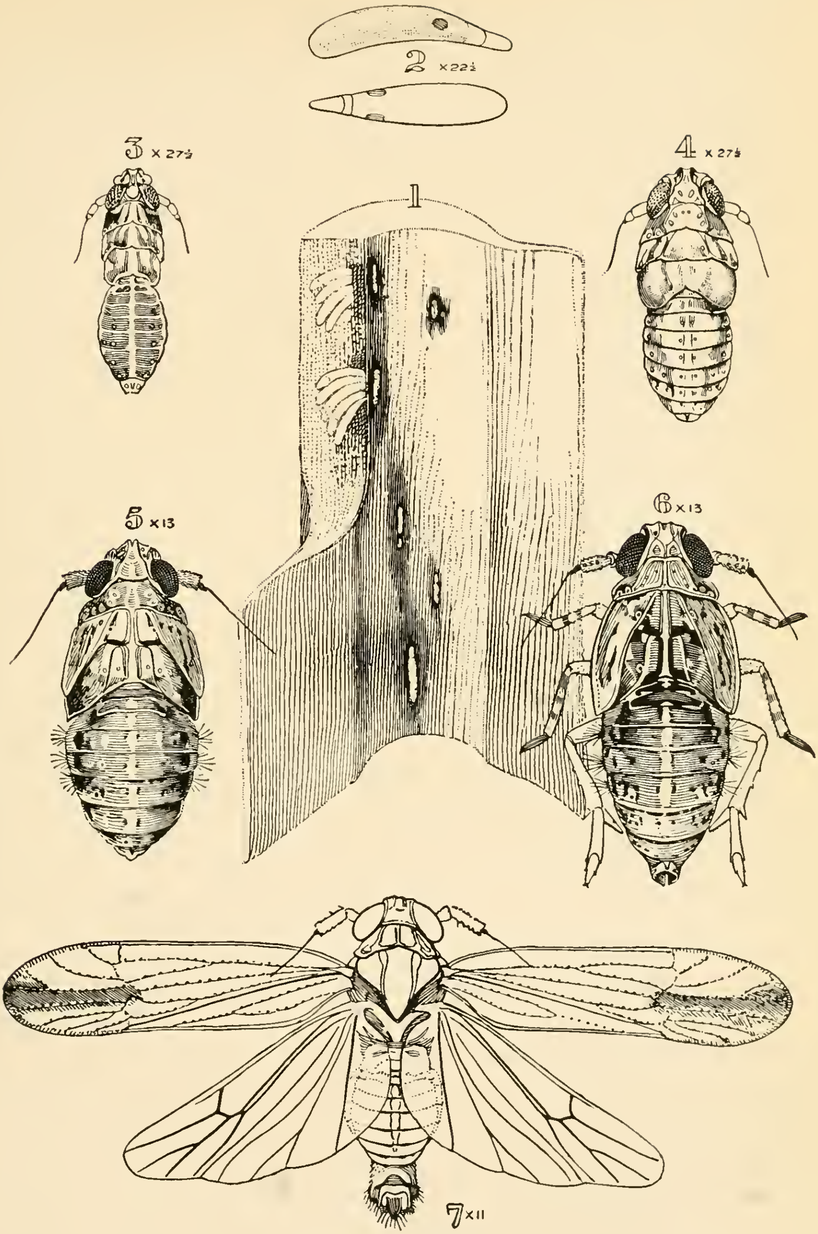
The length of the egg stage, under certain conditions, is much longer than the time given above. Mr. C. F. Eckart, director of the Hawaiian Sugar Planters' Experiment Station, records that hatching continued for 38 days from cane cuttings infested with eggs of the leafhopper.[a]

The fact that the eggs will hatch from cane cuttings during a period of at least 38 days is a very important point to bear in mind in the shipping of infested cane from one locality or country to another. Since practically the only means by which the Hawaiian leafhopper could be introduced into the cane fields of the Southern States is by the shipment of seed cane from New South Wales, Queensland, Java, or Hawaii to this country, the writer would emphasize the necessity of having all introductions made through officials engaged in sugar-cane investigations.

On issuing from the cavity, or chamber, the young, newly hatched leafhoppers appear at first small, slim, wingless nymphs, almost transparent. During the process of hatching or emerging from the egg chamber the insects slowly work their way head first to the surface of the leaf or stalk. The writer found, by timing the operation, that from 8 to 15 minutes were required, during which time the nymphs rest occasionally to unfold and dry their legs. When they become detached from their egg-cases and have emerged to the surface, they are at once active and scatter over the plant to feed, congregating at first down within the sheaths of the upper leaves. In a few hours the body becomes shortened and the outer covering, on exposure to the air, becomes darker in color. The habit of the very young in secluding themselves within the lower sheaths of the leaves renders them quite inconspicuous unless especially sought for. They may become very abundant and still remain undetected by an ordinary observer until the result of their feeding becomes apparent. (See nymphs, Plate II, figs. 3–6.)

Ordinarily when disturbed the adult leafhopper does not fly but moves off in an odd, sidewise fashion to another part of the leaf, or springs suddenly to another portion of the plant. (See adults, Plate II, fig. 7, and text fig. 1.)

[a] Eckart, C. F.—Report of the Hawaiian Sugar Planters' Association Experiment Station for 1903, Honolulu, 1904, pp. 78–79.



THE SUGAR-CANE LEAFHOPPER (PERKINSIELLA SACCHARICIDA).

Fig. 1.—Egg chambers in midrib of cane leaf, slightly enlarged. Fig. 2.—Eggs, greatly enlarged. Fig. 3.—First-stage nymph. Fig. 4.—Second-stage nymph. Fig. 5.—Third-stage nymph. Fig. 6.—Fourth-stage nymph. Fig. 7.—Adult male. (After Kirkaldy.)

SYMPTOMS OF LEAFHOPPER INJURY.

The presence of the pest on the plantations was noticed first by the appearance of a sooty black covering on the lower leaves of the cane plant. This black covering became known as smut. It is a fungous growth and finds a medium for development in the transparent, sticky fluid secreted by the leafhoppers during their feeding on the plant. This secretion is commonly known as honeydew.

The black smut or fungous growth in the honeydew secretion of the leafhopper and the red discoloration about the openings to the egg chambers in the midribs of the leaves are the most pronounced symptoms of the work of the leafhopper on cane.

In the case of heavy infestation a further result is the appearance of the plant as a whole. The leaves on which the insects have been feeding develop a yellowish appearance, and as the work of the insects progresses they become dried and resemble the fully matured lower leaves of the plant. This premature death of the leaves is due to the excessive amount of juice extracted for food. As long as the cane plant is able to produce new leaves its life is not actually in danger, the injury being a check to the growth and indicated by the small, shortened joints in the stalk. Leaves thus prematurely ripened do not drop away from the stalk at the junction of the sheath, as is the case under normal conditions, but break and hang down at the junction of the leaf to the sheath, leaving the sheath still wrapped about the stalk. Leaves in such a condition remain green for some time, attached to the sheath by the midrib, and an attempt to strip the cane results in leaving the sheaths still adhering to the stalk and wrapped about it.

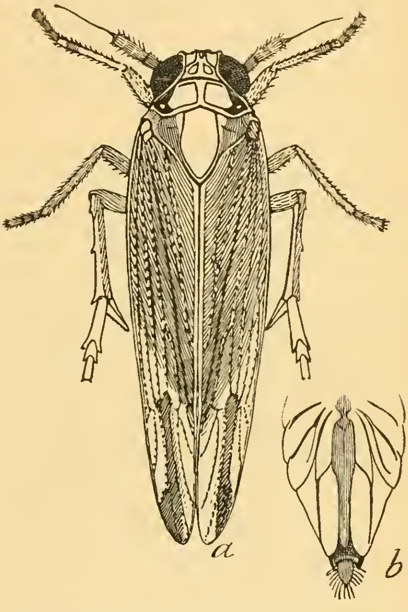


FIG. 1.—The sugar-cane leafhopper (*Perkinsiella saccharicida*): *a*, Adult female, much enlarged; *b*, ovipositor, greatly enlarged. (After Kirkaldy.)

In the last stages of an attack, when the plant is actually overcome by the pest, the young unfolded leaves at the top do not appear to have the vitality to unfold and the "bud" gradually dies out. At this stage the normal growth of the plant ceases. Many plants in such a condition will then throw out sprouts from the eyes. This is a serious circumstance, since the growth of the sprouts is supported by the stalk, and unless the cane is soon cut and ground the stalk is rendered worthless.

CHARACTER OF INJURY TO THE CANE.

The first injury to the cane plant by the leafhopper occurs through the piercing of the epidermal layer by the ovipositor (fig. 1, *b*) of the female and the later rupturing of the tissue of the plant on the hatching of the young. This injury to the tissue in itself is not serious, but the many openings in the leaves and stalks allow excessive evaporation to occur. Through these wounds various diseases may also gain entrance to the tissues of the plant, carried thereto by the leafhoppers themselves in flying from infested to noninfested plants, or by other insects, particularly certain flies, which frequent the cane plant.

The most serious injury to the plant is the drain upon its vitality caused by the young leafhoppers in feeding. The structure of the mouthparts of the leafhopper has been mentioned; that is, a piercing organ, which is inserted through the outer covering of the tissue, by means of which the insect sucks the juice or sap from within. The amount extracted in this manner by any particular individual is small and of little consequence, but the result of a myriad of individuals working constantly in this manner upon a plant is readily conceived to be serious in its consequences. The leafhopper in feeding upon the cane plant extracts therefrom an amount of juice greatly in excess of its own needs for development. This excess is excreted from the body of the insect upon the cane plant in the form of a sweet, sticky substance, known as honeydew. It is in this substance that the black smut develops.

The sooty covering or smut of the leaves referred to is a superficial fungus which bears a close resemblance to the fungi of the genus Sphæronema. The writer was informed by Dr. A. F. Woods, at that time Pathologist of the United States Department of Agriculture, that this fungus may be responsible for the dying back of canes which followed heavy leafhopper infestation. It is believed, however, that in the cane the smut affects the plant only by preventing the assimilation of the elements taken up by the plant from the soil as food, in cutting off the rays of direct sunlight, and also in closing the stomata of the leaves, preventing the entrance and escape of carbon dioxid and oxygen, respectively. In damp localities another fungus was taken in company with the smut, and was determined by Dr. Woods as a species of the genus Hypochnus. The resulting injury to the plant from the leafhopper attack is also complicated by the presence of the pineapple disease of sugar cane (*Thielaviopsis ethaceticus*) and the rind disease (*Melanconium sacchari*). The latter species, it is believed, gains entrance to the tissue of the plant through the wounds made by the leafhopper.

EXTENT OF INJURY.

It was estimated that the leafhopper caused a loss of $3,000,000 to the planters of Hawaii during 1903 and 1904.[a] In the writer's opinion this loss can not be attributed entirely to the leafhopper injury. Other species of insects and certain diseases were implicated. The leafhopper was directly responsible for the larger percentage of loss and indirectly responsible for the unusual development of certain diseases.

In speaking of the rind disease of sugar cane in Hawaii in 1907 Mr. L. Lewton-Brain says:[b]

> To bring before you the actual extent of the loss that the rind disease is now causing in your cane fields, I take the following fact obtained by Doctor Cobb from actual counts in the field. In one case the cane left on the ground represented about one ton of sugar to the acre. That is to say, that if the cane left on the field had been sound cane that portion of it left on an acre would produce about a ton of sugar. The area counted over, in this particular case, was representative of 200 acres.
>
> A few years ago, when the leaf-hopper was at the height of its glory in reducing the vigour and vitality of your canes, these figures would have been much higher. I have been assured that, at that time, there were acres and acres of cane to be seen on which the majority of the sticks had been ruined by rind disease.

Apart from the direct and indirect injury of the leafhopper (*Perkinsiella saccharicida* Kirk.), the sugar-cane borer (*Sphenophorus obscurus* Boisd.), the sugar-cane leaf-roller (*Omiodes accepta* Butler), and other minor pests contributed to the loss sustained.

The explanation of the undue increase on the part of the leafhopper is made clear when it is known that up to the time of the leafhopper invasion the sugar plantations had been particularly free from serious attacks of insect and disease pests. The planters were, therefore, unacquainted with the insect life to be found in their cane fields. They did not know the source or nature of the leafhopper attack and had at hand no general knowledge of insect warfare. The injury of the leafhopper, combined with that of the other species mentioned, and the complications arising through the development of certain diseases gave the leafhopper a favorable opportunity to develop great numbers in those localities where climatic influences or soil conditions were unfavorable to the sugar cane or where a deteriorated condition of the cane varieties prevailed.

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[a] Report Governor of Hawaii for fiscal year 1907, p. 22.

[b] LEWTON-BRAIN, L.—Rind Disease of the Sugar-Cane. <Hawaiian Sugar Planters' Exp. Sta., Div. Path., Bul. 7, p. 15, 1907.

FACTORS RESPONSIBLE FOR THE OUTBREAK OF 1903.

On those plantations where the outbreak of the leafhoppers became epidemic the writer made careful observations to determine, if possible, the conditions of season, soil, varieties, or methods of cultivation which might have contributed to the leafhopper development. Some of these conditions noted will be mentioned.

(1) The season during which the attack was most serious was not the growing season, and in some localities the weather was most unfavorable for the growth of the cane. In one instance, for example, there were during one month 24 rainy days out of the 30; and since the temperature on a rainy day is some ten degrees lower than on a bright day, and because of the absence of sunshine to carry on the work of assimilation, a less vigorous growth of cane resulted.

(2) The long duration of prevailing high winds.

(3) An impoverished condition of the soil. Certain fields in which the leafhopper was epidemic had been planted continuously to cane for over 20 years. The soil in certain parts of some fields, also, where the leafhopper infestation was greatest was found to be in poor condition because of lack of drainage.

(4) As the rainy season was followed by a long period of dry weather, without the means of irrigation, the cane lacked sufficient moisture to enable it to put forth a vigorous growth. This point was demonstrated on an unirrigated plantation in the district of Kohala, Hawaii. A portion of a field was seriously attacked by the leafhopper during the month of September, 1903, after several months of dry weather. The manager of the plantation, Mr. E. E. Olding, was able to run water into this portion of the field and irrigated the cane four times at intervals of about a week, with the result that the cane, although showing the attack in the smallness of the joints grown during that time, recovered, and when the writer visited the field during the month of November of the same year was, in appearance, not unlike healthy portions of the same field.

(5) The presence of other pests, principally the cane borer (*Sphenophorus obscurus*) and the leaf-roller (*Omiodes accepta*).

(6) The lack of thorough cultivation.

(7) The injury to cane on the makai (seaward) fields by the salt spray or the check to the cane by the cold on the mauka (mountainward) fields.

(8) The deterioration of varieties.

(9) The complications due to the presence of certain diseases.

THE LEAFHOPPER AND BEEKEEPING.

An interesting condition of affairs arising from the leafhopper attack on sugar cane is the collection of the honeydew by honey bees. The increase in the production of Hawaiian honey of recent years corresponds with the advent of the sugar-cane leafhopper into the cane fields, and the recent extensive proportions which the beekeeping business in the islands is assuming is in the vicinity of the immense areas of land given to cane culture.[a] (See fig. 2.)

The principal source of floral honey in the islands is the flowers of the algeroba (*Prosopis juliflora*). The total production of this floral honey does not exceed 600 tons. The output of honey for 1910 in the islands exceeds 1,000 tons, and the remaining 400 tons consists almost entirely of the product gathered from the honeydew of the sugar-cane leafhopper. Some 100 tons of this forms a typical

FIG. 2.—An apiary near a sugar-cane field. (From Phillips.)

honeydew honey, the remaining amount consisting of natural blends of these two types.

Honeydew honey from the sugar-cane leafhopper is noncrystallizable and usually of a very dark color. The aroma is very similar to that of molasses and the taste insipid. The product is abnormally high in ash, the amount ranging from 1 to 2 per cent, and it has a decided right-handed polarization, while the floral or algeroba honey is low in ash and has a left-handed rotation, which is

[a] VAN DINE, D. L.—The Source and Characteristics of Hawaiian Honeys. <Hawaii Agr. Exp. Sta., Bul. 17. Pt. I, pp. 1–12, 1908.

PHILLIPS, E. F.—A brief survey of Hawaiian Bee Keeping. <U. S. Dept. Agr., Bur. Ent., Bul. 75, Pt. V, Jan. 19, 1909.

characteristic of all floral honeys. The larger amount of honeydew is obtained from the insects on the young plant cane, for there the leafhoppers are more abundant. The amount of honeydew gathered depends on the maturity of the cane and the amount of rain which washes the secretion from the leaves.

CONTROL OF THE LEAFHOPPER.

Direct Measures.

Insecticides.—Those familiar with the culture of sugar cane will readily understand the difficulty of getting in and through the fields after the cane obtains any height. This difficulty renders the use of insecticides as a remedy unpractical. In Hawaii such a method becomes still more difficult because of the prevailing slope of the cane lands and the manner in which the fields in many districts are laid out for purposes of irrigation. The feeding habits of the leafhopper are such that a contact poison or irritant would be necessary for its destruction, and the activity of the leafhoppers—that is, the suddenness with which they disperse at the least disturbance—still further prevents the successful application of a contact insecticide. Then, too, the cane fields of Hawaii are subject to prevailing winds, which greatly interfere with the use of any substance in the form of a spray. In the face of the above difficulties the writer attempted the destruction of the leafhopper by direct measures and found that an application of kerosene emulsion applied in the shape of a finely divided stream with considerable force was capable of killing only a small percentage. A mixture of lime and caustic soda was also applied, with negative results. Lime, prepared by reducing fresh stone lime to a powder by the use of solutions of copper sulphate and caustic soda, was applied as a dust on cloudy days, or just after showers, and while in comparison to spraying a much larger area was covered, and the dust came in contact with a large percentage of the leafhoppers, no appreciable beneficial results were observed.

Collection by nets.—Ordinary sweeping nets supplied with short handles were placed in the hands of the laborers, and the leafhoppers were collected by having the laborers go in a body through adjoining rows and sweep the nets over the cane leaves. The insects collected were dumped from the nets into buckets of water and kerosene at the ends of the rows. While immense numbers were captured in this way, the number collected and the area covered were so small in comparison to the abundance of the leafhoppers and to the extent of the infested area that this measure was also discarded.

Cutting and burning in the infested centers.—The direct measures of control advised by the writer were confined to the cutting down and burning over of those centers in the fields where the species had become numerous. In this practice it was observed that many of the adults were able to take flight from the burning cane and escape to adjoining fields. However, many adults and all of the unhatched eggs in the leaves and the immature wingless forms were destroyed. The center of infestation was destroyed, and this gave the ratoon crop over these areas a chance under more favorable conditions.

Stripping the leaves.—For agricultural reasons it was a common practice in Hawaii to strip the lower mature leaves from the cane stalk. It was believed at first that this operation would greatly lessen the numbers of the leafhopper by the exposure of the unhatched forms in the leaves of the cane and by removing a place of shelter for the active forms. Observations made during the summer months indicated that stripping was beneficial from the standpoint of the control of the leafhopper. Later observations made during the winter months, however, when growth of the cane practically ceases, showed a very serious condition of affairs, namely, that in heavy infestation the internodes of the stalk of stripped cane contained hundreds of punctures from egg laying, while the internodes of unstripped cane were protected from such injury by the leaf-sheaths.

Burning of trash after harvesting.—The thorough burning of the trash after the cane is harvested is the most effective method practiced for the control of the insects of sugar cane. In the case of the leafhopper many of the adults no doubt take flight, but the destruction to the eggs and immature forms in the trash is enormous. The place where the greatest numbers of the leafhopper were noted in 1903 was on a plantation where the practice of "burning off" had been discontinued for several years, and the manager attributed the unusual increase of the pest to the fact that the trash had not been burned. Both for the leafhopper and the cane borer, burning off has become general once more.

Indirect Measures.

PREVENTIVE METHODS.

Selection of varieties of cane for planting.—There was noticeable in general throughout the plantations a marked difference in the power of the different varieties to resist the attack of the leafhopper. While the same variety would vary in different localities as regards growth and resistance, still the difference between any two varieties remained constant. For example, Yellow Caledonia was invariably the more resistant as compared to Rose Bamboo and Lahaina, and while the former was more seriously attacked in some localities than in others, wherever the opportunity offered itself for comparison with the latter, the Yellow Caledonia made the best showing. It is for the planter to decide whether or not the advantages of one variety over another are offset by the ravages of the leafhopper. If the loss from the leafhopper is greater than the gain in the yield between any two varieties in the absence of the leafhopper, then it is policy to select the more resistant cane.

The Yellow Caledonia (fig. 3) is a hardy cane and the plant makes a vigorous growth. These qualities, together with the showing which the variety made during the leafhopper epidemic, have made the cane a popular variety in the Hawaiian Islands. Mr. C. F. Eckart,

FIG. 3.—Yellow Caledonia sugar cane, a variety which is replacing Lahaina and Rose Bamboo in the Hawaiian Islands. Photograph taken during the leafhopper epidemic of 1903 (Original.)

Director of the Hawaiian Sugar Planters' Experiment Station, reports as follows on this cane:[a]

Probably no subject pertaining to the cultivation of cane in the Hawaiian Islands during recent years has held more interest for the planters, in various localities, than that relating to the introduction and trial of new varieties.

In the Hilo and Hamakua districts, the Lahaina first made way for the Rose Bamboo, and the latter, after a strong stand for many years, *is now being rapidly succeeded by the more vigorous Yellow Caledonia.* This cane with its upright growth and deep rooting propensities has proved a most valuable acquisition in wet and dry localities alike. Growing erect, with a natural tendency to shed its dried leaves, it becomes an admirable cane for rainy districts, where varieties that are prone to fall to the ground and remain in contact with a frequently saturated soil have shown extreme

[a] ECKART, C. F.—Varieties of cane. <Report of the Experiment Station Committee, Hawaiian Sugar Planters' Association, for the year ending September 30, 1904, Appendix IV, p. 31.

sensitiveness. The frequent stripping, required for Lahaina and Rose Bamboo in these wet places, has necessarily added to the cost of cultivation, and the ready manner in which Yellow Caledonia tends to strip itself is no small item in favor of economy. Again the manner in which it keeps down weeds, which were such a menace to its predecessors on the unirrigated plantations, is another strong point in its favor. In dry districts subject to occasional drought, it has amply demonstrated its hardihood over Rose Bamboo, which in turn is more resistant to such unfavorable climatic features than Lahaina. By sending its roots down deep into the soil it draws from a larger reserve supply of water than the older varieties, which are more shallow feeders and which soon feel the effects of a rainless period.

Dr. R. C. L. Perkins reports as follows on the relative immunity of different varieties of cane from leafhopper attack:[a]

It seems certain that some varieties of cane will stand the attack of leaf-hopper better than others. Mr. Eckart, Director of the Hawaiian Sugar Planters' Experiment Station, has furnished me with a list of new varieties of cane (see Appendix, Note II below), grown there, arranged in order, according to the relative injury that each sustained from leaf-hopper.

There may come, however, so severe an attack that no cane can resist it. Thus we have seen plants of "Yellow Caledonia" (at the extreme end of the list) which were of the strongest and most thrifty nature previous to the attack, some entirely destroyed and others very badly injured after a bad outbreak. It is, however, probable that from an attack of hopper which would entirely destroy a field of "Rose Bamboo," for instance, a field of "Yellow Caledonia" might recover.

The following is the note to which Doctor Perkins refers above:

The following list of new varieties (i. e., varieties other than the old standard ones of these islands) of cane at the Hawaiian Planters' Experiment Station has been drawn up for me by Mr. C. F. Eckart, the Director. They are arranged in order, according to the amount of damage sustained from leaf-hopper attack, Queensland 4 suffering most and Yellow Caledonia least:

(1) Queensland 4
(2) Queensland 1
(3) Queensland 8A.
(4) Louisiana Purple
(5) Demerara 95
(6) Gee Gow
(7) Cavengerie
(8) Demerara 74
(9) Yellow Bamboo
(10) Tiboo Merd
(11) Louisiana Striped
(12) Striped Singapore
(13) Big Ribbon
(14) Queensland 7
(15) Demerara 117
(16) White Bamboo
(17) Yellow Caledonia.

Cultural methods on the plantation.—The writer has already mentioned the fact that the epidemic of 1903 began during the winter months, in a wet season, and at a time when the cane was making practically no growth. The centers from which the infestation spread over the cane fields were invariably unfavorable locations for growth. It has been noted in this report that all varieties suffered in these unfavorable locations but that certain varieties made a better showing. The extension of the acreage of one variety in particular,

[a] Perkins, R. C. L.—The leaf-hopper of the sugar-cane. <Bd. of Agr. and Forestry, Hawaii, Div. Ent., Bul. 1, p. 13, 1903.

Yellow Caledonia, will be a leading factor in preventing another epidemic. One other point was brought home to the Hawaiian planters as a result of the leafhopper epidemic, and that was the importance of intensive cultivation. The grass and weeds must be kept down by cultivation, the low places drained, and the impoverished lands fertilized. Those plantations which were in a high state of cultivation suffered less from the leafhopper attack, and the estates provided with the means of irrigation, in addition, suffered the minimum loss. There is a direct relation between intensive cultivation, fertilization, and irrigation and the amount of insect injury to any crop, showing that these operations are of great value in lessening insect damage.

Diversification of crops.—Sugar cane has been the leading crop in Hawaii since the days when the islands turned from the sandal-wood trade and the whaling fleet as a source of revenue. Some of the lands have been under cultivation to cane continuously for over twenty-five years. The time is at hand when the sugar-cane planters will find it both necessary and more profitable to diversify their crop. Some lands at present require a change from sugar cane, and the lands which are still highly productive will also require such a change as the years go by. When the general practice of inter-cropping cane with other plants does come, it will have a direct bearing on the control of the sugar-cane insects, the leafhopper included. The intermediate crop may be one of value in itself or one to be plowed under for green manure. Since it is not wise to cease the practice of burning off the trash after harvesting the cane, the planters can find no cheaper source of plant food, or no way in which the requisite texture and water-holding capacity of the soil can be more easily obtained than by removing their lands from cane cultivation in regular rotation and planting some nitrogen-gathering plant to be turned under when the land is put back into cane.

Control of the rind disease of sugar cane.—As has been mentioned, leafhopper injury is aggravated by the presence of the rind disease. In a discussion of the rind disease (*Melanconium sacchari*) Dr. N. A. Cobb says:[a]

> According to my observations on thousands of cuttings dug up on some twenty-five plantations a considerable part of the cuttings in some fields fail to grow on account of this disease, which, being present in the cuttings when they are planted, develops sufficiently to prevent germination. This is a difficult thing wholly to avoid by means of inspection of the seed, as the disease is sometimes present in cane that looks sound. It may be suspected to be present in any cane that has been attacked on the stalks by leaf-hopper or by borers. Other wounds that give admission to the rind disease fungus are those made by injudicious stripping, cracks at the bottom of the cane due to the effects of storms, and what are sometimes called "growth cracks."

[a] COBB, N. A.—Fungus maladies of the sugar cane. <Hawaiian Sugar Planters' Exp. Sta., Div. Path., Bul. 5, p. 107, 1906.

Cane raised specially for seed and not stripped until wanted for planting is more likely to be free from insect punctures, and will therefore be less likely to develop rind disease after planting.

Mr. L. Lewton-Brain in a report on the rind disease thus describes the relation between the leafhopper and the disease: [a]

Under field conditions, of course, the spores gain access to the interior of the plant through natural wounds. Perhaps the most abundant wounds offered for this purpose are leafhopper punctures; even more favorable for the fungus are the tunnels of borers, leading as they do right into the heart of the sugar-containing tissue; other wounds may be made in stripping; in fact, it is a difficult matter to find a stalk of cane without a wound of some sort. The spores are produced in immense numbers on every stick of rotten cane. They are doubtless distributed partly by the wind, though the mucilaginous substance by which they are joined does not favor this; insects are certainly also important distributers of the spores, leafhoppers will get infected and deposit the spores in their punctures, ants will carry them into borer and other wounds in their search for food, flies may also serve the fungus in the same way.

The control of the rind disease of cane on the plantation will be another factor in reducing leafhopper injury. Since the leafhopper can not be exterminated and the punctures from this insect will always occur on a plantation to a greater or less degree, it becomes particularly essential for the planter to eradicate the disease.

On the control of the rind disease, Doctor Cobb has the following on pages 109 and 110 of his report referred to above:

The number of spores of this disease that exist on every plantation is past calculation, and almost inconceivable. This abundance of the spores of the disease tends of course to increase the losses. If there were no spores there could be no rind disease. Anything that can be done to reduce the number of spores will tend to reduce the amount of the disease. Something can certainly be done in this direction. Stalks dead of the disease can be destroyed, and there can be no doubt that in some cases expenditure in this direction will be well repaid. There can be no doubt that the collecting and complete destruction of the stalks on the field would be a paying operation. How to destroy them is the question. The ordinary burning off destroys only a part of these rind disease stalks, leaving the rest untouched or only partially roasted, to go on producing their millions upon millions of spores.

It is the custom on all the Hawaiian plantations to leave on the ground after harvest the sticks of cane that have been attacked by borers or are worthless for other reasons. The reason for this is easy to understand. Such material is unsuitable to the highest efficiency of the mill as an extractor of cane juice. It is also of such a nature that it may interfere with the clarification, evaporation, or crystallization.

Notwithstanding this I think it would be advisable to consider whether this material, which is really a menace to the health of future crops, cannot in some way be run through the mill and burned. This is a practice adopted in some other parts of the world. On Saturday afternoons a special run of the mill is devoted to the milling of such refuse as I have mentioned, the "bagasse" being burned. The juice is allowed to run to waste, being first sterilized by heat.

In Hawaii it is usual to attempt to burn this diseased material, but from careful observation I am certain that this attempt often ends in failure, that is to say the disease that exists in the waste-cane is only partially destroyed.

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[a] Lewton-Brain, L.—Rind disease of the sugar cane. <Hawaiian Sugar Planters' Exp. Sta., Div. Path., Bul. 7, p. 21, 1907.

It may be that it would be better, at least from the disease point of view, if the harvesting of the fields were more in the nature of a clean sweep. If the diseased sticks are not too numerous they would not seriously interfere with the working of the mill. The advantage would be that whatever diseased material was thus dealt with would be dealt with in the very best manner, that is, it would be utterly destroyed.

NATURAL ENEMIES.

Species Already Present in the Islands.

Many beneficial species of insects, already present in the islands at the time of the leafhopper invasion, adapted themselves to the leafhopper as a source of food. The following species were noted during 1903:

A ladybird beetle, *Coccinella repanda* Thunb., one of Mr. Koebele's Australian introductions, was particularly abundant in the cane fields and the larva did good work against the young leafhoppers. An enemy of this species, the hymenopterous parasite *Centistes americana* Riley, has found its way to the islands and will no doubt reduce the effectiveness of the ladybird. The writer observed also the ladybird *Platyomus lividigaster* Muls. in the cane fields. A predaceous bug, *Œchalia griseus* Burm., was found in large numbers in the infested cane fields on the Island of Hawaii. The larvæ of two lacewing flies, *Chrysopa microphya* McLachl., and *Anomalochrysa* sp., were observed feeding on the young leafhoppers, the first species being particularly abundant in some localities.

Several species of spiders were abundant in the cane fields and were active enemies of the leafhopper. The writer collected two species, *Tetragnatha mandibulata* Walck. and *Adrastidia nebulosa* Simon. On the writer's advice large numbers of the egg-nests of spiders were collected in the localities where they were abundant and placed in sections where they had not as yet become established in the cane fields.

In the forest above the Kohala district, on the island of Hawaii, the writer found a fungous disease infecting to a great extent the common leafhopper *Siphanta acuta* Walk., a species belonging to the same family as the cane leafhopper. Quantities of this fungus were distributed in the cane fields in the hope that it would infest the cane leafhopper. No striking results were obtained, though diseased cane leafhoppers were found in some of the rainy districts.

Several species of ants were very active about the leafhoppers in the cane fields, the honeydew being an attraction to them.

Doctor Perkins mentions further in his early report a predaceous bug, *Zelus peregrinus* Kirk., and describes as new a hymenopterous parasite of the leafhopper under the name *Ecthrodelphax fairchildii* Perk.[a]

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[a] Perkins, R. C. L.—Bd. Comrs. Agr. and Forestry, Hawaii, Div. Ent., Bul. 1, pp. 20–22.

More recently the species of beneficial insects which were already present in the islands when the leafhopper was introduced and which have sought the leafhopper in the cane fields have been reported upon in detail by the entomologists of the Hawaiian Sugar Planters' Experiment Station.[a]

SPECIAL INTRODUCTIONS.

In 1903 Mr. Albert Koebele, after consulting with Dr. L. O. Howard, undertook extensive observations on the American parasites of leafhoppers. In Ohio Mr. Koebele had the assistance of Mr. Otto H. Swezey. A large quantity of living material was collected both in Ohio and in California and shipped to Doctor Perkins at Honolulu. The American material consisted in the main of insects belonging to the hymenopterous family Dryinidæ. The Hawaiian parasite *Ecthrodelphax fairchildii* Perkins is also a member of this family and, at the time of Mr. Koebele's American introductions, was being reared and distributed over the islands by Doctor Perkins. These introductions are discussed by Doctor Perkins in Part I of Bulletin 1, Division of Entomology, Hawaiian Sugar Planters' Experiment Station, 1905.[b]

Mr. Koebele also collected during his American investigations representatives of the order Strepsiptera (Stylopidæ) and a single species of an egg-parasite, *Anagrus columbi* Perk., belonging to the family Mymaridæ.[c]

In the spring of 1904 Messrs. Koebele and Perkins sailed for Australia to continue the search for parasites of the leafhopper. They reached Sydney in May and because of the cold weather which prevailed they proceeded to Brisbane. The results of the work in Australia are thus summarized by Doctor Perkins:[d]

Early in June we arrived at Brisbane, and on the first cane that we saw, a few plants in the public gardens, we at once observed the presence of the cane leaf-hopper. A

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[a] Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1.

PERKINS, R. C. L.—Part I, pp. 1–60, May, 1905. (*Ecthrodelphax fairchildii.*)

PERKINS, R. C. L.—Part IV, pp. 113–157, pls. 5–7, September, 1905. (Pipunculidæ.)

TERRY, F. W.—Part V, pp. 159–181, pls. 8–10, November, 1905. (Forficulidæ, Syrphidæ and Hemerobiidæ.)

SWEZEY, O. H.—Part VII, pp. 207–238, pls. 14–16, December, 1905. (Orthoptera, Coleoptera, and Hemiptera.)

[b] PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, Part I, pp. 1–60, May, 1905. (Dryinidæ.)

[c] PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, Pt. III, pp. 86–111, pls. 1–4, August, 1905. (Stylopidæ.)

PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, Pt. VI, p. 198, November, 1905. (*Anagrus columbi.*)

[d] PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, introduction, pp. III, IV, May, 1906.

short stay of about ten days gave ample proof of the existence in Australia of a considerable variety of Hymenopterous parasites of leaf-hoppers, of Dipterous parasites of the genus *Pipunculus*, and of Stylopid parasites of the genus *Elenchus*.

At Bundaberg, about twelve hours by rail north of Brisbane, we spent another ten days in June. Here is an extensive cane district with our leaf-hopper everywhere present, but never in numbers such as we are accustomed to in these islands. In fact we never saw the hoppers nearly as numerous as they are on our least affected plantations. From eggs collected here Mr. Koebele soon bred out specimens of the Mymarid parasites he had felt so confident of finding.

From our observations on the habits of the cane leaf-hopper in these islands, it seemed probable that in tropical Australia this species would be in its greatest numbers in the colder months, so after a brief stay in Bundaberg, we proceeded north to Cairns, which place we reached at the beginning of July. This plan seemed very expedient, for by retreating gradually towards the south, as the hot season advanced, we hoped to prolong the season during which natural enemies for the cane leaf-hopper could be obtained. It appeared likely that effective work could only be done at Cairns for a month or two, since without a reasonably large supply of hoppers, it was evident that the parasites could not be found in sufficient numbers for shipment. This indeed proved to be the case, and by the end of August, leaf-hoppers and their eggs had become so scarce in the cane fields, that we came south again to Bundaberg. At Bundaberg we made a long stay on this occasion, regularly sending off consignments of parasites, until here too, owing partly to the season and partly to the harvesting of the crop, the locality became unprofitable. After a short stay in Brisbane, at the end of the year, I returned to Honolulu, while Mr. Koebele proceeded to Sydney, where his attention was largely given to collecting beneficial insects for pests other than leaf-hopper. On the return journey Mr. Koebele spent one month in Fiji, the enemies of the cane-hopper in those islands being mostly similar to those already found in Australia. A fine consignment of the Chalcid egg-parasite (*Ootetrastichus*) of leaf-hopper was most important, as it enabled us to establish that important species without any doubt.

During January and February, 1906, Mr. F. Muir continued the work in the Fiji Islands begun by Mr. Koebele in the latter part of 1904. He reported as follows concerning the Fijian sugar-cane leaf-hopper and its parasites:[a]

The Fijian sugar-cane leaf-hopper (*Perkinsiella vitiensis*) I found all over the island, but it does no damage, being kept in check by several natural enemies.

The most important of these are the egg-parasites, *Ootetrastichus*, *Anagrus* and *Paranagrus*. The first of these was introduced from Fiji into Hawaii by Mr. Koebele, and the other two appear to me the same as the Queensland species. In some fields as many as 90 % of the hopper eggs were parasitized, but in other fields it was lower. Observations extending over my six months' stay, and made at the various parts of the island visited, show that an average of 85 % of hopper eggs were destroyed by these parasites. These figures are only approximate, as I have to estimate that one Chalcid (*Ootetrastichus*) destroys four hopper eggs, which is a low estimate. This Chalcid is more numerous, and on account of destroying the whole batch of hopper eggs, is of very much higher economic value than the Mymarids.

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[a] Muir, F.—Notes on some Fijian insects. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 2, p. 3, November, 1906.

The Australian and Fijian material has been described in detailed reports with elaborate illustrations by Messrs. Perkins, Terry, and Kirkaldy.[a]

Regarding the effectiveness of the various parasites and enemies of the leafhopper, Dr. Perkins says:[b]

If we consider the effectiveness of the four egg-parasites, *Paranagrus optabilis*, *P. perforator*, *Anagrus frequens*, and *Ootetrastichus beatus*, *in areas where all are well established*, we must rate the first-named as *at present* by far the most effective. As I have previously pointed out, this species is capable by itself of destroying about 50 per cent of the cane-hopper's eggs and *Anagrus frequens* and *P. perforator*, extraordinarily numerous as they appear, where seen alone, are but as isolated examples in the crowd, where all are well established in one spot. The *Ootetrastichus* slowly but steadily increases in numbers, and on many plantations I expect that it will ultimately be the most efficient of all parasites. I do not think that it can show its full value till 1908, for each harvesting of the cane crop is necessarily a very great setback to its natural increase. *Anagrus frequens*, under which name are probably more than one species, or at least one or two distinct races of a single species, although it appears at a disadvantage, when in company with *Paranagrus optabilis*, is nevertheless a most abundant parasite. In Part VI of this Bulletin I have compared the habits of the two and need not refer to the matter here, but I may say that as many as eighty or a hundred exit holes of the *Anagrus* have been counted in a single cane-leaf, so that its great utility is unquestionable. *P. perforator*, common in Fiji, attacking eggs of hopper laid in thick stems of grass, more rarely those in cane, will probably gradually wander away from the cane-fields to attack the eggs of native hoppers, that are laid in stems and twigs, as it now chiefly attacks the cane-hopper eggs when these are laid in the stems.

Nor must it be forgotten, what valuable aid these egg-parasites receive in the control of leaf-hopper from other insects parasitic and predaceous, native or introduced. In fact, had there existed previously no restraint to the multiplication of the pest, no

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[a] Hawaiian Sugar Planters' Exp. Sta., Div. Ent.:

Perkins, R. C. L.—Bul. 1, Pt. I, pp. 1–69, May, 1905 (Dryinidæ).

Perkins, R. C. L.—Bul. 1, Pt. II, pp. 71–85, figs. 1–3, June, 1905 (Lepidoptera).

Perkins, R. C. L.—Bul. 1, Pt. III, pp. 86–111, pls. 1–4, August, 1905 (Stylopidæ).

Perkins, R. C. L.—Bul. 1, Pt. IV, pp. 113–157, pls. 5–7, September, 1905 (Pipunculidæ).

Terry, F. W.—Bul. 1, Pt. V, pp. 177–179, November, 1905 (Syrphidæ).

Perkins, R. C. L.—Bul. 1, Pt. VI, pp. 183–205, pls. 11–13, November, 1905 (Mymaridæ, Platygasteridæ).

Perkins, R. C. L.—Bul. 1, Pt. VIII, pp. 239–267, pls. 18–20, January, 1906 (Hymenoptera).

Kirkaldy, G. W.—Bul. 1, Pt. IX, pp. 269–479, pls. 21–32, February, 1906 (Leafhopper).

Perkins, R. C. L.—Bul. 1, Pt. X, pp. 481–499, pls. 33–38, March, 1906 (Hymenoptera, Diptera).

Kirkaldy, G. W.—Bul. 3, pp. 1–186, pls. 1–20, September, 1907 (Leafhoppers, Supplement).

Perkins, R. C. L.—Bul. 4, pp. 1–59, May, 1907 (Parasites of Leafhoppers).

[b] Perkins, R. C. L.—Leaf-hoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, introduction, pp. xv–xvii, May, 1906.

one who has paid the least attention to such matters can doubt that it would some time since have become impossible to raise any crop of sugar cane in the islands. The reason why these natural enemies have not alone got the upper hand of the hopper is due to various causes. In the first place, a number of the parasites such as the Dryinid *Ecthrodelphax fairchildii* and the parasitic flies of the genus *Pipunculus* are of local occurrence, and in many places cannot (for climatic or other unknown reasons) maintain their existence. This was well shown by the behavior of the first-named, which was distributed in thousands by the entomologists and the Plantation managers themselves to all the districts in the islands, but in many places did not thrive. Such, too, is the case with the predaceous black earwig (*Chelisoches morio*) which, a natural immigrant to the islands and no doubt acclimatised centuries ago, is found on comparatively few plantations. Other natural enemies are themselves periodically decimated by parasites, as is the case with the introduced green cricket (*Xiphidium varipenne*), which has its own egg-parasite (*Paraphelinus*). Other enemies like the common lady-bird (*Coccinella repanda*) introduced by Koebele years ago for other purposes, prey on young leaf-hoppers, in default of more favorite food, and this valuable predator too is itself subject to parasitic attack by the common Braconid (*Centistes*). At present the whole number of parasites and predaceous insects that attack cane leaf-hopper to such an extent as to render their services worth noting is considerable, as the following summary shows.

The most valuable are the four egg-parasites, which there is every reason to hope will become still more effective with reasonable time, one (*Ootetrastichus*) having as yet had no chance to show its full effectiveness.

The two Pipunculus flies (*Pipunculus juvator* and *terryi*) are restricted to certain localities and are native species, which have transferred their attacks from native Delphacids to the cane leaf-hopper.

The ubiquitous lady-bird (*Coccinella repanda*) is valuable as a destroyer of leaf-hopper, though originally imported by Koebele to destroy Aphis. It is hoped that other lady-birds, especially *Verania strigula*, may become established and do good work, as in Australia and Fiji, whence they were imported.

The earwig *Chelisoches morio* is a local species, but no doubt useful where it exists in numbers.

The green cricket (*Xiphidium varipenne*) is very valuable, but is most unfortunately heavily attacked at certain seasons by an egg-parasite.

The Dryinid *Ecthrodelphax fairchildii* is locally valuable. At certain seasons in suitable, but limited, localities, it destroys a considerable percentage of hoppers. Its services are underestimated because for a large part of the year it lies as a dormant larva in the cocoon, and parasitized hoppers at such a time are naturally hardly to be found.

There are many other natural enemies of more or less importance, e. g. the various predaceous Hemiptera, and the several lace-wing flies (*Chrysopinæ*).

In addition to these insect enemies, we must mention the two fungous diseases of hoppers (amounting locally and at certain seasons to epidemics) which, long previously known to kill the native leaf-hoppers, have become transferred to the introduced pest. We also found one or more fungous diseases attacking leaf-hopper eggs in Fiji and Australia in all localities. With material imported from these countries, I easily infected eggs of the cane leaf-hopper under cover, and subsequently established the fungus at large in the field. As it was most probable that parasitized and healthy hopper eggs would be affected alike by the disease, and consequently many of the egg-parasites would be destroyed, it became a subject of discussion whether we should attempt to establish the fungus or not. As, however, throughout Australia, the fungus and parasite both attacked the eggs, Mr. Koebele was of opinion that we should try and establish the same conditions here. Consequently with the first cages sent to the plantations the cane cuttings and the cane itself were well sprayed with water containing spores of the fungous disease, so that these would be certainly carried abroad by the emerging hoppers and parasites. I imagine there is no doubt as to this disease becoming established in all suitable localities.

In speaking of the necessity for the continued propagation and distribution of the introduced parasites of the leafhopper, Doctor Perkins reports as follows:[a]

Owing to the manner in which cane is cultivated in these islands, the entomologist working along the lines that have been adopted to control the leaf-hopper pest, meets with a serious obstacle such as is not encountered in dealing with insects injurious to our other vegetation. I refer here to the universal custom of burning off the trash over great acreages, after the crop has been harvested. I have been told that on the Colonial Sugar Refining Company's estates in Australia no such burning off is allowed. If this is correct, it may help to account for the insignificant numbers of our cane-leaf hopper there, as well as of several other insects of the same group, which are fortunately not known in our cane fields. As, however, burning of trash is an established fact here, it becomes necessary to see what steps can be taken to provide against this serious disadvantage. I will first show whereof this disadvantage consists. The parasitic enemies of the leaf-hopper are mostly delicate and minute creatures, not accustomed to take prolonged flights. Their wings serve well to bear them from plant to plant, but for further distribution they are dependent on air-currents. If when a field of cane is cut the wind blows towards another cane field, no doubt some or many parasites will reach it, but if otherwise, probably none will do so. In burning over a field it is quite certain that almost every parasite yet present will be destroyed, but the adult leaf-hoppers on the other hand are well able to take care of themselves. When, as an experiment, a patch of about nine acres of cane, so heavily attacked by leaf-hopper as to be useless, was set on fire all around to destroy these, it was noticed that the adult hoppers rose from the cane in a cloud and spread to other fields; so this plan for destroying them was of no value. I have in an earlier publication shown how quickly the leaf-hoppers spread to new fields of very young cane, and with what regularity they distribute themselves over the young plants. It cannot be hoped that the parasites will (except under rare and fortuitous circumstances, such as constant favorable winds) spread themselves in like manner, and in the same time. Yet it is essential that the parasites should be on the spot when the leaf-hopper *begins to lay* in order to secure proper control. If the supply of laying hoppers at the beginning of the great breeding season is very small, it means that there is not time for the attack to become serious before that season is over. It is when the hopper is least abundant, that one wants to be assured that it is being attacked by all possible enemies. When a field is already seriously injured and swarming with hoppers, not much immediate help can be given for obvious reasons. It will be easier to prevent such a condition than to find a remedy. If one could provide that in each large area of cleared land, ready for planting, there should be in the middle a small patch of some variety of cane most susceptible to the attack of leaf-hoppers, that this cane should be kept well stocked with these, and with a variety of parasites and predaceous insects, and itself be of sufficient growth to afford good shelter to all these, the condition from an entomological standpoint would be ideal. This patch of cane, being already of suitable age and growth and stocked as aforesaid, at the time the much younger cane of the rest of the field began to be infested with hoppers, would

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[a] PERKINS, R. C. L.—Leaf-hoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, introduction, pp. XVIII–XXI, May, 1906.

daily be distributing thousands of natural enemies, that should control these. Although such a plan or modification of it might be adopted on some plantations, on others (at least such as are under irrigation) it would either be difficult, or altogether impracticable. Only in the case of some fields of long ratoons would the matter be very simple, when a small area of the original ratoon growth in each field could be left uncut, and if well supplied with hoppers and their natural enemies would serve later on to stock the rest of the field. Unfortunately, owing to the fact that ratoons are (except in unusual cases) not severely attacked as compared with plant-cane, this matter becomes one of minor importance. Otherwise, in the majority of cases, owing to the clearing of large areas and the burning of trash, it is probable that new fields will have to be supplied by cages similar to those already used. Two things will be absolutely necessary: (1) that the new fields be well supplied with parasites; (2) that they be stocked immediately the hoppers enter them and commence laying. This plan, though less satisfactory than would be the other method, is nevertheless simple, and does not call for much expenditure of time, nor for skilled labor. The one thing necessary to be positively ascertained is that the spot whence the cuttings for distribution are taken is well supplied with *all* the kinds of parasites that it is desired to establish in new fields. It is now well known to us that *all* these destroyers are not yet established *in all parts* of all plantations, and therefore at present unless an entomologist previously test samples from the spot, whence distribution is to be made, it is quite likely that some of the most valuable parasites will not be taken to the new fields. If a sample be submitted to the entomologists, it can be passed as fit to supply all necessary parasites to new fields, or if not, cages of the deficient species can always be supplied from the cane in the grounds of the Experiment Station in Honolulu. As the parasites are continually spreading and increasing, such expert examination will at the most be necessary for a year or two; for it is perfectly certain that by that time all the species will be so general that it will be quite impossible to take any extensive sample of cane-leaves that bear eggs of leaf-hopper, which will not contain all. Such in fact is now the case in the cane at the Experiment Station. To sum up, the clearing of all cane from large acreages is a decided obstacle to the complete success of natural enemies of leaf-hopper, and the burning of trash aggravates the difficulty. As an offset to these conditions new fields should be supplied artificially with natural enemies, and they should be supplied as soon as any leaf-hoppers enter them. Of course future observation may prove this distribution unnecessary, but for the present it should be adopted.

RELATED SPECIES.

The Hawaiian sugar-cane leafhopper *does not occur on the mainland of the United States*. The insect is closely related to the corn leafhopper (*Dicranotropis maidis* Ashm.), common on corn in the Southern States.[a] A West Indian species of leafhopper is recorded as injurious to sugar-cane, by Westwood, in 1841, under the name *Delphax saccharivora* and is a member of the same family of insects as the Hawaiian sugar-cane and the corn leafhoppers.[b] Three further species of this same family, the Fulgoridæ, are recorded as sugar-cane pests in Java by W. van Deventer.[c]

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[a] Quaintance, A. L.—Fla. Agr. Exp. Sta., Bul. 45, 1898.

[b] Westwood, J. O.—Mag. Nat. Hist., vol. 6, p. 407, 1841.

[c] *Phenice maculosa*, *Dicranotropis vastatrix*, and *Eumetopina krügeri*. Van Deventer, Handboek ten dienste van de Suikerriet-cultuur en de Rietsuiker-Fabricage op Java, II. De Dierlijke vijanden van het Suikerriet en hunne Parasieten. Amsterdam, pp. 167–169, 1906.

THE HAWAIIAN SUGAR-CANE BORER.

([*Sphenophorus*] *Rhabdocnemis obscurus* Boisd.)

GENERAL CHARACTERISTICS.

The sugar-cane "borer" ([*Sphenophorus*] *Rhabdocnemis obscurus* Boisd.) (fig. 4), infesting the cane stalk in Hawaii is the grub of a beetle belonging to the weevil family Calandridæ. The sugar-cane stalk-borer of the southern United States is the caterpillar of a moth,

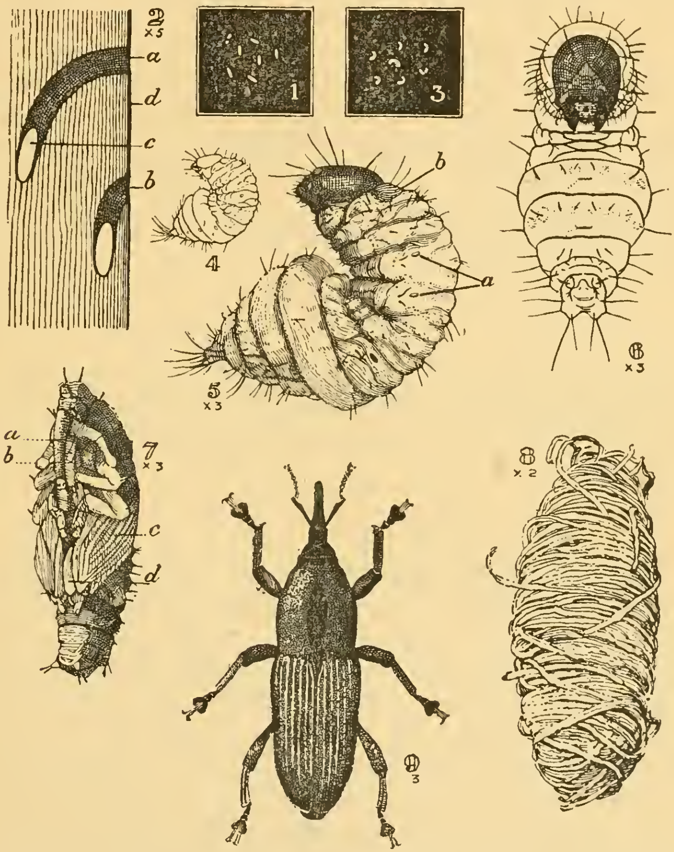

FIG. 4.—The Hawaiian sugar-cane borer ([*Sphenophorus*] *Rhabdocnemis obscurus*): *1*, Eggs, natural size. *2*, Eggs in situ, much enlarged: *a*, Section of egg passage with egg, *c*; *b*, egg placed unusually near the rind, *d*. *3*, Larvæ, just hatched and older, natural size. *4*, Full-grawn larva, natural size. *5*, Larva, side view, enlarged: *a*, Spiracles; *b*, cervical shield. *6*, Larva, front view, enlarged. *7*, Pupa, enlarged; *a*, Rostrum or beak; *b*, antenna; *c*, elytron or wing cover; *d*, folded wing. *8*, Pupal case or cocoon, enlarged. *9*, Adult, enlarged. (After Terry.)

Diatræa saccharalis Fab. Entomologically the two species are widely separated, belonging to entirely different orders of insects, but in the character of their injury to the cane stalk these two insects are quite similar—that is, they both develop within the cane stalk, and by feeding on the interior cause great destruction to the plant. Comparatively, the Hawaiian borer is more destructive and, because of the habits of the adult, a more persistent species to combat. The adult beetle of the Hawaiian borer is a stronger flyer than the adult moth of the mainland borer and therefore has a wider range over any infested territory. As the adult of the Hawaiian borer, too, can emerge from any reasonable depth when buried in the soil, this renders the question of infested seed cane a serious one in Hawaii, while on the mainland the careful covering of infested seed cane is effective in preventing the emergence of the adult moth. These points are mentioned to bring out the fact that we are discussing here a species in no way related to the cane borer of the Southern States and in many ways not subject to the same means of control.

[*Sphenophorus*] *Metamasius sericeus* Oliv. is a species injurious to cane in the West Indies, being recorded from Jamaica, Barbadoes, St. Kitts, Antigua, St. Lucia, and British Guiana.

In Porto Rico *Sphenophorus sexguttatus* Drury is recorded by Busck[a] as boring in the stalks of sugar cane.

DISTRIBUTION.

The sugar-cane borer of Hawaii is recorded also from Fiji, New Guinea, New Ireland, Tahiti, Queensland, and the Malay Archipelago and probably occurs pretty generally throughout the islands of the southern Pacific.

OCCURRENCE IN HAWAII.

This species is a pest of long standing in the islands. The insect is recorded from the Island of Oahu in 1885 by the Rev. Thomas Blackburn,[b] who found the species breeding in the stems of bananas in the mountains, and the files of the Bureau (then Division) of Entomology, record the receipt of the borer from the Hawaiian Islands, as early as 1888.[c] It is believed that the sugar-cane borer was introduced into the islands from Tahiti in the stems of the banana plant during the early communications between the Hawaiian Islands and those of the South Seas. Hon. H. P. Baldwin, of Puunene, Maui, informed the writer that to his personal knowledge the beetle was injurious to sugar cane in the vicinity of Lahaina, the ancient capital of the islands, as early as 1865.

Aside from the banana plant and sugar cane, the beetle infests the coconut palm, the sago palm, the royal palm, the wine palm, (*Caryota urens*), and the papaia (*Carica papaya*).

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[a] U. S. Dept. Agr., Bur. Ent., Bul. 22, p. 89, 1900.

[b] BLACKBURN, REV. T., AND SHARP, D.—Memoirs on the Coleoptera of the Hawaiian Islands. <Sci. Trans. Roy. Dublin Soc., 2 ser., vol. 3, pp. 119–290, pl. 1, 1885.

[c] General Notes, Bureau of Entomology, No. 4332b.

Until the recent injury by the leafhopper (*Perkinsiella saccharicida*) the sugar-cane borer was the principal insect affecting cane in the islands.

The species was determined by the Bureau of Entomology at Washington, D. C., in 1888 from specimens forwarded by the late King Kalakaua and was discussed under the title "The Sandwich-Island Sugar-cane Borer," in Insect Life, vol 1, No. 6, pages 185–189, December, 1888.

In 1896 Mr. Koebele gave the following record on the work of the borer in Hawaii: [a]

> This may be classed as the most injurious enemy of the sugar cane present on these islands. Its ravages will exceed those of all other insects combined. Its attacks on the sugar cane, however, seem confined to the more damp localities, whilst in drier places, such as Lahaina, the borer is hardly noticed. I have been informed that the Lihue Plantation has recently suffered severely from the attacks of the borer. Not only sugar cane is damaged by this insect, but many other plants are damaged by it, chiefly the bananas and cocoanuts. A grove of the latter was shown me in Hilo, in 1894, that was badly infested by the beetles. Setting fire to the dry leaves was recommended; this was done and the plants have since entirely recovered. Dying cocoanut palms were examined and in the tender heart of the palm were found great numbers of the insects, in all stages.

More recently (1907) Mr. F. W. Terry has discussed the sugar-cane borer in the Hawaiian Islands in a circular of the Hawaiian Sugar Planters' Experiment Station. [b]

LIFE HISTORY AND HABITS.

The eggs are found beneath the epidermis of the cane stalk, or more rarely in the tissue of the leaf sheath, having been placed singly in small cavities. The cavity is made by the female with her proboscis before depositing the egg.

The young grub or larva, on hatching from the egg, bores on into the stalk of the cane, completely honeycombing the interior with tunnels running lengthwise with the stalk (see fig. 5). The evidence of its work is not indicated by the outward appearance of the stalk. Many times a stalk, seemingly in a normal condition, is found on examination to be utterly destroyed. The life of the borer within the stalk of the cane is estimated to be about seven weeks by Mr. Koebele, [c] who points out the fact that the length of the larval life

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[a] KOEBELE, ALBERT.—Report on insect pests. <Hawaiian Planters' Monthly, vol. 15, no. 12, p. 590, December, 1896.

[b] TERRY, F. W.—Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Cir. 3, pp. 22, plates 2, fig. 1, December, 1907.

[c] KOEBELE, ALBERT.—Hawaiian Planters' Monthly, vol. 19, no. 11, p. 520, November, 1900.

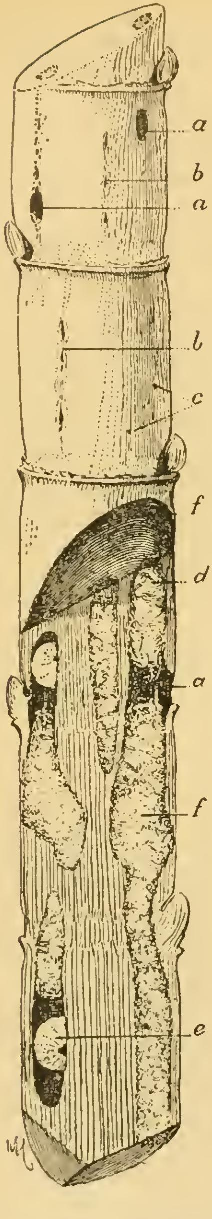

FIG. 5.—Work of the Hawaiian sugar-cane borer in sugar cane: *a, a, a*, Emergence holes made by the larva before pupation; *b, b*, "rupture" holes, apparently accidental and made by the larva while feeding; *c*, holes made by the female borer for the reception of her eggs; *d*, cocoon; *e*, larva; *f, f*, "frass" or undigested cane fiber, passed by the larva. One-half natural size. (After Terry.)

depends to a great extent upon the condition of the food plant and climatic conditions; that is, the development will be more rapid in softer cane and during the warm summer months than during the low temperatures of winter.

When ready to pupate—that is, to transform to the inactive stage preparatory to emerging from the stalk as an adult beetle—the larva (fig. 5, *a*) forms about itself a cocoon (fig. 5, *b*) from the fiber of the stalk within the tunnels it has made in feeding. The adult beetle on issuing from this cocoon bores its way through the side of the stalk to the exterior, and this opening in the lower joints of the cane is the first distinct symptom of the presence of the borer. The length of the pupal period is as variable as that of the larval, the average time for transformation and emergence being from two to three weeks.

The beetles are night flying and hide during the day down within the sheaths of the lower leaves. The softer varieties of cane are more subject to attack than the hardier varieties, and the borer is more abundant in the wet districts than in the dry. Cane which has received an abundant supply of water by irrigation suffers more from the work of the borer than unirrigated cane. The borers occur in the largest numbers in young cane and the suckers are infested to a much greater degree than the stalks. The borers always occur in the largest numbers in the vicinity of the track used to haul cane to the factory, issuing from infested stalks that have dropped from the cars and have not been collected and destroyed afterwards.

The borer is a strong flyer and spreads from field to field in this manner. It is distributed in infested seed cane and also develops from the stalks left in the field after harvest or dropped from the wagons or cars in hauling to the factory.

CONTROL MEASURES.

SELECTION OF VARIETIES FOR PLANTING.

As has been mentioned, the softer varieties are more subject to attack than the hardier ones. The Yellow Caledonia, a variety which is replacing to a great extent the common Lahaina and Rose Bamboo in Hawaii, is injured to a much less extent than other varieties. The infestation is not necessarily less in Yellow Caledonia, but the borer meets with greater resistance in its feeding and consequent development because of the firmness of the fiber.

IRRIGATION.

Excessive irrigation favors the development of the pest, since cane in a succulent condition is more easily infested by the borer and its development within the stalk is more rapid. It is plain that in fields heavily infested by the borer the minimum amount of water should be used in irrigation.

BURNING OF TRASH.

The burning of trash after harvesting the cane is the most effectual method of keeping the borer in check. In this practice not only should the fields be burned over, but all the unburned stalks left in the fields and all stalks dropped from carts and cars along the roads and tracks used in hauling the cane to the factory should be collected and burned. One plantation found it necessary to collect such stalks in piles and use crude oil on them in order to destroy them completely, and by a careful estimate of the labor and cost of material found that the money had been well invested, as was shown by the reduction in the numbers of borers in the fields the following season.

SELECTION OF NONINFESTED SEED CANE.

The Hawaiian sugar-cane borer is able to emerge to the surface from any reasonable depth when planted with seed cane. For this reason great care should be exercised in the selection of cane for planting purposes, since new areas can in this way be readily stocked with the pest. It is not practical to treat successfully cane infested with the borer, since the borer is fully protected within the stalk. Therefore, next in importance to the thorough burning of all trash after harvest is the selection of noninfested seed cane.

PICKING AND BAITING.

The most effective direct measure employed against the cane borer is the collecting of the adults during the daytime from their hiding place within the lower leaf sheaths. The supply of labor will influence the ability to use this method. The method is more feasible where the plantation is so situated that women and children can be employed for the work. Care should be exercised in this work in order that the growing leaves may not be broken down. It is obvious that a larger number of beetles will be collected when the wages are based on the numbers collected, but the results are more satisfactory, as regards breaking down the cane, when the wages of the laborers are fixed at a certain amount per day.

In the Fiji Islands a method of baiting the beetles is employed, which consists of splitting cane stalks and placing pieces about the edges of the field and within the rows at certain intervals. The method as practiced in Fiji is thus described by Mr. Koebele.[a]

> At the request of the Colonial Sugar Company we looked into the matter with a view of getting rid of the beetles the best way possible; all sorts of devices were employed and none worked better than pieces of split cane about 12 inches long, placed along the edges of the field and through the same at intervals of 12–18 feet; thus with seven little Indian girls, I collected over 16,000 beetles in some four hours, and the same little girls alone brought in the following noon over 26,000 beetles.
>
> This method was kept up, and followed on all the plantations for the next three years, or until no more of the borers could be found. Tons of the same were brought in at the Nausori mill alone, and the expenses of collecting were practically nothing compared to the cost at Lihue, where such work has to be done by the day laborers. About four cents per pint of the insects was paid to the children. The result has been highly satisfactory, for, ever since the last five years, the cane borer has not been a pest in those islands.

An important point regarding this split cane is that the females usually infest these pieces heavily with eggs and the young resulting grubs bore into the split stalks and perish as the pieces of cane become dry. In dry localities the pieces of split cane should be placed in the irrigation ditches during the day and placed out as bait in the evening, otherwise they dry out rapidly and cease to attract the beetles.

RELATED SPECIES.

The Hawaiian sugar-cane borer is represented in the United States by the "corn bill-bugs," of the genus Sphenophorus, several species of which in the adult stage attack the leaves of corn, but rarely breed in the stalk of corn as does the Hawaiian Sphenophorus in the stalk of cane. *The Hawaiian cane borer does not occur on the mainland of the United States.*

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[a] KOEBELE, ALBERT.—Hawaiian Planters' Monthly, vol. 19, no. 11, p. 522, November, 1900.

THE HAWAIIAN SUGAR-CANE LEAF-ROLLER.

(*Omiodes accepta* Butl.) (Plate III.)

EARLY HISTORY IN THE HAWAIIAN ISLANDS.

During the investigations relating to the leafhopper in 1903 the writer found the Hawaiian sugar-cane leaf-roller, the caterpillar of a native moth, doing serious damage to cane in the upper fields of plantations in the Kohala district, Island of Hawaii. The larvæ were collected also from Hilo grass (*Paspalum conjugatum*) growing wild above the cane areas. The species, primarily a grass feeder, occurs in the higher altitudes and invades the bordering fields from these locations. It is recorded by Meyrick [a] in 1899 from the islands of Hawaii, Maui, Molokai, and Kauai at elevations ranging from 1,500 to 5,000 feet. The caterpillar was described for the first time by Dr. H. G. Dyar, of the United States National Museum, from specimens collected by the writer on cane in the Kohala district.[b]

Swezey states that the leaf-roller occurs on practically all of the plantations of the islands, but is less abundant in the dry districts. Regarding its injury he says:[c]

> It is present in some fields of cane sometimes in such large numbers as to do considerable damage; in fact, cases have been reported where the young cane has been entirely stripped of leaves. Such instances are not numerous, however, and even in the worst cases would not result in entire destruction of the crop of cane as it would grow again after the caterpillars had obtained their growth, or their parasites had got them checked. It is not usually to be considered a serious pest. Possibly it is not so abundant now as it was a few years ago when reports were made of cane fields having been entirely stripped by them.
>
> At present there are a number of parasites preying upon this species and this keeps them well in check.

In this same report, page 10, the author describes the habits of the caterpillar as follows:

> On sugar cane the very young larvæ feed in the crown of the plant where the young leaves have not yet unrolled. They are thus protected between the natural rolls of the leaf; later on they roll over the margin of a leaf forming a tube for their "retreat." When nearly full grown, they are usually found in tubes towards the tip of the upper leaves. These tubes are easily observed if the ragged leaves where the larvæ have fed, are examined. The work of the smaller larvæ shows as oval or elongate dead spots on leaves which have unrolled in the growing of the cane after the young larvæ have fed upon them.
>
> When disturbed in its retreat, as by its being torn open, or violently shaken, or jarred, the larva wriggles very lively and drops to the ground for escape. This habit is

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[a] MEYRICK, E.—Fauna Hawaiiensis, vol. 1, Pt. II, p. 204, 1899.

[b] DYAR, H. G.—Note on the larva of an Hawaiian pyralid (*Omiodes accepta* Butler). <Proc. Ent. Soc. Wash., vol. 6, no. 2, p. 65, 1904.

[c] SWEZEY, OTTO H.—The sugar-cane leaf-roller, *Omiodes accepta*. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 5, p. 7, August, 1907.

probably to escape from parasites, many of which prey upon them. The retreat which it constructs is undoubtedly for the same purpose, as well as for protection from wasps and birds which prey upon it.

The caterpillars are full grown in about three weeks from hatching. They molt five times at intervals of about three to five days, and five to seven days between the fifth molt and the spinning of the cocoon and pupation. Pupation takes place within a slight cocoon of white silk in the "retreat" where the caterpillar has lived; however, the cocoon is sometimes made beneath the leaf-sheaths of cane, and in other favorable places.

CONTROL MEASURES.

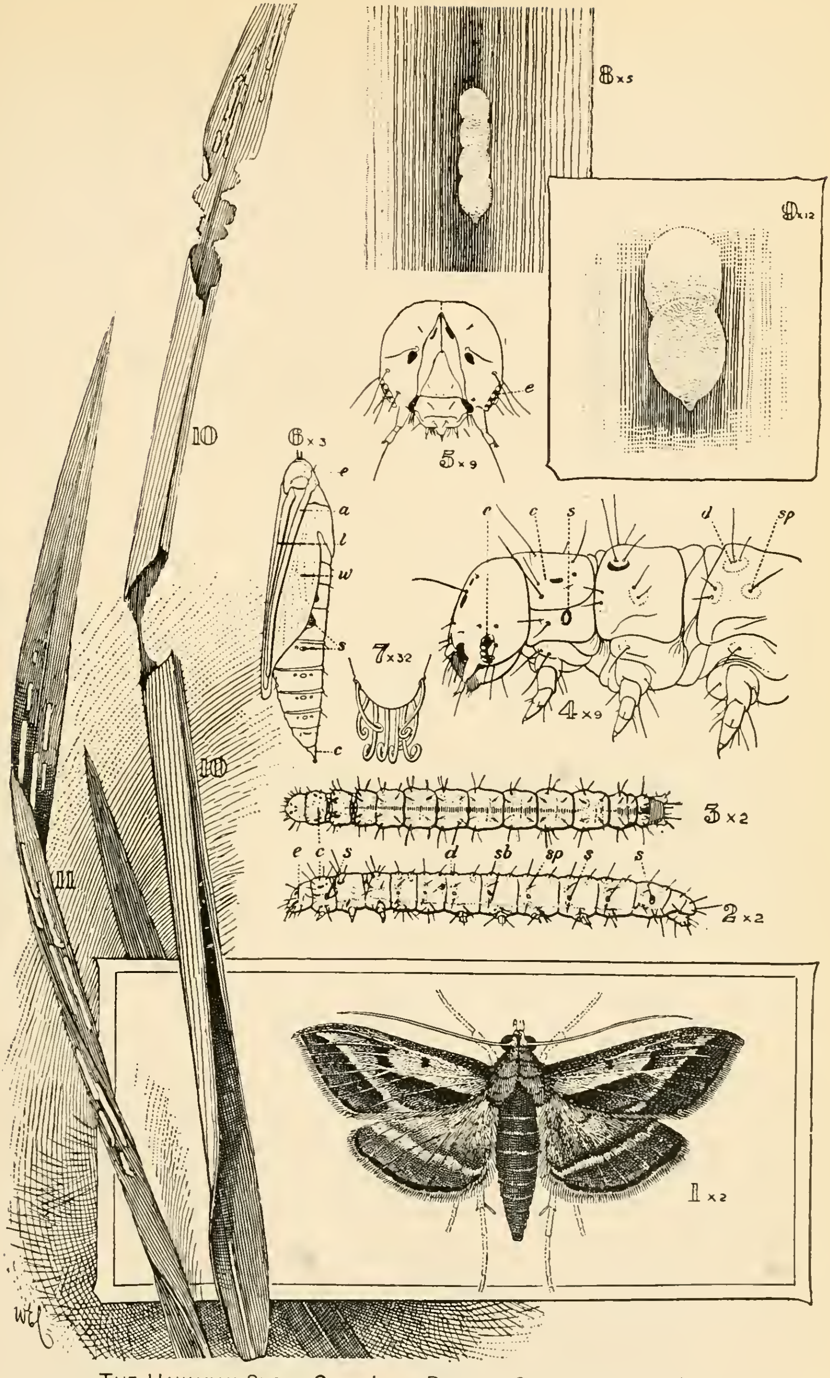
No special remedies are employed in cane fields against this pest. Swezey suggests that in fields of young cane a spray of Paris green or arsenate of lead might be used with effect, and mentions that at times laborers have been sent over the field to pinch the caterpillars in their retreat between the folded cane leaves.

PARASITES.

The species is attacked, fortunately, by several introduced parasites. Regarding the natural enemies of the species of moths belonging to the genus Omiodes, Mr. Swezey reports as follows on pages 36 and 37 in his article above referred to:

Omiodes caterpillars are attacked by a large number of species of parasites, some of which are native, and several which are the most valuable have been introduced. The most of the species are kept in check by their natural enemies, so that they do not become very numerous; in fact, several of them are very rare. Two species feed so numerously on cultivated plants that they become serious pests; *accepta* on sugar cane, and *blackburni* on palms. These two species are preyed upon very extensively by the parasites and checked considerably, but not sufficiently to keep them from doing considerable injury in certain localities and at certain seasons. Apparently the moths are more prolific in the winter months (about December to March) and the parasites are scarcer owing to their having had fewer caterpillars for them to keep breeding on during the preceding summer. Hence, when the winter broods of caterpillars appear, there may be two or three generations of them before the parasites breed up to sufficient numbers so that they produce any noticeable check on the number of the caterpillars; then in another generation or two the caterpillars may be much reduced in numbers and a large percentage of them found to be parasitized; for example, on one occasion 75 % of the cane leaf-rollers in a field at Hutchinson plantation, Hawaii, were found to be destroyed by one species of parasite; at Olaa plantation, Hawaii, in a certain field, on one occasion a much higher percentage of them than that were killed; in Honolulu, of a large number of the palm leaf-roller caterpillars collected, 90 % were parasitized.

Since there are so many species of parasites preying on the leaf-rollers which are pests, it might be asked "Why do they not become exterminated, or at least cease to be pests?" Apparently, with all of the parasites, they are still not numerous enough to overbalance the prolificness of the pest, even though they do kill such high percentages of them at times. Since so many are killed by parasites, and yet there are enough left to do considerable injury at times, one cannot help but wonder to what extent these pests might increase were there no parasites preying on them, and how many times more serious would be the damage done by them. The extreme difficulty and impracticability of treating sugar cane fields, or large palm trees, artificially, for



THE HAWAIIAN SUGAR-CANE LEAF-ROLLER (OMIODES ACCEPTA).

Fig. 1.—Adult moth. Figs. 2, 3, 4, 5.—Larvæ and details. Fig. 6.—Pupa. Fig. 7.—Apex of cremaster, showing the curled spines by which the pupa is fastened to the cocoon. Fig. 8.—Cluster of 4 eggs in groove on surface of leaf. Fig. 9.—Eggs more highly enlarged. Fig. 10.—Leaf spun together for "retreat" or hiding place of caterpillar; showing where caterpillar has eaten. Fig. 11.—Leaf, showing spots where very young caterpillar has eaten, leaving one epidermis intact, instead of eating holes through the leaf. (After Swezey.)

the destruction of these pests, makes it all the more important that there are so many valuable parasites preying upon them; and shows the value of introducing natural enemies to control a pest, for the four best parasites of these leaf-rollers are introduced species, viz., *Macrodyctium omiodivorum*, *Chalcis obscurata*, *Frontina archippivora* and *Trichogramma pretiosa*.

THE SUGAR-CANE MEALY-BUG.

(*Pseudococcus calceolariæ* Mask.) (Plate IV.)

IDENTITY.

This insect (see Pl. IV, from photographs by Mr. T. C. Barber) is identical with the sugar-cane mealy-bug common on cane in the southern parishes of Louisiana. The species is recorded by Mrs. Maria E. Fernald from Australia, Hawaii, Fiji, Jamaica, and Florida.[a] Koebele earlier records this mealy-bug on cane in Hawaii.[b]

RELATED SPECIES.

The mealy-bug of the cane belongs to a very large family of insects, Coccidæ, which are world-wide in their distribution. Two other species of this family, *Pseudococcus sacchari* Ckll. and *Aspidiotus cyanophylli* Sign., have recently been recorded from Hawaii by Mr. J. Kotinsky.[c]

Three species, namely, *Pseudococcus calceolariæ, P. sacchari*, and *Aspidiotus sacchari* Ckll., are known to attack sugar cane in the West Indies.[d]

Van Deventer records several scale insects, among them *Lecanium krugeri* Zehntn., *Aspidiotus saccharicaulis* Zehntn., *Chionaspis* spp., and a species of Pseudococcus very similar to *P. calceolariæ*, on cane in Java.[e]

In Mauritius two species of related insects, *Icerya seychellarum* Westw. and *Pulvinaria iceryi* Guér., are reported as pests of sugar cane.[f]

FOOD PLANTS.

Mrs. Fernald gives the food plants of the sugar-cane mealy-bug as *Calceolaria*, *Danthonia*, *Phormium tenax*, *Cordyline australis*, and

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[a] Fernald, Mrs. Maria E.—A Catalogue of the Coccidæ of the World. <Bul. 88, Hatch Exp. Sta., Mass. Agr. Coll., p. 98, 1903.

[b] Koebele, Albert.—Hawaiian Planters' Monthly, vol. 15, no. 12, p. 596, December, 1896; vol. 17, no. 5, p. 209, May, 1898.

[c] Kotinsky, Jacob.—Coccidæ not hitherto recorded from these islands. <Proc. Hawaiian Ent. Soc., vol. 2, no. 3, pp. 127–131, 1910.

[d] Ballou, H. A.—Review of the insect pests affecting the sugar cane. <West Indian Bul., vol. 6, no. 1, p. 41, 1905.

[e] Deventer, W. van.—Handboek ten dienste van de Suikerriet-cultuur en de Rietsuiker-Fabricage op Java. II. De Dierlijke vijanden van het Suikerriet en hunne Parasieten, Amsterdam, pp. 227–266, 1906.

[f] Fernald, Mrs. Maria E.—A Catalogue of the Coccidæ of the World. <Hatch Exp. Sta. Mass. Agr. Coll., Bul. 88, pp. 27, 133, 1903.

sugar cane. In Louisiana the mealy-bug infests, aside from sugar cane, the Johnson grass (*Sorghum halepense*) and the saccharine sorghums.

LIFE HISTORY AND HABITS.

The feeding habits of the mealy-bug are similar to those of the cane leafhopper; that is, their mouthparts are formed for piercing the epidermis of the plant and sucking the plant sap from the inner tissues. The distinction in the feeding habit is that the leafhopper is active throughout its entire life cycle, and jumps or flies from plant to plant, while the mealy-bug when partly grown remains practically stationary and feeds upon but one portion of the same plant.

Where the cane mealy-bugs occur in Hawaii, they can be found about the lower leaves of the cane, congregating for the most part behind the older leaves near the ground. The species may be recognized by the white mealylike covering of the adult female, to which the common name applies. The insects occur in a mass and when abundant are readily observable by the white covering of the females. This white covering serves as a receptacle for the eggs, which, upon close examination, may be observed embedded therein.

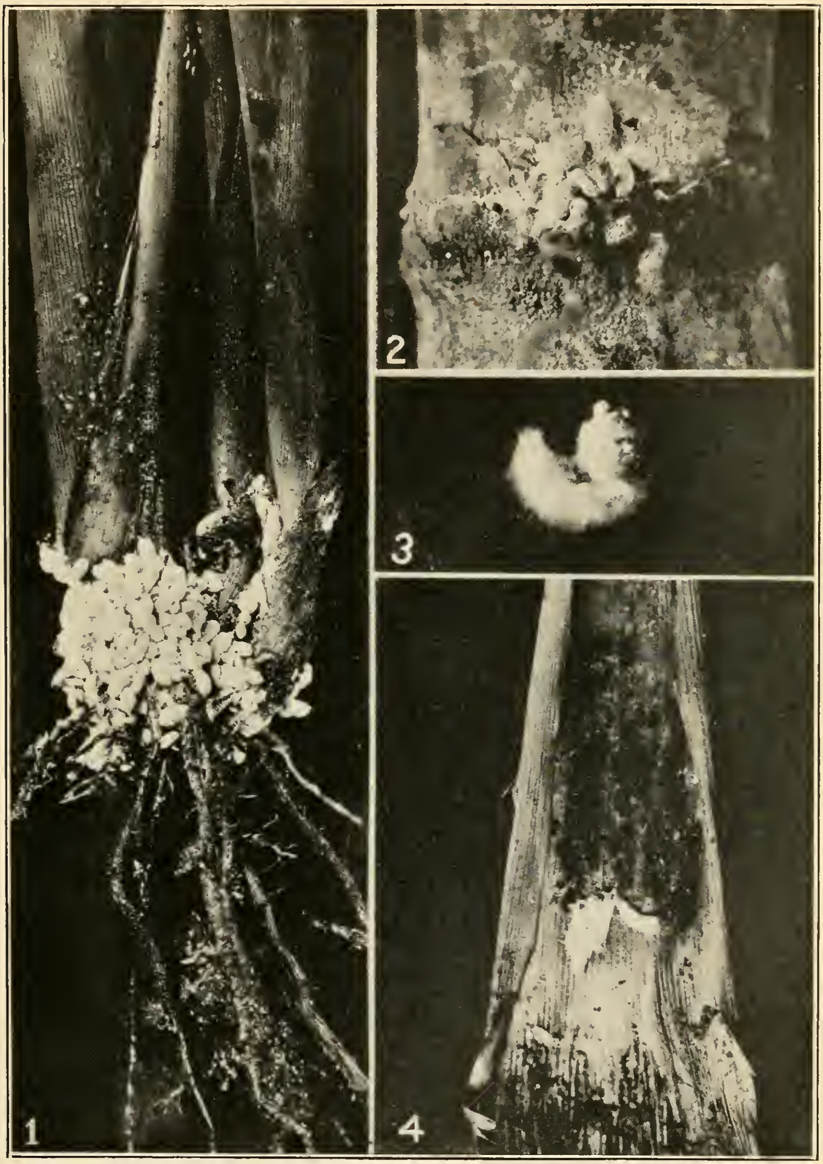
In Louisiana the insects occur not only about the lower leaves of the plant, but are to be found also around the crown (Plate IV, fig. 1) and beneath the surface of the ground about the roots of the plant. In this latter location they hibernate during the cold months of winter on both cane and Johnson grass.

The young mealy-bugs upon hatching from the eggs are quite active and disperse over the cane plants, finally congregating when partly grown about the lower nodes of the stalk. The females are practically inactive, remaining in a mass about one of the nodes or beneath the leaves throughout their development and secreting about themselves in these locations the characteristic white covering (Plate IV, fig. 3). The young males do not remain stationary on the plant, but, after completing their development, spin a narrow white cocoon (Plate IV, fig. 4) within which they transform to a delicate winged adult.

CONTROL.

Selection of seed cane.—Since the common method of distribution is by the transportation of infested seed cane from plantation to plantation or from one part to another of the same plantation, care should be exercised to select clean stalks and not those which are infested, for seed cane.

Burning of the trash.—The practice of burning the trash after harvest is very effective in destroying this insect, since those remain-



THE SUGAR-CANE MEALY-BUG (PSEUDOCOCCUS CALCEOLARIÆ).

Fig. 1.—Adult mealy-bugs clustered about the base of young cane. Fig. 2.—Adult female, twice natural size. Fig. 3.—A single adult female, with white mealy-like covering. Fig. 4.—Cocoons of male mealy-bug. (Original.)

ing on the stalks are killed in the process of milling, and the remaining forms on the discarded stalks and leaves in the field are destroyed by the fire.

NATURAL ENEMIES.

There is present in Hawaii a ladybird beetle, *Cryptolæmus montrouzieri* Muls., which is a special mealy-bug feeder. This ladybird is one of Mr. Koebele's introductions from Australia. It has proved particularly beneficial in feeding upon the sugar-cane mealy-bug in the Hawaiian cane fields, and through its work the numbers of the mealy-bug have been greatly reduced in recent years. This important predator has been established in California, and the Bureau of Entomology at Washington, D. C., has under way at present negotiations to import this beetle into the cane fields of southern Louisiana which are infested by the mealy-bug.

The ladybird is thus described by Prof. W. W. Froggatt, government entomologist of New South Wales.[a]

This beetle is very variable in size, measuring from under 2 to 3 lines in length, with the head, thorax, extreme tip of both wing covers light orange-yellow; the whole of the under surface reddish-brown, and both the upper and under surface clothed with fine hairs. In a number of specimens the under surface is variable in coloration, the middle and hind pairs of legs with the thorax dark reddish-brown to black.

The larva is of the usual smoky-brown tint, but so thickly clothed on the upper surface with white filaments that it appears to be of a uniform white, the pupa hidden beneath the larval skin and the immature beetle are pale yellow.

MISCELLANEOUS INSECTS AFFECTING SUGAR CANE IN HAWAII.

An aphis, *Aphis sacchari* Zehntn., is occasionally injurious to sugar cane. Koebele records an outbreak of the species on the Island of Kauai in 1896 under the name *Aphis* sp.[b] The species was determined by Kirkaldy in 1907.[c] This insect is known to occur on cane in Java. In Hawaii, the species is fed upon by the ladybird *Coccinella repanda* Thunb., though the benefit from this beetle is offset by the work of its braconid parasite, *Centistes americana* Riley.

In some districts where the cane fields are situated in moist locations, a mole cricket, *Gryllotalpa africana* Beauv., is sometimes abundant enough to be injurious. Another species of mole cricket, *Scapteriscus didactylus* Latr., is a most important pest of sugar cane

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[a] FROGGATT, W. W.—Australian ladybird beetles. <Agr. Gazette of New South Wales, vol. 13, pt. 9, pp. 907, 908, September, 1902.

[b] KOEBELE, ALBERT.—Hawaiian Planters' Monthly, vol. 15, no. 12, pp. 596–598, December, 1896.

[c] KIRKALDY, G. W.—On some peregrine Aphidæ in Oahu. <Proc. Hawaiian Ent. Soc., vol. 1, pt. 3, pp. 99, 100, July, 1907.

in the island of Porto Rico.[a] Regarding the work of the Hawaiian mole cricket, Prof. Koebele reports as follows:[b]

A species of mole cricket has appeared in very large numbers in some of the moist valleys on Oahu, it is likely another Asiatic introduction, as a rule these crickets are found around the muddy borders of shallow ponds and watercourses where they live in burrows resembling those of moles, and like that animal their food consists chiefly of earth worms and the larva of various insects. The opinions as to its habits are as yet divided; whilst some authorities claim that it is beneficial, others place it amongst the injurious insects.

Specimens kept in confinement here with pieces of sugar cane would hardly touch them, yet they readily devoured a large number of the larva of the Adoretus or Japanese beetle, as well as those aphodius and a number of earth worms, all within 24 hours.

The ground infested by these crickets was examined and found to be very wet and completely riddled with the burrows down to a depth of three and even four feet, as many as three and four specimens were brought to light in a single shovel full of the soil. In such localities there is no question as to the injurious effects of the crickets on young cane plants, wherever they were numerous almost all of the seed cane was destroyed; they would burrow into the seed from all sides, destroying all the eyes, where the plants had made a growth of a couple of feet the cricket would burrow in below the ground and eat to the center, killing the plant. This is the only instance so far observed of the depredations of these crickets here. In rice and taro fields no damage has been observed as yet, and the only damage that is likely to occur to cane is when it is planted in wet swampy land, as the cricket can only live and thrive in such places, and is not found in ordinary arable land; even in the swamp where the cricket was very numerous, it did not attack the old cane but paid its attention solely to the newly planted seed and very young plants.

This cricket, although living in marshy land, cannot live under water, yet it is a good swimmer; the only remedy that can be recommended at present is to flood the land with water and collect the crickets as they come to the surface, destroying them by placing them in a vessel containing kerosene and water.

The fungoid so contagious to many insects and larva here, does not seem to have any effect on this lively cricket, nor will he have anything to do with poison given in the style of bran, sugar and arsenic.

Certain army worms and cutworms, among them *Heliophila unipuncta* Haw., *Agrotis ypsilon* Rott., and *Spodoptera mauritia* Boisd., are occasionally known to strip fields of young cane. These species and related forms, together with their natural enemies, are discussed in a recent report by Mr. O. H. Swezey.[c]

A bud moth, *Ereunetis flavistriata* Wlsm., is found generally throughout the Hawaiian cane fields and at times is quite numerous. Regarding its injury Swezey says:[d]

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[a] BARRETT, O. W.—The changa or mole cricket in Porto Rico. <Porto Rico Agr. Exp. Sta., Bul. 2, pp. 19, fig. 1, 1902.

[b] KOEBELE, ALBERT.—Hawaiian Planters' Monthly, vol. 15, no. 12, pp. 594–596, December, 1896.

[c] SWEZEY, O. H.—Army worms and cutworms on sugar cane in the Hawaiian Islands. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 7, pp. 32, pls. 3, November, 1909.

[d] SWEZEY, O. H.—The Hawaiian sugar cane bud moth (*Ereunetis flavistriata*) with an account of some allied species and natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 6, pp. 40, pls. 4, October, 1909.

It is usually not particularly injurious as it customarily feeds on the dead and drying tissues of the leaf-sheaths of sugar cane; but when very numerous and on particularly soft varieties of cane the caterpillars do considerable eating of the epidermis, and also eat into the buds and destroy them, occasioning a good deal of loss where the cane is desired for cuttings to plant.

The grasshoppers *Xiphidium varipenne* Swezey and *Oxya velox* Fab. feed to some extent on the leaves of cane. The former species is also predatory in habit, attacking the young leafhoppers and the larvæ of the sugar-cane leaf-roller.

Two species of beetles which occasionally invade the cane fields from their common food plants and attack the leaves of the sugar cane are Fuller's rose beetle, *Aramigus fulleri* Horn,[a] and the Japanese beetle, *Adoretus tenuimaculatus* Waterh.[b]

RATS INJURING GROWING SUGAR CANE IN HAWAII.

The so-called roof-rat (*Mus alexandrinus*) in former years was very common in the cane fields of Hawaii and did considerable damage by eating the stalks. This is also the cane-field rat of the island of Jamaica. The species in Hawaii lives now for the most part in trees and the upper stories of dwellings, since it has been driven to a great degree from the cane fields by the introduced mongoose. The introduction of the mongoose was a benefit as regards its destruction to the rats in the cane fields, but the animal is an undesirable acquisition to the fauna of the islands for the reason that in recent years it has included in its dietary the eggs and young of ground-nesting birds and domestic fowls. The destruction of the ground-nesting birds is most regrettable.

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[a] VAN DINE, D. L.—Hawaii Exp. Sta., Press Bul. 14, p. 5, October, 1905.

[b] KOEBELE, ALBERT.—Hawaiian Planters' Monthly, vol. 17, no. 6, pp. 260–264, June, 1898.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 94.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

CONTENTS AND INDEX.

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BUREAU OF ENTOMOLOGY—BULLETIN No. 94.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

I. DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

By THOMAS E. SNYDER, M. F., *Agent and Expert.*

II. BIOLOGY OF THE TERMITES OF THE EASTERN UNITED STATES, WITH PREVENTIVE AND REMEDIAL MEASURES.

By THOMAS E. SNYDER, M. F., *Entomological Assistant Forest Insect Investigations.*

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Mabel Colcord, *in charge of library.*

Forest Insect Investigations.

A. D. Hopkins, *Forest Entomologist in charge.*

H. E. Burke (in charge of Pacific Slope Station at Placerville, Cal.), Josef Brunner (in charge of Northern Rocky Mountain Station at Missoula, Mont.), T. E. Snyder, W. D. Edmonston (in charge of Southern Rocky Mountain Station at Colorado Springs, Colo.), F. C. Craighead, J. M. Miller (in charge of seed insect station at Ashland, Oreg.), and A. B. Champlain, *assistants in forest entomology.*
L. C. Griffith, *assistant in shade tree insects.*
S. A. Rohwer, *specialist on forest Hymenoptera* (in charge of Eastern Station at East Falls Church, Va.).
A. G. Böving, *specialist.*
C. T. Greene, *specialist on forest Diptera.*
W. S. Fisher, *specialist on forest Coleoptera.*
Carl Heinrich, *specialist on forest Lepidoptera.*
Jacob Kotinsky, *entomological assistant.*
William Middleton, *scientific assistant.*

PREFACE.

Bulletin 94, entitled "Insects Injurious to Forests and Forest Products," consists of two parts and an index.

Part I, "Damage to Chestnut Telephone and Telegraph Poles by Wood-Boring Insects," by Thomas E. Snyder, comprises the results of a special study of a serious damage to the base of standing chestnut telephone and telegraph poles by the wood-boring larva of a beetle designated by the author as the chestnut telephone-pole borer (*Parandra brunnea* Fab.).

Part II, "Biology of the Termites of the Eastern United States, with Preventive and Remedial Measures," by Thomas E. Snyder, is based mainly on investigations and experiments conducted during the past three years by Mr. Snyder in connection with his work in the Branch of Forest Insect Investigations. It also includes unpublished notes by Messrs. H. G. Hubbard and F. L. Odenbach. Termites are among the most destructive insects to both crude and finished forest products in North America, among which may be listed construction timbers in bridges and wharves, telephone and telegraph poles, hop poles, mine props, fence posts, lumber piled on the ground, railroad ties, and the woodwork of buildings. The sudden crumbling of bridges and wharves, the caving in of mines, and the settling of floors in buildings, are sometimes directly due to the concealed work of these insects. The use of untreated wood-pulp products, such as the various composition-board substitutes for lath, etc., is restricted in the Tropics and southern United States because of the ravages of termites. In the cities of Washington, Baltimore, St. Louis, Cleveland, New York, and Boston, and throughout the eastern and southern United States, damage by termites to the woodwork of buildings is occasionally serious.

Methods of prevention and control against injuries to finished and utilized forest products, etc., are based on the results of experiments conducted by this branch of the bureau.

A. D. Hopkins,
Forest Entomologist.

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ERRATUM.

Page 10, footnote *a*, for *Priorus* read *Prionus*.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 94, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

BY

THOMAS E. SNYDER, M. F.,

Agent and Expert.

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L. O. Howard, *Entomologist and Chief of Bureau.*
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R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
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Mabel Colcord, *librarian.*

Forest Insect Investigations.

A. D. Hopkins, *in charge.*

H. E. Burke, J. L. Webb, Josef Brunner, S. A. Rohwer, T. E. Snyder, W. D. Edmonston, *agents and experts.*
Mary E. Faunce, *preparator.*
William Middleton, Mary C. Johnson, *student assistants.*

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U. S. D. A., B. E. Bul. 94, Part I. F. I. I., December 31, 1910.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

By Thomas E. Snyder, M. F.,
Agent and Expert.

OBJECT OF PAPER.

It has recently been determined through special investigations conducted principally by the writer that serious damage is being done to the bases of standing chestnut telephone and telegraph poles in certain localities by the grub or larva of a wood-boring beetle, here called the chestnut telephone-pole borer.[a] The character and extent of the damage under different conditions of site in several localities have been determined, and poles treated with various preservative substances have been inspected to compare the efficiency of both chemicals and methods of treatment. These investigations have resulted in the determination of practical methods of preventing injury to poles by wood-boring insects.

HISTORICAL DATA.

The first information of serious damage to standing chestnut poles by wood-boring insects was conveyed in a letter, dated December 15, 1906, from E. O. Leighley, a correspondent of this Bureau, reporting damage to telephone poles in Baltimore, Md., by borers. Mr. A. B. Gahan, assistant entomologist of the Maryland Agricultural Experiment Station, College Park, Md., who investigated the injury to the poles, stated that it was the work of a borer and was located just beneath the surface of the ground. Mr. Gahan brought specimens of the work and the insect to this office. The borers were identified as cerambycid larvæ, and later were determined to be the chestnut telephone-pole borer (*Parandra brunnea* Fab.).

On December 16, 1906, Mr. H. E. Hopkins, division superintendent of a telephone company, stated that the poles in West Virginia were

[a] *Parandra brunnea* Fab.; Order Coleoptera, Family Spondylidæ.

badly injured by borers and that these borers were abundant. On March 8, 1907, he collected larvæ from chestnut telephone poles at Pennsboro, W. Va. These were determined to be the larvæ of the chestnut telephone-pole borer.

The writer on October 3, 1909, inspected some chestnut telegraph poles which had been standing for about twelve years on New York avenue, in Washington, D. C. The poles had been taken down under orders from the city authorities, which necessitated the placing of wires in conduits under ground, and they had been lying in piles for about a month before they were inspected. The chestnut telephone-pole borer had been working in the base of the poles, and white ants, or termites, were associated with them. Twelve out of the 103 poles examined had been damaged, some more seriously than others.

On October 15, 1909, Mr. H. E. Hopkins sent a reply to a request by Dr. A. D. Hopkins for further information regarding insect damage to poles in West Virginia. He stated that in one line built twelve years ago (40 miles long, 36 chestnut poles to the mile, poles 20 to 40 feet long and 5 to 12 inches in diameter at the top) approximately 600 poles had been rotted off at the top of the ground, and inspection showed that 95 per cent of the damage was directly or indirectly due to insects. Other lines in this division were reported to be in about the same condition. It was later determined that most of the insect damage was the work of the chestnut telephone-pole borer.

Dr. A. D. Hopkins states in a recent comprehensive bulletin [a] that "construction timbers in bridges and like structures, railroad ties, telephone and telegraph poles, mine props, fence posts, etc., are sometimes seriously injured by wood-boring larvæ, termites, black ants, carpenter bees, and powder-post beetles, and sometimes reduced in efficiency from 10 to 100 per cent." Thus, while it has been known that almost all classes of forest products that are set in the ground are seriously injured by wood-boring insects, the problem of insect damage to standing poles, posts, and other timbers has never been made the subject of a special investigation.

In May, 1910, this study was assigned to the writer, and, in addition to a study of the insects involved, investigations in cooperation with telephone and telegraph companies have been conducted in the District of Columbia, Maryland, Virginia, Pennsylvania, New Jersey, and New York. Through the courtesy of the Western Union Telegraph Company several telegraph lines were inspected in July and August, 1910, in Virginia, where the poles were being reset or replaced. Here the butts of over 200 poles set under different conditions of site were thoroughly examined for insect damage, and sometimes the

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[a] Insect Depredations in North American Forests. <Bul. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, p. 67, 1909.

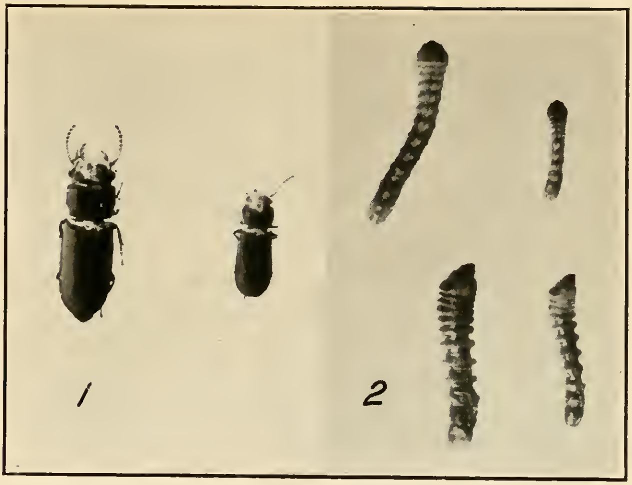

FIG. 1.—THE CHESTNUT TELEPHONE-POLE BORER (PARANDRA BRUNNEA): MALE AND FEMALE BEETLES. FIG. 2.—THE CHESTNUT TELEPHONE-POLE BORER: YOUNG LARVÆ, DORSAL AND LATERAL VIEWS. FIG. 1, SLIGHTLY ENLARGED; FIG. 2, TWICE NATURAL SIZE. (ORIGINAL.)

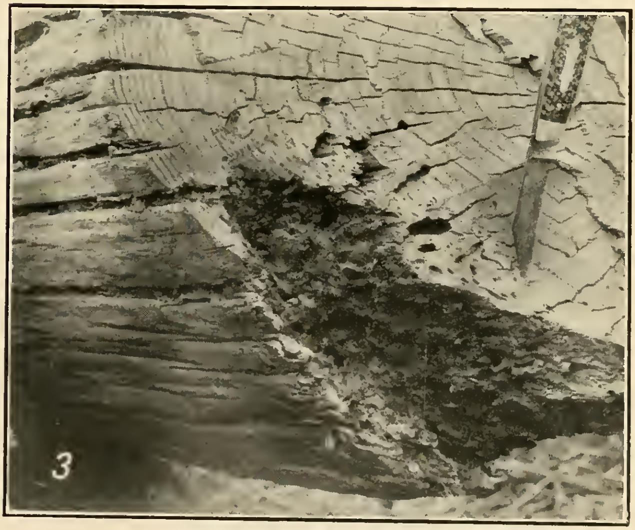

FIG. 3.—DAMAGE TO AN UNTREATED CHESTNUT TELEGRAPH POLE NEAR SURFACE OF GROUND BY THE CHESTNUT TELEPHONE-POLE BORER. (ORIGINAL.)

entire pole was split open. In one line 10 to 12 years old (approximately 30 chestnut poles per mile, 25 feet long, about 6 inches diameter at the top, 10 inches at the base, and apparently of second quality), between Petersburg and Crewe, Va.—the poles had already been reset once, east of Wilson, Va.—serious damage by the chestnut telephone-pole borer rendered from 15 to 20 per cent of the poles unserviceable. After the present second resetting it was estimated that the poles can not last more than four or five years longer. West of Wilson the poles were naturally in much worse condition, and many were broken off and only held up by the wires on the sounder poles. In another line examined, between Portsmouth and Boykins, Va. (poles 30 feet long and apparently of second quality), serious damage by this borer averaged about 10 or 15 per cent, and between Boykins, Va., and Weldon, N. C., according to a linesman, 50 per cent of the poles are badly decayed near the surface of the ground. Much of this damage, however, is due to fungous heart rot. According to a statement by the foreman of a resetting crew, between Asheville, N. C., and Spartanburg, S. C., hundreds of chestnut poles were badly decayed in the 67 miles of line reset, and were only held up by the wires. The line was 15 years old. There was serious damage by "wood lice" (termites) and also by "white wood worms."

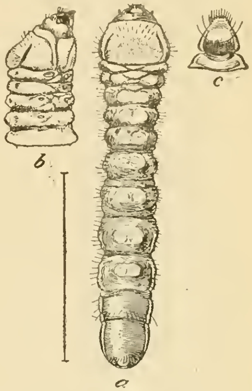

FIG. 1.—The chestnut telephone-pole borer (*Parandra brunnea*): Full-grown larva. (About twice natural size. (Original.)

THE CHESTNUT TELEPHONE-POLE BORER.

(*Parandra brunnea* Fab.)

CHARACTER OF THE INSECT.

The chestnut telephone-pole borer is a creamy white, elongate, stout, cylindrical, so-called "round-headed" grub or "wood worm" (fig. 1), which hatches from an egg deposited by an elongate, flattened, shiny, mahogany brown, winged beetle from two-fifths to four-fifths of an inch in length. (Plate I, fig. 1; text fig. 2.) The eggs are probably deposited from August to October in shallow natural depressions or crevices on the exterior of the pole near the surface of the ground; often the young larvæ enter the heartwood through knots. The young borers (Plate I, fig. 2) hatching therefrom eat out broad shallow galleries running longitudinally in the sapwood, then enter the heartwood, the mines being gradually enlarged as the larvæ develop. As they proceed, the larvæ closely pack the fine excreted boring dust behind them. This débris, which is characteristic of their work, is reddish to dunnish yellow in color and has a claylike consistency. The mines eventually end in a broad chamber, the entrance to which is plugged up by the excelsior-like fibers of wood chiseled out by the strong mandibles of the larva. Here the resting stage (fig. 3), or pupa, is formed, and in this chamber the perfect adult spends considerable time before emerging. Often all stages from very young larvæ only about one-fourth inch long to full-grown larvæ over 1 inch long, pupæ, and adults in all stages to maturity are present in the same pole. Adults have been found flying from July to September. As yet the seasonal history of this borer has not been completely worked out.

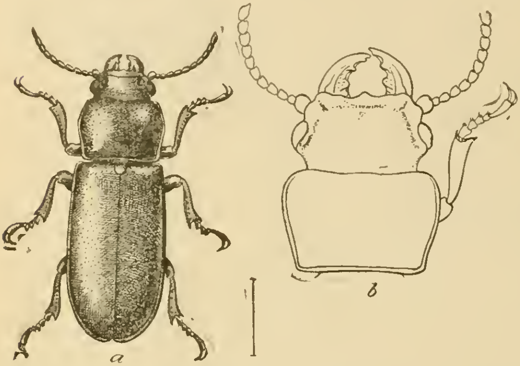

FIG. 2.—The chestnut telephone-pole borer: Female beetle, three and one-half times natural size. Head and pronotum of male beetle. (Original).

DISTRIBUTION.

This insect is very widely distributed, ranging from Ontario, Canada, to Texas, eastward to the Atlantic coast, and westward to Arizona and southern California. It is common throughout the natural range of the chestnut—and in this connection it should be observed that most of the chestnut poles are purchased from local timber-land owners.

CHARACTER OF THE INJURY.

The injury to the poles consists in large mines in the wood near the line of contact of the pole with the ground, necessitating the frequent resetting or even the replacement of the damaged poles. These irregular galleries of the grub (Plate II, fig. 1) run both horizontally and longitudinally throughout the heartwood, and are sometimes 7 inches long, but vary with the individuals, which show great differences in size. The borers usually work in the outer layers of the wood at the base of the pole for a distance of from 2 to 3 feet below, and sometimes from 1 to 2 feet above the line of contact of the pole with the surface of the ground. The greatest damage is to that area just below and just above the surface of the ground (Plate I, fig. 3); here the conditions of air and moisture are most favorable. Often the entire butt up to a distance of from 4 to 6 feet and higher, according to the depth of setting, is mined. The numerous galleries, often very close together, completely honeycomb the wood in a zone

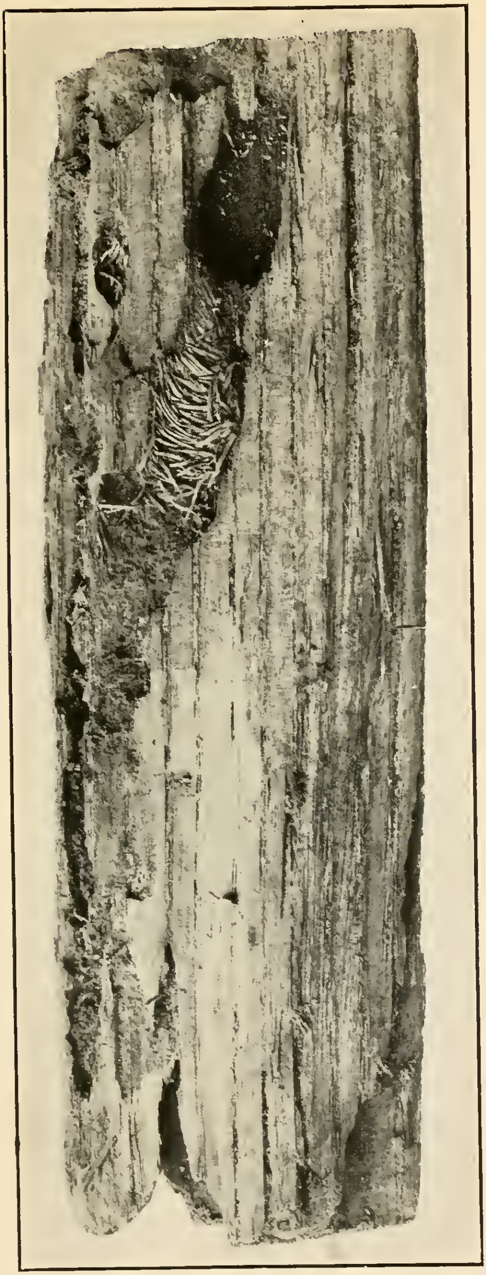

FIG. 1.

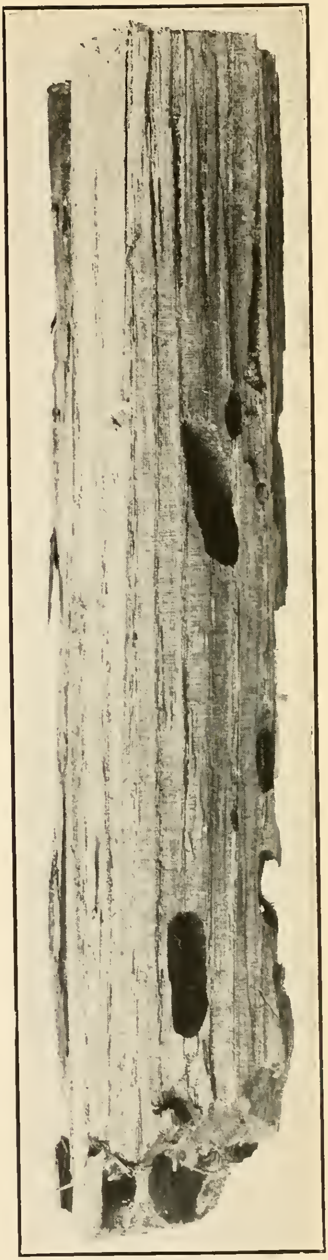

FIG. 2.

WORK OF THE CHESTNUT TELEPHONE-POLE BORER.

Fig. 1.—Gallery of the chestnut telephone-pole borer, showing pupal chamber with the entrance plugged with excelsior-like wood fibers; work near base of pole, below ground. Fig. 2.—Mines of the chestnut telephone-pole borer near surface of ground. Natural size. (Original.)

3 to 4 inches in from the exterior of the poles; this so weakens the poles that they break off close to the surface of the ground. The basal 2 feet is usually sound. Even if the damage is not serious enough to cause the poles to break off under strain, they are likely to go down during any storm, and thus put the wire service out of commission; such damaged poles are a serious menace along the right of way of railroads. The beetle will attack poles that are perfectly sound, but evidently prefers to work where the wood shows signs of incipient decay; it will not work in wood that is ''sobby'' (wet rot), or in very "doty" (punky) wood. It has not yet been determined just how soon the borers usually enter the poles after they have been set in the ground. However, poles that had been standing only four or five years contained larvæ and adults of this borer in the heartwood, and poles that had been set in the ground for only two years contained young larvæ in the outer layers of the wood.

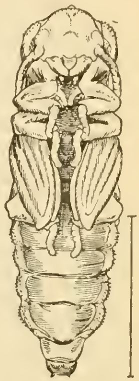

Fig. 3.—The chestnut telephone-pole borer: Pupa. Slightly more than twice natural size. (Original.)

Poles that appear sound on the exterior may have the entire basal interior riddled, and the work of the borers is not noticed until the poles break off. If merely isolated poles are injured, the poles that are broken off are held up by the wires and can be detected by the fact that they lean over, but if several adjacent poles are affected, especially where there is any unusual strain, that portion of the line is very likely to go down. The presence of the borers in injurious numbers can be determined only by removing the earth from about the base of the pole; the exit holes of the borer are found near the line of contact with the soil. Often large, coarse borings of wood fiber project from the exit holes. Sometimes old dead parent adults are found on the exterior of the poles underground. During August the young adults may be found in shallow depressions on the exterior of poles below the ground surface.

IMPORTANCE OF THE PROBLEM.

The subject of the relation of insects to the rapid decay of chestnut poles has not been thoroughly investigated in the past, but now that the supply is becoming scarcer it is especially important to know what are the various primary causes of the deterioration of these poles, hitherto described under the vague term "decay." Although the chestnut telephone-pole borer has not hitherto been considered an insect of any economic importance, and has been described in entomological literature as only living under bark, principally of pine, or in the decomposing wood of various species of deciduous and coniferous trees, the evidence is abundant that breeding in the bases of chestnut poles is not a newly acquired habit. It has also been determined that this beetle damages many species of living forest, fruit, and shade trees that have been previously injured by fire or other causes, and often leads to the destruction of trees that would otherwise recover from such wounds, and while not normally a primary enemy to trees, may thus become of more than secondary importance.

The damage by the chestnut telephone-pole borer is especially serious in consideration of the fact that in many parts of its range the chestnut is threatened with extinction as a tree species on account of the very severe ravages of the combined attack of an insect [a] and a fungous disease. Further unnecessary drain upon the supply of chestnut timber should be avoided by protecting that already in use and thus prolonging its length of service.

EXTENT OF DAMAGE AND LOSS.

As more than one-fourth of the 3,500,000 round poles exceeding 20 feet in length used annually by telephone, telegraph, and other electric companies are chestnut (Kellogg, 1909),[b] and as this borer has seriously damaged as high as 10 to 40 per cent, varying with conditions of site, of the chestnut poles which have been set in the ground for from ten to twelve years in lines in North Carolina, Virginia, West Virginia, Maryland, and the District of Columbia, it is evident that this insect is an important factor in decreasing the normal length of service of the poles.[c] In lines from twelve to fifteen years old the damage is much greater, and at the end of this number of years of service any line in which poles of this species are set has to be practically renewed. According to a statement in Forest Service Bulletin 78 (Sherfesee, 1909), "approximately 4 per cent, or 5,908 feet board measure of the 147,720 feet board measure of standing poles annually requiring replacement in the United States, is destroyed by insects." If only chestnut poles be considered, at least 10 per cent of the poles reset or replaced are injured by insects.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR DESTRUCTIVE WORK.

The damage is apparently greatest and the borers are most abundant where the poles are set in high or level dry ground under good conditions of drainage. Such sites are the crests of railroad cuts through low hills, slopes of "fills," and in cultivated or other fields. Where the poles are in wet sites there is usually but little injury by

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[a] *Agrilus bilineatus* Web.

[b] See list of publications, page 11.

[c] The average life of a chestnut pole is eight to ten years (Sherfesee and Weiss, 1909).

wood-boring insects except to that portion near the surface of the ground. Conditions of drainage are more important than different soil combinations, and the condition of the soil is more important than its composition; *i. e.*, where the soil is hard packed there is apparently less damage than where it is loose. The quality and condition of the poles before setting is a very important factor to consider before arriving at any conclusions as to the relative longevity of poles under various conditions of site. Green (unseasoned) or imperfectly seasoned poles are less durable than those thoroughly seasoned. Poles that are defective [a] before setting, as they very often are (i. e., showing evidence of incipient decay), and poles that have the heartwood mined by the chestnut timber worm,[b] the work of which is very abundant, will, of course, decay much more rapidly than poles that are in an absolutely sound condition. The galleries of the chestnut timber worm afford an entrance to the spores of wood-destroying fungi, and thus greatly accelerate decay. White mycelium compactly filled these galleries throughout many standing poles, thus clearly proving that these mines aid greatly in enabling the fungous heart rot more rapidly and completely to penetrate the entire heartwood of the poles. If the injury by both wood-boring beetles and wood-destroying fungi (between which there is a varying interrelation) be considered, then in several lines from ten to twelve years old in North Carolina, Virginia, and West Virginia at least 50 per cent of the poles are either rendered unserviceable or their length of service is much shortened.

ASSOCIATED WOOD-BORING INSECTS.

It is not to be concluded that this wood-boring beetle is the only insect that injures standing chestnut poles. Indeed, the most common injury is by the "wood lice" or white ants.[c] In lines from ten to twelve years old these insects have seriously damaged as high as 15 per cent of the poles, and their work is often present, at least superficially, in as high as 75 per cent of the poles under all conditions of site. However, the damage is usually to the outer layers of the wood, where it is moist or there is incipient decay, and is more superficial and localized than that of the chestnut telephone-pole borer. Nevertheless, white ants often completely honeycomb the sound heartwood of poles, especially at the base. They work both in sound wood, "doty" (dry rot) wood, and "sobby" (wet rot) wood. Sometimes a large channel runs up through the core of the heart

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[a] Often this evidence is the old galleries of the destructive two-lined chestnut borer (*Agrilus bilineatus* Web.), showing that the tree must have been dead before it was cut for a pole, and hence is more likely to be defective throughout the interior; in other instances heart rot is clearly present.

[b] *Lymexylon sericeum* Harr.

[c] Identified by Mr. Theodore Pergande of this Bureau as *Termes flavipes* Kollar.

and the sides are plastered with clay, forming a hollow tube with several longitudinal galleries. Their work often extends from 2 to 4 feet above the surface of the ground. They leave the outer shell of the wood intact and work up through the longitudinal weathering checks, covering the exterior of the pole with earth to exclude the light. White ants will damage poles that have been set in the ground only two years. Evidently they enter the pole from below the surface of the ground. The habits and characteristics of these peculiar and interesting insects have been thoroughly discussed in Circular No. 50 of this Bureau by Mr. C. L. Marlatt.

A giant round-headed borer [a] is sometimes found in the poles, usually in association with the chestnut telephone-pole borer. In poles where the wood is sound this borer apparently works as a rule only in the outer layers of the wood, the galleries running longitudinally through the heart below the surface of the ground. In poles where there is decay it will completely honeycomb the heartwood near the surface of the ground.

In several poles where the wood was "doty" a large Scarabæid [b] which has before been found in decayed oak railroad ties was present and caused the poles to break off sooner than they otherwise would. The irregular galleries of the grub completely honeycomb the decayed heartwood near or just below the surface.

A flat-headed borer [c] and wireworms [d] were found in galleries locally in the more or less decayed heartwood of several poles. A large black carpenter ant [e] does some damage to sound poles set in dry ground through woodland. This ant often widens the longitudinal weathering checks and thus accelerates decay. A small black ant [f] was very numerous in many poles, but its work is usually confined to the outer layers of the wood. The work is often throughout "doty" poles. Injury by this ant is not primary, but it also widens weathering checks, enlarges other defects, and induces more rapid decay.

PREVENTION OF THE INJURY.

Doctor Hopkins makes the following statement in a recent bulletin:[g]

Insect damage to poles, posts, and similar products can be prevented to a greater or less extent by the preservative treatments which have been tested and recommended by the Forest Service for the prevention of decay. These should be applied

[a] *Prionus* sp.

[b] Identified by Mr. E. A. Schwarz, of this Bureau, as *Polymœchus brevipes* Lec.

[c] Identified by Mr. H. E. Burke, of this Bureau, as *Buprestis rufipes* Oliv.

[d] Species of the family Elateridæ. The large larvæ of *Alaus* sp. were especially injurious.

[e] Identified by Mr. Theodore Pergande as *Camponotus pennsylvanicus* Mayr.

[f] Identified by Mr. Theodore Pergande as *Cremastogaster lineolata* Say.

[g] Insect Depredations in North American Forests. <Bul. 58, Part V, Bur. Ent., U. S. Dept. Agr., p. 84, 1909.

before the material is utilized for the purposes intended, or, if it be attacked after it has been utilized, further damage can be checked to a certain extent by the use of the same substances.

It is often of prime importance to prevent injury from wood-boring insects, for the reason that such injuries contribute to more rapid decay. Therefore anything that will prevent insect injury, either before or after the utilization of such products, will contribute to the prevention of premature deterioration and decay.

Through the courtesy of the American Telephone and Telegraph Company and the Forest Service, about 40 chestnut poles set in a test line near Dover, N. J., were inspected by the writer on July 15, 1910, in company with engineers of the telephone company and Mr. H. F. Weiss, Assistant Director, Forest Products Laboratory, Forest Service, to determine the relative merits of various methods of preventing damage by wood-boring insects to the bases of poles. In this line, which is eight years old, variously treated poles alternated with untreated poles in order that each chemical preservative and method of treatment might be given an absolutely fair test under the same conditions of site. The poles were 30 feet long, 7 inches in diameter at the top, and 33 inches in circumference 6 feet from the base. In this inspection the earth was removed (to a depth of about 1 foot) from the base of the pole, and then the pole was chopped into to determine the rate of decay. This method of inspection for insect damage is not very satisfactory. The various methods experimented with in this test line were brush treatments with a patented carbolineum preservative and spirittine, charring the butt, setting the pole in sand, and setting it in small broken stone. It was found that, although these methods may temporarily check the inroads of wood-boring insects, they will not keep the insects out of the poles. The most serious damage to the poles in this line was by white ants. Other insect damage was by a large black carpenter ant[a] and the larvæ of a round-headed borer.[b]

An inspection was made, between September 6 and 14, 1910, of the bases of over 400 chestnut poles set in a similar test line near Warren, Pa., and Falconer, N. Y. These poles were treated by the creosote "open-tank" method of impregnation, and brush treatments of creosote, wood creosote, creolin, two different carbolineum preservatives, and tar; they had been set in the ground for a period of five years. All these treatments, except the brush treatments with creolin and tar, were efficient in preventing the attacks of wood-boring insects, at least for a five-year period, in this northern climate. There was but little damage by insects to the poles in this test line. The most common injury to the untreated poles was by the large black carpenter ants which widen the longitudinal weathering checks, and hence induce more rapid decay. The work of the chestnut tele-

[a] *Camponotus pennsylvanicus* Mayr.
[b] *Prionus* sp.

phone-pole borer was found in several poles, and this beetle was evidently just beginning to attack these poles. There was some damage by a round-headed borer.[a] No white ants or termites were present, and this is evidently too far north for these destructive borers. A report by inspectors of the American Telephone and Telegraph Company and the Forest Service on the remainder of the poles in this test line (between Jamestown and Buffalo, N. Y.) not personally inspected by the writer, showed that these conclusions can be applied to all the poles in the line with the exception that there was superficial injury by small black ants to two poles treated by brush treatments of carbolineum avenarius and to two treated with wood creosote; also, as the inspection progressed, injury by the chestnut telephone-pole borer became more abundant and serious, and the borers seemed to be established in the poles. The poles treated by the creosote "open-tank" method of impregnation and by brush treatments with creosote and with "S. P. F." carbolineum remained uninjured.

Methods of treating poles superficially by brushing with various preservatives have proved to be temporarily efficient in keeping wood-boring insects out, if the work is thoroughly done and not only the butt, but also the base, is treated. If the pole is not thoroughly brushed, insects enter through the untreated or imperfectly treated portions, especially through weathering checks and knots. Where the base is left untreated, insects, especially white ants or termites, enter the pole from below ground and, avoiding the treated portions, come right up through the pole.

The few poles of southern yellow pine in a line near Bartley, N. J., inspected on July 15, 1910, which had been impregnated with creosote by the Bethell cylinder-pressure process, 12 pounds of oil to the cubic foot, and had been set in the ground since February, 1903, were apparently absolutely free from signs of decay or damage by wood-boring insects. In another line, running between Norfolk, Va., and Washington, D. C., the few poles (12 years old, of squared—with the sapwood cut away—southern yellow pine) inspected on August 10, 1910, near Portsmouth, Va., which had been impregnated with creosote by the Bethell cylinder-pressure process, were also apparently absolutely sound.

Thus, it is evident that impregnating the poles with creosote by some standard process (either the open-tank or the cylinder-pressure processes) will keep wood-boring insects out and preserve the poles for a much longer period than they would last untreated. In the open-tank method only the area most subject to the attacks of wood-boring insects and deterioration in general (i. e., the basal 8 feet) is treated, while by the cylinder-pressure processes the entire pole is impregnated. Alternating less susceptible juniper (red cedar)[b] poles

[a] *Priorus* sp.

[b] *Juniperus virginiana.*

or pine poles thoroughly impregnated by some standard process in the line with the chestnut poles would be a safeguard in holding up an old line where the damage is found to be serious on resetting.

A list of some available publications on wood preservation is appended.

PUBLICATIONS ON WOOD PRESERVATION AND STATISTICS ON POLES.

1903. Von Schrenk, H.—Seasoning of timber. <Bul. 41, Forest Service, U. S. Dept. Agr.

1906. Grinnell, H.—Prolonging the life of telephone poles. <Yearbook U. S. Dept. Agr. for 1905, Extract No. 395.

1907. Crawford, C. G.—The open-tank method for the treatment of timber. <Cir. 101, Forest Service, U. S. Dept. Agr.

1907. Crawford, C. G.—Brush and tank pole treatments. <Cir. 104, Forest Service, U. S. Dept. Agr.

1907. Grinnell, H.—Seasoning of telephone and telegraph poles. <Cir. 103, Forest Service, U. S. Dept. Agr.

1908. Sherfesee, W. F.—A primer of wood preservation. <Cir. 139, Forest Service, U. S. Dept. Agr.

1908. Weiss, H. F.—Progress in chestnut pole preservation. <Cir. 147, Forest Service, U. S. Dept. Agr.

1909. Sherfesee, W. F.—Wood preservation in the United States. <Bul. 78, Forest Service, U. S. Dept. Agr., pp. 24, 25, Table I.

1909. Sherfesee and Weiss.—Wood preservation. <Rep. Natl. Conserv. Com., vol. 2, p. 663.

1909. Kellogg, R. S.—The timber supply of the United States. <Cir. 166, Forest Service, U. S. Dept. Agr., pp. 20–21.

1910. Willis, C. P.—The preservative treatment of farm timbers. <Farmers' Bul. 387, U. S. Dept. Agr.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 94, Part II.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

BIOLOGY OF THE TERMITES OF THE EASTERN UNITED STATES, WITH PREVENTIVE AND REMEDIAL MEASURES.

BY

THOMAS E. SNYDER, M. F.,
Entomological Assistant,
Forest Insect Investigations.

ISSUED FEBRUARY 17, 1915.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1915.

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Morris Chrisman, Geo. Hofer, J. D. Riggs, P. D. Sergent, J. J. Sullivan, Albert Wagner, W. E. Glendinning, James Fleming, L. O. Swartz, *entomological rangers.*
Esther H. Hart, *artist.*
Mary E. Faunce[a], Mary C. Johnson, Margaret Fagan, Elizabeth Ritchie, Maude Taylor, Edna O. Haslup, Pearl L. Boone, *preparators.*
G. A. Swift, *student assistant.*

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[a] Resigned.

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INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

BIOLOGY OF THE TERMITES OF THE EASTERN UNITED STATES, WITH PREVENTIVE AND REMEDIAL MEASURES.

By Thomas E. Snyder, M. F.,
Entomological Assistant.

INTRODUCTION.

The following notes on the biology of the common termites,[a] or "white ants," of the eastern United States were, for the most part, made while conducting investigations to determine the character and extent of damage by termites and other forest insects to various classes of crude and finished forest products and to devise methods of preventing the injury. During 1910 and 1911 special investigations were conducted by the writer as to the character and extent of damage to telephone and telegraph poles and mine props by wood-boring insects. This contribution is thus based, largely, on these investigations, as well as on additional experiments conducted during the past three years by the writer in the branch of Forest Insect Investigations and on some of the unpublished notes of the late H. G. Hubbard and those of Rev. F. L. Odenbach.

"White ants" are among the most destructive insects of North America to both crude and finished forest products, among which may be listed construction timbers in bridges, wells, and silos, timbers of wharves, telephone and telegraph poles, bean and hop poles, mine props, wooden cable conduits, fence posts, lumber piled on the ground, railroad ties, and the foundations and woodwork of buildings, etc. The sudden crumbling of bridges and wharves, caving in of mines, and settling of floors in buildings are sometimes directly due to the hidden borings of termites. The use of untreated wood-pulp products such as the various "composition boards" used as substitutes for lath, etc., is restricted in the Tropics and portions of the southern United States because of the ravages of termites. In the cities of Washington, Baltimore, St. Louis, Cleveland, and New York, and throughout the Southern States damage by termites to

[a] Order *Platyptera*, Packard (1886), suborder *Isoptera*, Brullé (1832), family *Mesotermitidæ*, Holmgren, genus *Leucotermes* Silvestri.

the woodwork of buildings is occasionally serious. As far north as Boston, Mass., damage of this sort occurs, and in Michigan cases are reported in which furniture in buildings has sunk through the floors, mined by "white ants."

The preventives and remedies against injury to forest products and nursery stock herein given are based on the results of experiments conducted by the Bureau of Entomology. The species to be considered in this paper are *Leucotermes flavipes* Kollar and *Leucotermes virginicus* Banks. The former is widely distributed [a] over the United States, but the recorded distribution of the latter is more limited.[b]

CLASSIFICATION.

Termites are naturally to be classed among that most interesting group of social insects comprising the ants, bees, wasps, etc., since they live in colonies which are made up of various highly specialized forms or castes. Each of these forms has a distinct rôle in the processes of the social organization, as there is a well-defined division of labor. In the systematic classification of insects, however, termites are widely separated from the other social insects. These latter represent the highest and most specialized development, whereas termites represent the lowest and are among the oldest of insects. Furthermore, in many points in their life habits termites are widely different from the other social insects.

The tropical genus Termes, from which the family and generic names of termites are derived, is a Linnæan creation [c] and appears for the first time in 1758, in the tenth edition of Systema Naturæ, where it was placed among the Aptera, between the genera Podura and Pediculus. Since then termites have been classed [d] among the orders Neuroptera, Corrodentia, and Pseudoneuroptera, although Brullé, in 1832 (Expéd. Sc. Morée, t. 3 (Zool.), p. 66, Paris, 1832), had founded the distinct new order Isoptera.[e] Packard,[f] in 1863, stated that "seven out of the eight well-established families of the Neuroptera sustain a synthetic relation with each of the six other suborders." Hagen,[g] in 1868, stated in regard to the error that he made in describ-

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[a] Marlatt, C. L. The White Ant (*Termes flavipes* Koll.). U. S. Dept. Agr., Bur. Ent., Circ. 50, pp. 8, figs. 4, June 30, 1902. See p. 4.

[b] Banks, N. A new species of Termes. Ent. News., v. 18, no. 9, p. 392–393, November, 1907.

[c] Desneux, J. Isoptera, Fam. Termitidæ, pp. 52, figs. 10, pls. 2. (Wytsman, P., Genera Insectorum, fasc. 25, Bruxelles, 1904, p. 1–3.)

[d] Feytaud, J. Contribution à l'étude du termite lucifuge. Arch. Anat. Micros., t. 13, fasc. 4, p. 481–606, figs. 34, 30 juin, 1912.

[e] Desneux, J. Loc. cit.

[f] Packard, A. S. On synthetic types in insects. Boston Jour. Nat. Hist., v. 7, no. 4, p. 590–603, fig. 4, June, 1863.

[g] Hagen, H. A. Proc. Boston Soc. Nat. Hist., v. 12, p. 139, October 21, 1868, Boston, 1869.

ing [a] a damaged earwig (Forficula) from Japan as a wingless termite, "that the three families, Termitina, Blattina, and Forficulina, are coordinated and very nearly allied." Packard,[b] in 1883, placed termites in a new order, the Platyptera, including the Termitidæ, Embiidæ, Psocidæ, and Perlidæ, and three years later he dismembered [c] the Pseudoneuroptera into the Platyptera, Odonata, and Plecoptera. Knower,[d] in 1896, stated that in the development of the embryo of termites there is a resemblance to that of the Orthoptera. Desneux, in 1904,[e] stated that termites are derived phylogenetically from the "Blattides," an idea accredited to Handlirsch in 1903, although Hagen, in 1855, had already formulated this theory based on purely biological considerations. Comstock,[f] in 1895, also placed termites in the order Isoptera. Enderlein,[g] in 1903, placed termites with the Embiidæ in the order Corrodentia, suborder Isoptera. In this order he also placed the Psocidæ and Mallophaga. Handlirsch [h] contests the affinity of the Termitidæ with the Embiidæ; he further states [i] that termites are derived from all deposits from the lower Tertiary on, but that all older fossils formerly mistaken for termites by Hagen, Scudder, and Heer do not belong to this order. Banks [j] (1909) considered termites to be in the order Platyptera, suborder Isoptera, with two other suborders, the Mallophaga and Corrodentia. Holmgren states[k] that he believes both groups, the "Termiten" and "Blattiden," are offshoots of a more primitive group, the "Protoblattoiden." The oldest "Blattoiden" occur in the first part of the middle, upper Carboniferous (Pottsville, North America), the oldest "Protoblattoiden," in the last

[a] Hagen, H. A. On a wingless white ant from Japan. Proc. Boston Soc. Nat. Hist., v. 11, p. 399–400, illus., February 26, 1868.

[b] Packard, A. S. Order 3, Pseudoneuroptera, U. S. Dept. Agr., U. S. Ent. Com., 3d Rept., p. 290–293, 1883.

[c] Packard, A. S. A new arrangement of the orders of insects. Amer. Nat., v. 20, no. 9, p. 808, September, 1886.

[d] Knower, H. McE. The development of a termite—*Eutermes* (*Rippertii?*) A preliminary abstract. Johns Hopkins Univ. Circ., v. 15, no. 126, p. 86–87, June, 1896.

[e] Desneux, J. Loc. cit.

[f] Comstock, J. H. Manual for the Study of Insects. Ithaca, N. Y., 1895, p. 95–97, fig. 104–106.

[g] Enderlein, G. Über die Morphologie, Gruppierung und Systematische Stellung der Corrodentien. Zool. Anzeig., vol. 26, p. 423–437, figs. 4.

[h] Handlirsch, A. Zur Systematik der Hexapoden. Zool. Anzeig., vol. 27 (1904), p. 733–769.

[i] Handlirsch, A. Die fossilen Insekten und die Phylogenie der rezenten Formen, pt. 8, p. 1240, Leipzig, 1908.

[j] Banks, N. Directions for Collecting and Preserving Insects, pp. 135, figs. 188, Washington, 1909. U. S. Nat. Mus. Bul. 67. Platyptera, p. 6–7.

[k] Holmgren, N. Termitenstudien 1. Anatomische Untersuchungen. K. Svenska Vetensk. Akad. Handl., Bd. 44, No. 3, pp. 215, Taf. 1–3, Uppsala & Stockholm, 1909. Die Verwandtschäftsbeziehungen der Termiten, p. 208–213.

part of the coal measures (Allegheny, North America), but the youngest "Protoblattoiden" occur in the lower Permian formation of Europe. Holmgren considers the termites to be in a distinct order, the Isoptera.

The order Isoptera, according to Holmgren (1911),[a] is divided into three families, the Protermitidæ, the Mesotermitidæ, and the Metatermitidæ. All of these families are represented in North America, and while this paper is restricted to a discussion of species of the genus Leucotermes Silvestri, subfamily Leucotermitinæ Holmgren, family Mesotermitidæ Holmgren, a species in the genus Termopsis Heer, subfamily Termopsinæ Holmgren, family Protermitidæ Holmgren, is briefly mentioned. Thus it will be seen that the species under observation occupy a middle position between the highest and the lowest genera in the systematic classification of termites.

HISTORICAL.

According to Desneux, Smeathman's marvelous descriptions in Some Account of the Termites Which Are Found in Africa and Other Hot Climates (London, 1781) are the real basis of scientific researches on the biology of termites.[b] Hagen [c] gives a résumé of the researches on termites up to 1860. Drummond's Tropical Africa (London, 1889), in chapter 6, gives an interesting account of "white ants." Froggatt, in Australian Termitidæ,[d] gives a résumé of the studies of various workers on termites. Saville-Kent, in Chapter III of the Naturalist in Australia (London, 1897), describes the habits of termites in the Tropics; Smeathman, Drummond, and Saville-Kent in their popular accounts of termites stimulated interest in the habits of these insects and led to scientific researches. Grassi and Sandias,[e] in their classical work, have outlined the results of the more important biological researches. Sharp[f] gives an excellent

[a] Holmgren, N. Termitenstudien 2. Systematik der Termiten. K. Svenska Vetensk. Akad. Handl., Bd. 46, No.6, pp. 86, Taf. 1–6, Uppsala & Stockholm, 1911. Ordnung Isoptera, p. 10–11.

[b] Smeathman, H. Some account of the termites, which are found in Africa and other hot climates. In Philos. Trans. London, v. 71, p. 139–192, 3 pls., 1781. (Smeathman's observations were afterwards confirmed by Savage in 1850 and the late G. D. Haviland.)

[c] Hagen, H. A. Monographie der termiten. Linnæa Entomologica, v. 10, 1855, p. 1–144, 270–325; v. 12, 1858, p. 1–342, pl. 3; v. 14, 1860, p. 73–128.

[d] Froggatt, W. W. Australian Termitidæ, Part I. Proc. Linn. Soc. N. S. Wales, v. 10, ser. 2, p. 415–438, July 31, 1895. Distribution, p. 416–426.

[e] Grassi, B., and Sandias, A. The constitution and development of the society of termites; observations on their habits; with appendices on the parasitic protozoa of Termitidæ and on the Embiidæ translated by F. H. Blandford. Quart. Jour. Micros. Sci. [London], v. 39, pt. 3, n. s., p. 245–322, fold. pl. 16–20, November, 1896, and v. 40, pt. 1, p. 1–75, April, 1897.

[f] Sharp, D. Cambridge Nat. Hist., vol. 5, Insects, Pt. 1, chap. 16, p. 356–390, London, 1901.

summary of the various writings on termites up to 1901. Escherich[a] gives a résumé of the more important work up to 1909, and also an extensive bibliography. Holmgren's treatise[b] deals with anatomy, systematic classification, development, and biology, and gives a summary of the effect of the social life, as shown in the progressive and retrogressive development of termites. Bugnion[c, d] has recently made observations that lead him to state that (in *Eutermes lacustris* Bugnion and *Termes* spp.) the differentiation of the three castes occurs in the embryo. Feytaud[e] has published an account of the life history of *Leucotermes lucifugus* Rossi, a species closely related to our common species of the eastern United States. His observations confirm those of Heath on the same species in this country. He also made studies of the internal anatomy. The more important contributions to our knowledge of termites are the results of researches by Bobe-Moreau, Bugnion, Czervinski, Desneux, Doflein, Drummond, Escherich, Feytaud, Froggatt, Grassi and Sandias, Hagen, Haldemann, Haviland, Holmgren, Jehring, Latreille, Leidy, Lespès, Fritz Müller, Pérez, Perris, Petch, Rosen, Savage, Silvestri, Sjöstedt, Smeathman, Wasmann, and many others. In the United States, Banks, Buckley, Hagen, Heath, Howard, Hubbard, Joutel, Knower, Marlatt, Porter, Schaeffer, Schwarz, Scudder, Stokes, Strickland, and Wheeler have contributed to the knowledge of the habits of our native species. The following paragraph gives a brief résumé of the more important researches on the biology of the common species of Leucotermes in the United States.

H. A. Hagen contributed several articles on the habits of *flavipes*, and has described forms[f, g] found by the late Mr. H. G. Hubbard, of the Division of Entomology. Hubbard, many of whose unpublished notes are herein included, was the first to find royal individuals, both

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[a] Escherich, K. Die Termiten . . . eine biologische Studie, p. 2–7, Leipzig, 1909.

[b] Holmgren, N. Termitenstudien 3. Systematik der Termiten. Die Familie Metatermitidæ. K. Svenska Vetensk. Akad, Handl., Bd. 48, No. 4, 166 p., Taf. 1–4, Uppsala & Stockholm, 1912.

Blick auf dem mutmasslichen, stammesgeschichtlichen Entwicklungsverlauf der Termiten, p. 129–153.

Holmgren, N. Termitenstudien 2. Systematik der Termiten. K. Svenska Vetensk. Akad. Handl., Bd. 46, No. 6, pp. 86, Taf. 1–6, Uppsala & Stockholm, 1911. Ordnung Isoptera, p. 10–11.

[c] Bugnion, E. La differenciation des castes chez les termites [Nevr.]. Bul. Soc. Ent. France, 1913, no. 8, p. 213–218, April 23, 1913.

[d] Bugnion, E. Les termites de Ceylan. Le Globe: Memoires, Soc. Geog. Geneva, t. 52, p. 24–58, 1913.

[e] Loc. cit.

[f] Hagen, H. A. The probable danger from white ants. Amer. Nat., v. 10, No. 7, p. 401–410, July, 1876.

[g] Riley, C. V. Social insects from psychical and evolutional points of view. Proc. Biol. Soc. Wash., v. 9, p. 1–74, figs. 12, April, 1894.

true and neoteinic, in the United States, and his material forms an important auxiliary to later investigations. Much of Hubbard's collecting in Florida and Arizona was done in company with Mr. E. A. Schwarz, of the Bureau of Entomology, who has since published[a] some of his observations on the habits of termites in southwestern Texas. The Rev. F. L. Odenbach, S. J., of Cleveland, Ohio, has studied the habits of our native species of termites since 1893, and has contributed many manuscript notes. Mr. L. H. Joutel, of New York, has studied the habits of our common species[b] and has contributed some unpublished notes. Dr. H. McE. Knower,[c] late of Johns Hopkins University, in 1894 published new and important contributions on the embryology of termites (Eutermes). His observations are not in accord with those of Bugnion, since he determined that the nasutus develops from a worker-like larva nearly as large as a young nasutus, having 13 joints to the antenna and worker-like head and jaws. This worker-like larva had a small head gland with no "corne frontale" on the outside of the head, although sections show essentially the same structure in the gland as that of the nasutus. Mr. C. Schaeffer, of Brooklyn, N. Y., was the first to record[d] the presence of a fertilized true queen of *flavipes* in a colony. The researches[e] of Dr. Harold Heath, of Stanford University, Cal., on the habits of California termites confirm the statements of Pérez and Perris that some colonizing individuals of *Leucotermes lucifugus* succeed in establishing new colonies. Mr. Nathan Banks, of the Bureau of Entomology, has contributed several articles on our native termites, and has described a new species of Leucotermes (*virginicus*)[f] from the eastern United States. Mr. C. L. Marlatt, assistant chief of the Bureau of Entomology, has described the distribution, life history, and destructiveness of *flavipes* in the United States and figured the castes.[g] Mr. E. H. Strickland,[h] Carnegie scholar in economic entomology at Bos-

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[a] Schwarz, E. A. Termitidæ observed in southwestern Texas in 1895. Proc. Ent. Soc. Wash., v. 4, No. 1, p. 38–42, Nov. 5, 1896.

[b] Joutel, L. H. Some notes on the ravages of the white ant (*Termes flavipes*). Jour. N. Y. Ent. Soc., v. 1, No. 2, p. 89–90, June, 1893.

[c] Knower, H. McE. Origin of the "Nasutus" (soldier) of Eutermes. Johns Hopkins Univ. Circ., v. 13, No. 111, p. 58–59, April, 1894.

[d] Schaeffer, C. Jour. N. Y. Ent. Soc., v. 10, No. 4, p. 251, December, 1902.

[e] Heath, Harold. The habits of California termites. Biol. Bul., v. 4, No. 2, p. 47–63, January, 1903.

[f] Banks, N. A new species of termes. Ent. News, v. 18, No. 9, p. 392–393, November, 1907.

[g] Marlatt, C. L. The White Ant (*Termes flavipes*, Koll.). U. S. Dept. Agr., Bur. Ent., Circ., No. 50, rev. ed., pp. 8, figs. 4, June 27, 1908.

[h] Strickland, E. H. A quiescent stage in the development of *Termes flavipes* Kollar. Jour. N. Y. Ent. Soc., v. 19, No. 4, p. 256–259, December, 1911.

ton, Mass., has described and illustrated a quiescent stage in the development of the nymph of the first form of *Leucotermes flavipes*, which stage was discovered by Prof. W. M. Wheeler, of Bussey Institute.

While investigating damage to the bases of telegraph poles by wood-boring insects a large fertilized true queen of *Leucotermes flavipes* was found by the writer on August 12, 1910.[a] The finding of this interesting form, usually considered to be rare in colonies of our native termites, served as an incentive to further biological study on the habits of our common species. On August 11, 1911, molting

FIG. 4.—View at Falls Church, Va., showing a portion of the treated experimental stakes under test, as to the relative effectiveness of preventives against termite attack. (Original.)

larvæ in the quiescent stage were observed by the writer for the first time, in a colony in Illinois. Special investigations were begun at Falls Church, Va., in March, 1912, to determine (1) the habits of our common termites, (2) the effectiveness of various methods and chemical wood preservatives in preventing attack by our native termites (fig. 4), and (3) the "immunity" (?)[b] or relative resistance of native and tropical species of wood.[c]

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[a] Snyder, T. E. Record of the finding of a true queen of *Termes flavipes* Kol. Proc. Ent. Soc. Wash., v. 14, No. 2, p. 107-108, June 19, 1912.

[b] It is doubtful if any species of native wood of economic importance is absolutely immune to termite attack.

[c] Impregnation of wood to resist insect attack. Amer. Lumberman, Nov. 15, 1913

BIOLOGICAL EXPERIMENTS.

THE TERMITARIUM.

Early in March, 1912, work was begun on a large outdoor termitarium, at Falls Church, Va. The projects outlined for study in connection with the termitarium were (1) to observe the progressive development of the termite from the larva to the adult, especially in the case of the colonizing form; (2) to watch the insects when they swarmed, to determine whether this swarming is a nuptial flight, i. e., whether or not the sexes leave the nests in separate swarms and at what time copulation occurs; (3) to observe how the new colony is established, (4) in what proportion the pairs survive, and (5) the conditions in the parent colony after the swarm is over.

The termitarium was merely a large cage in which the termites could swarm under conditions as nearly similar to those in nature as possible. The cage consisted of a bottom of galvanized iron in the form of a rectilinear box sunk in the ground to the depth of a foot, a framework of wood to support the wire netting, and a wooden roof covered with tarred paper. The bottom of the cage consisted of a galvanized-iron box 10 by 6 feet and 1 foot deep, of 27-gauge galvanized sheet iron with an inch flange turned inwards. (Fig. 5, *a*.) This box was raised off the ground on a wooden floor of seven-eighths inch material, 4 inches wide, which was laid on 2 by 4 inch studding. There was an air space of 1 inch between the sides of the box and the earth, as well as a similar space between the sheet-iron bottom and the earth. The top of the sheet-iron box was nailed to a framework of 2 by 4 inch studding, which was supported on cedar posts, the top of the box being several inches above the surface of the ground. Loose earth was placed in the box to about half its depth, over which was spread a shallow layer of black earth (leaf mold) from the forest floor, for the purpose of retaining moisture. The wooden framework consisted of 2 by 4 inch studding, which was covered on the inside with galvanized-wire netting (14 squares mesh per inch) and reinforced at the side and ends by boards 4 inches wide by seven-eighths inch thick. The cage is about 7 feet in height, and the roof, slanting away from a shed against which it is built, acquires sufficient pitch to shed rainfall. (Fig. 5, *b*.)

Two chestnut logs which had been cut and allowed to season about one month before the experiment was begun were placed in the cage. One was placed on end in the dirt, the top of the log approximating the height of a stump, while the other, a tangential section, was partially buried in the ground. The bark was loosened, but was left intact on both logs. The logs were both sound, but were kept moist. A number of small decaying branches and strips of decaying chestnut boards were also laid flat upon the earth in the

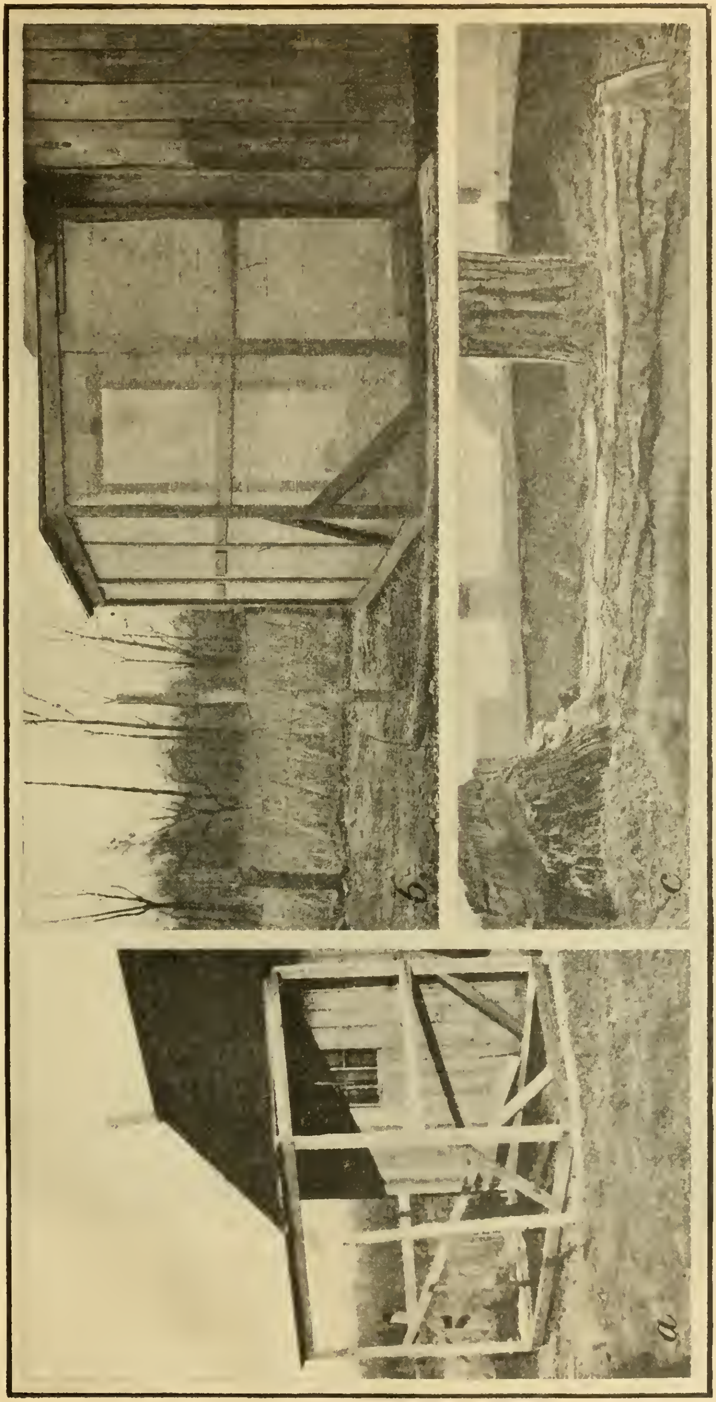


FIG. 5.—*a*, Unfinished termitarium showing iron bottom; *b*, finished termitarium; *c*, interior view of same termitarium showing infested log in foreground, infested stump, and trap logs. (Original.)

termitarium, after a careful examination to determine that no termites were already present. The earth in the cage was kept sufficiently moist in the endeavor, in so far as possible, to approximate natural conditions. (Fig. 5, *c*.)

The termitarium was ready for occupancy on April 8, and a chestnut log infested with a colony of *Leucotermes flavipes* was introduced. This log had the bark on and was partially buried. On April 9 a decaying oak stump containing a colony of the same species was also placed in the cage and partially buried in the earth. Several termite colonies in logs and stumps in the forest were kept under observation at the same time, and seasoned logs and slabs with loosened bark were placed near by under conditions similar to those in the cage. The following notes are based on observations of colonies of termites in the termitarium, colonies in small tin boxes, and colonies in nature.

COMMUNAL ORGANIZATION.

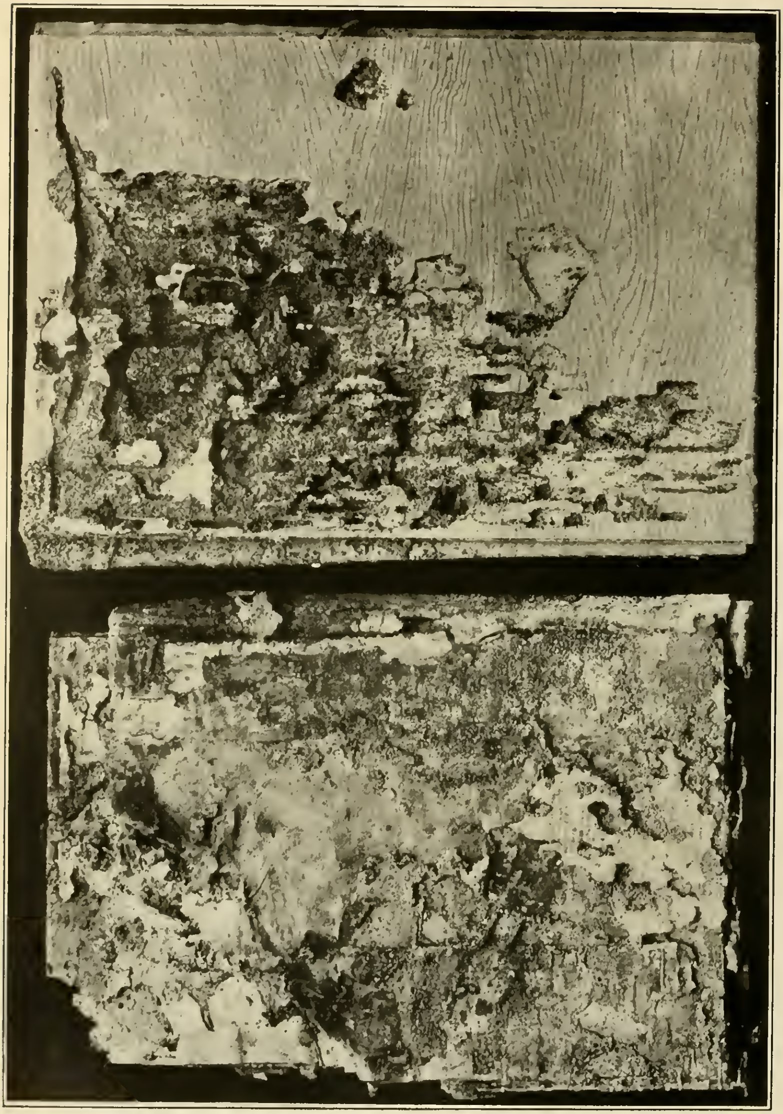
SITUATION OF THE NESTS.

Termites in the eastern United States usually make their nests in decaying stumps or in logs and even small pieces of wood on the forest floor, although they also inhabit dead standing trees as well as injured living trees. They never form mounds as in the Tropics. These soft-bodied insects always conceal themselves within wood or in earth as means of protection against sunlight and their enemies, in consequence of which much of the damage they do is hidden. Termites of the genus Leucotermes are essentially wood destroyers and infest and seriously injure a great variety of crude and finished forest products which are in contact with the ground. The longitudinal excavations usually follow the grain of the wood,[a] and in the more sound wood their work is confined to the outer layers, where there is abundant moisture and incipient decay. A protective outer shell of wood is always left intact, since all except the winged, sexed, colonizing forms shun the light and are blind. Small, transverse, round tunnels which nearly pierce the outer shell are to be found when their tunnels closely approach the exterior. Sometimes the thickness of this protective shell is less than one-half millimeter. These may be soundings to see how nearly the surface is being approached, or merely unfinished excavations for the exit of the sexed adults, or possibly they may be feeding burrows. Termites often take advantage of the burrows of other wood-boring insects, enlarging and adapting them to their purposes; by these means they are

[a] Termite work can be readily distinguished from that of carpenter ants, whose excavations do not follow the grain. Sometimes in decayed wood, however, termites construct long, deep, but narrow, transverse galleries across the grain, forming ledges or shelves.

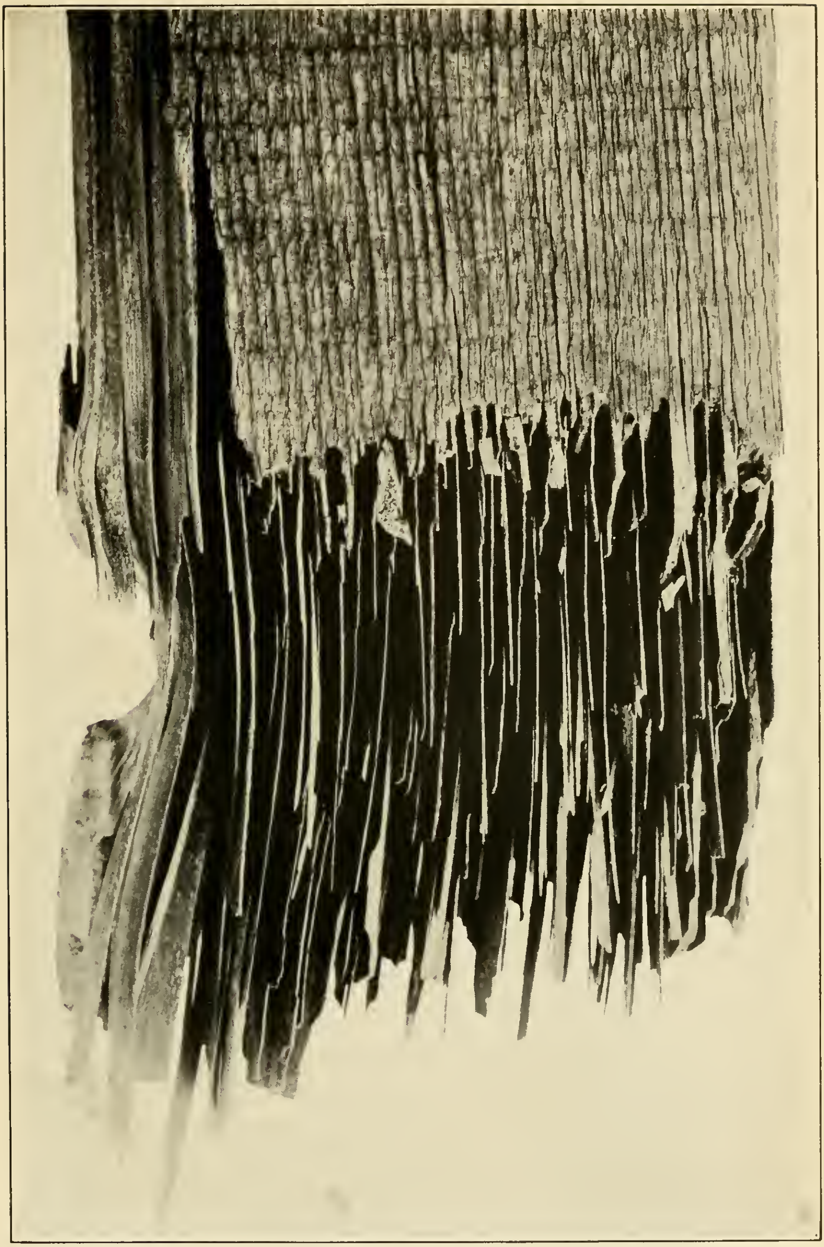
LEUCOTERMES VIRGINICUS.

All castes in heartwood of a maple tree infested by *Parandra brunnea*. (Original.)



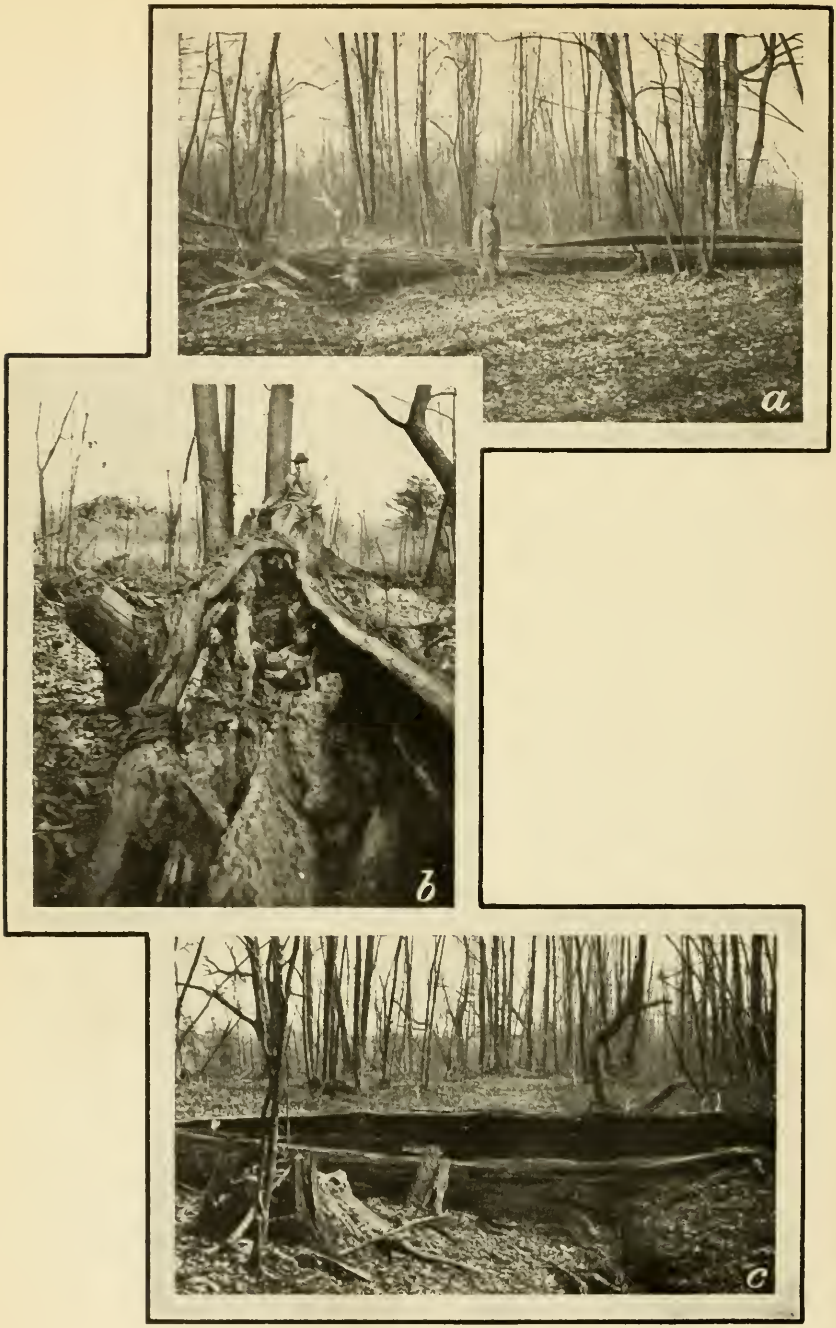
DAMAGE BY TERMITES.

A book destroyed by termites, Georgetown, D. C. (Photograph by W. S. Clime.)



DAMAGE BY TERMITES.

Pine barn sill cut into ribbons by *Leucotermes* sp. at Mayfield, Kans. (Original.)



DAMAGE BY TERMITES.

Living stag-headed chestnut tree, 50 feet in length, Falls Church, Va. *a*, Complete length of tree showing stag top and lightning scar on side; *b*, view of interior showing heartwood completely honeycombed; *c*, view of north side of tree showing width of scar, and honeycombed interior (Original.)

able to penetrate more rapidly to the heartwood and honeycomb the interior.

Termites quickly disintegrate the wood of dead trees and stumps, which soon becomes converted to humus, the rapidity with which this is done depending on the relative resistance of the species of wood. This beneficial rôle in nature, however, is offset by the enormous destruction they accomplish in rapidly rendering insect, fire, and disease killed timber unmerchantable and by the damage they inflict to the roots and trunks of injured living trees. Termites will infest the heartwood of living trees injured at the base by fire, disease, or other insects (Pl. III), and sometimes in such trees they excavate upward, throughout the dead heartwood, longitudinal tunnels, irregular in diameter, the sides of which are lined with earth mixed with excrement. These insects also infest the roots of living trees, finding ingress through abandoned burrows of the large, roundheaded (Prionid) borers. Sometimes they girdle young trees—forest-tree nursery stock, for example—eventually cutting the trees off near the ground, examination disclosing that the stems were honeycombed. This is not necessarily due to the presence of dead wood near by, since termites will tunnel for long distances underground. While usually confining their work to moist or decaying timber or to vegetable material of any sort, and to books (Pl. IV) and papers that are somewhat moist, termites will attack seasoned, dry wood, provided there is access to moisture elsewhere; i. e., they use moist frass and earth in extending the burrows, thus creating more favorable conditions. In the Southern States termites will infest the bark and outer layers of the wood of the base of yellow pines killed by barkbeetles before the foliage has all fallen; trees that have been killed in the spring and show reddish-brown needles and much fallen foliage being infested by the middle of August. Trees killed in the spring will also have the outer layers of wood of the base honeycombed by the following December. (Fig. 6.) The larger-celled, thin-walled spring wood is eaten away first, leaving the smaller-celled, harder summer wood uneaten. (Pl. V.)

Where the heartwood is decayed in a standing living tree termites will work for a considerable distance above the ground, completely honeycombing the heartwood. In a living chestnut tree at Falls Church, Va., with the decayed heartwood exposed in a long scar, termites had infested the heartwood to a height of from 45 to 50 feet above the ground. The outer shell of living sapwood was intact. (Pl. VI.)

Termites are quite effective in clearing fields of old snags and stumps, but this benefit is offset by the damage they do to posts and buildings.

Termites (*Leucotermes* spp.) also inhabit subterranean passages. Drummond has compared tropical species of termites to earthworms and declared that they are equally as beneficial to man in aerating the soil. After swarming, many of the sexed adults excavate shallow cells in the earth under small pieces of decaying wood, and later enter the wood. The royal cell is constructed in decaying wood or in the earth slightly below the surface of the ground. Termites usually infest wood by entering from the ground underneath, rather than directly on the exposed surface, the latter being usually the habit at the time of the swarm. (*Termopsis angusticollis* Walk. usually infests wood by gaining ingress through wounds and abrasions.) None of the sound traplogs with loose bark in the termitarium or in the forest was infested except at the point of contact with the ground, but termites in pairs have been found under loose split bark on decaying logs where more moisture was present. Workers and soldiers are frequently to be found in the spring in small pieces of decaying wood lying on the ground, and termites probably extend old colonies or establish new colonies by means of subterranean tunnels. During the winter the members of the colony are to be found in a labyrinth of undergound passages.

FIG. 6.—Work of termites in insect-killed southern yellow pine. Tree killed in the spring; wood at base honeycombed by following December. Spartanburg, S. C. (Original.)

These excavations are of varying size and shape, and extend in all directions. Some of the tunnels are partitioned off into separate chambers, while others are unpartitioned runways. In the main runways the very young are absent. The partitions consist either of uneaten portions of the wood or small conical piles of moist earth mixed with frass (excreted, finely digested wood) of clay-like consistency. Sometimes in broad, shallow channels a small irregular mass nearly blocks the channel. The sides of the channels are smooth, and the uneaten masses of wood which serve as barricades appear as little islands and are distinct because of the rough appearance due to the pores and cell walls of the wood. The walls of these channels are spotted with little piles of finely digested, excreted wood, giving the wood a characteristic mottled appearance.

Large cavities encountered by termites when working in the wood of logs, poles, or trees with decayed heartwood or hollow core are usually filled up with moist earth mixed with frass, the whole having a clay-like consistency and a conglomerate appearance due to the irregular deposits of excreted, finely digested wood. The "doty" hollow cores in the bases of infested poles are filled up in this manner.

In all their operations the termites carefully wall up and conceal themselves. Usually there is but little evidence on the exterior of infested wood to indicate the presence of termites, and they may not be detected until the interior is completely honeycombed. Sexed adults swarming from infested buildings are always a warning of their presence. Again, the outer surface is covered over with longitudinal viaducts of small diameter constructed of earth (Pl. VII, figs. 1 and 2), and whereas the interior channel is smooth, the exterior has a rough granular appearance. These viaducts are resorted to in order to extend the colony or to reach some object, such as decayed wood, or when their pathway crosses some impenetrable substance, the object, of course, being always protection from the light—all except the winged sexed adults shun the light—and their numerous enemies. Viaducts, or "sheds," can be seen running up to a considerable height above the ground in the longitudinal weathering checks on poles and posts, as well as between the crevices in the bark of infested dead and living trees, and uncovered viaducts are found under the loose bark on dead trees. Viaducts in the interior of hollow-cored poles or trees may be of large diameter and may consist of several irregular longitudinal interior channels.

Termites sometimes resort to another type of viaduct, which for descriptive purposes may be called suspended tubes. On May 26, 1912, at Elkins, W. Va., Dr. A. D. Hopkins found termite tubes of earth, 5 to 6 inches long, hanging from the end of a Virginia scrub pine sapling which had fallen, leaving the broken base 2 feet from the ground. The termites had evidently infested the base of the sapling through the ground before it fell and were trying to make connection with the ground by means of these suspended tubes. (Figs. 7 and 8.)

These covered viaducts or sheds, the uncovered viaducts, and the tubes—all constructed by termites of earth and excreted wood—are fragile.

NUMBER OF INDIVIDUALS IN COLONIES.

Young colonies of *Leucotermes flavipes*—that is, colonies but recently established, in decaying wood or in the ground under decaying wood, by sexed couples that have swarmed—are small, and since the rate of egg-laying by the young queens is remarkably slow, the increase in numbers is also correspondingly slow. Observations of such incipient colonies in the spring of 1912 and 1913, after the swarm, the time of which varies with the season, from the middle of June to early July, indicate that from 6 to 12 eggs are normally to be found with pairs of *flavipes*. While the brood first hatched is relatively small, contrary to the habits in the other social insects coition is repeated and the young colony gradually increases in numbers.

On April 25, 1912, at Falls Church, Va., a small colony or subcolony of *Leucotermes flavipes*, the branch of a larger colony, was found under a small chestnut slab sunken in the ground. The day was warm and bright and many members of the colony were congre-

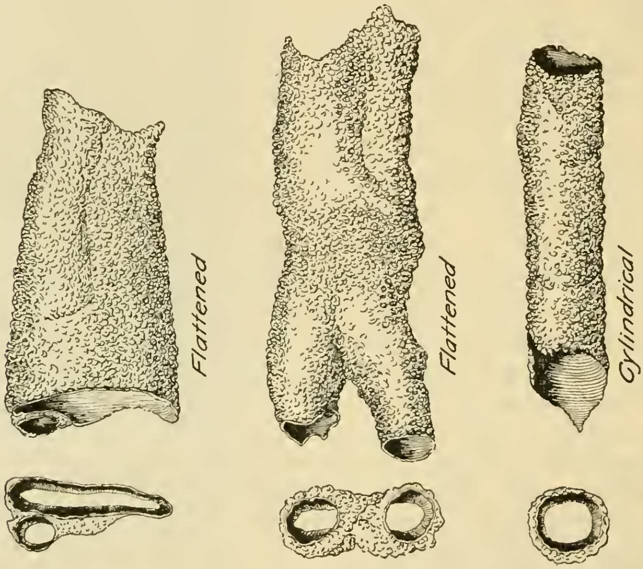
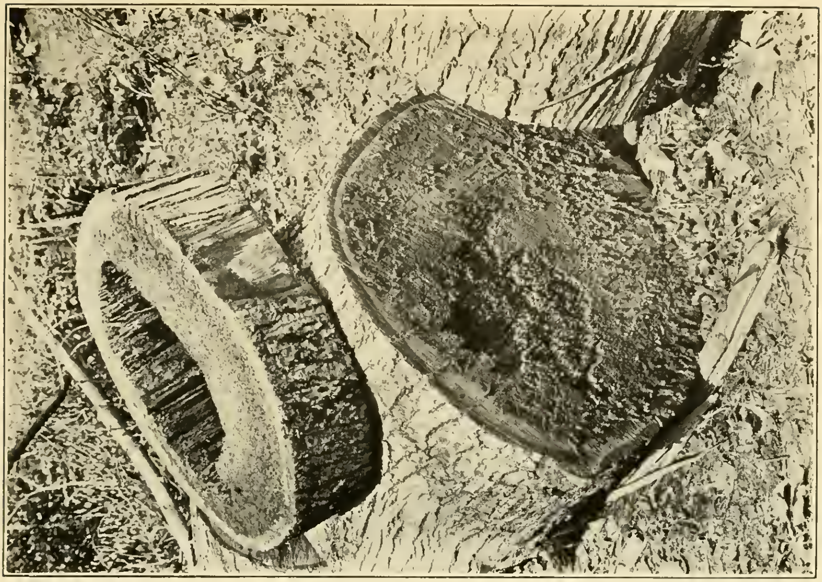
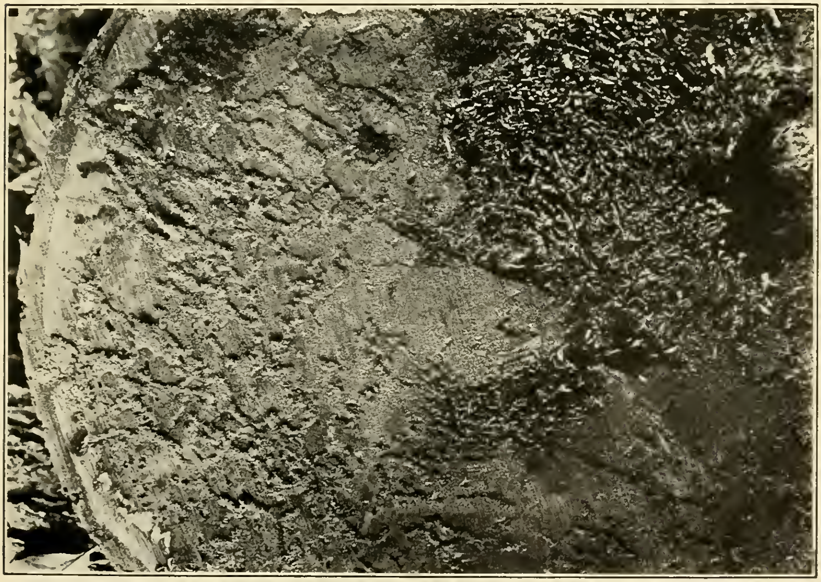


FIG. 7.—Suspended tubes, constructed by termites of earth and excreted wood. (Original.)

gated under the slab above ground. An attempt was made to capture the entire colony in order that the relative proportions of the various castes might be ascertained. Although nymphs of the first form constituted the most abundant caste, some few transforming nymphs and a few sexed adults were present, as well as a few workers and soldiers. Workers constituted the second most abundant caste. Nymphs of the second form appeared more active than the nymphs of the first form. The following possibly is not a fair statement, either of the number of individuals in the colony or the relative proportions of the different castes, since (1) the nymphs were probably above ground to take advantage of the warm afternoon sun which would aid their development—a common procedure; (2) only a few workers and soldiers were necessary to attend them and no doubt many more were still in the subterranean passages; (3)





WORK OF LEUCOTERMES VIRGINICUS.

Maple tree on Plummers Island, Md., infested by *Parandra brunnea* and by termites; showing sheds constructed by termites to cover up galleries exposed by sawing. (Original.)

many escaped and the workers would escape more easily than the nymphs; (4) probably, unconsciously, more effort was made to capture nymphs and soldiers than workers. The following figures, however, will probably approximate the relative abundance of castes. Nymphs of the first form, 279; nymphs of the second form, 86; nymphs of the first form in the quiescent stage, 31; individuals in the stage following, that is, with wings unfolded and held away from the body, 3; immature sexed adults without pigmentation, 17; immature sexed adults with gray pigmentation, 26; nearly mature adults, 5; nymphs of the second form molting, 4; workers, 93; soldiers, 24; the total being 568. Nymphs of the second form were only one-fourth as numerous as nymphs of the primary form, and, including all stages to sexed adults, gave a count of 90 to 361, respectively.

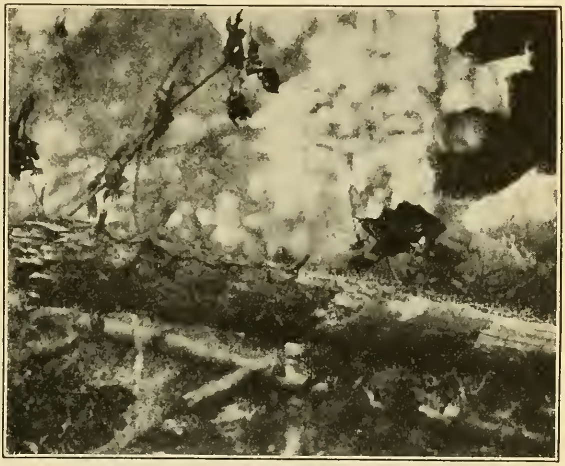


FIG. 8.—Broken-off pine sapling from basal end of which tubes in figure 7 were suspended by termites toward stump. (Original.)

On March 22, 1913, at Black Mountain, N. C., nymphs of the second form (*flavipes*) taken in a small decaying oak branch on the ground greatly outnumbered nymphs of the first form, although usually the latter is by far the more numerous form.

Due to the wandering habits of species of this genus, it is difficult to estimate the size and extent of an old, well-established colony, which may branch out over several acres of ground.[a] However, the number of individuals in well-established, permanent colonies probably runs up into the ten thousands, since from 5,000 to 10,000 (estimated) eggs, scatteringly or in clusters the size of a pea, were found in a large colony of *Leucotermes virginicus* near Chain Bridge, Va., on June 19, 1913. This colony, which was in a large decaying black oak log, consisted of a large number of workers and soldiers, and numerous larvæ.

THE DIFFERENT CASTES—POLYMORPHISM.

In a termite colony there are several different forms, or castes, of mature individuals, as well as those of different castes in the various stages of development. The castes are the workers, the soldiers, the

[a] The spreading out of a colony is largely due to increase in numbers and consequent need of fresh supply of food; that is, decaying wood.

colonizing winged adults of both sexes, the supplementary or neoteinic[a] reproductive forms (often in large numbers), both "ergatoids" and nymphal "neotenes," and the single true royal pair. Besides these mature forms there are freshly hatched, undifferentiated larvæ, differentiated larvæ, and nymphs of the first and second forms. Of course, all these forms are not present in a colony at the same time, as there is seasonal variation.

Workers are developed from larvæ that will not mature the sexual organs, but, unlike the bees, are of both sexes. They are dirty white in color, are large-headed and soft-bodied, with 10 segments to the abdomen, and at maturity are approximately 5 millimeters in length in *flavipes* and 3.5 millimeters in *virginicus*. The antennæ consist of 15 to 17 segments exclusive of the base in *flavipes* and 13 to 15 in *virginicus*. The workers constitute the most injurious wood-destroying form and have well-developed mandibles. The left mandible has five pointed teeth, the fifth tooth with a broad base, and the inner margin having parallel carinæ. The right mandible has two pointed teeth, the third and fourth teeth being broad, and the fourth with parallel carinæ. The mandibles evidently have both tearing and rasping functions. The labrum is rounded. The worker termites possess a large intestinal paunch and the contents enable the outline of this paunch to be seen through the tissue of the abdomen. Workers are blind.

Soldier termites (fig. 9, *a*) are more highly specialized workers, being also developed from large-headed workerlike larvæ that will not mature the sexual organs, and the caste is represented by both sexes. While they are soft-bodied, the head, which is pigmented yellowish-brown, is chitinized and is more oblong and elongate than in the worker, tapering slightly toward the apex, or being slightly broader at the base. The mandibles, which are enormously developed, are long, slender, saberlike, with no marginal teeth, chitinized, and of a yellowish-brown color. The body is of a dirty white or pale yellowish color. The labrum of the soldier is more narrow than that in the worker, elongate, and subelliptical. The "menton," which is chitinized, is convex, elongate, and more slender in comparison with the worker. Mature soldiers are from 6 to 7 millimeters in length in *flavipes* and 4.5 to 5 millimeters in length in *virginicus*. The antenna has from 14 to 17 segments in *flavipes* and 15 segments in *virginicus*. The soldiers, as well as the sexed adults, of these two

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[a] Grassi, B., and Sandias, A. Op. cit., p. 249: "The term neoteinia has been introduced by Camerano (Bul. Soc. Ent. Ital. [v. 17], 1885, pp. 89–94) to denote the persistence during adult life of part or all of the characteristics normally peculiar to the immature, growing, or larval stages. * * * Neoteinia, or the persistence of larval characteristics, does not necessarily imply that anticipation of sexual maturity which is usually connoted with the use of the term pædogenesis, which, moreover, is strictly applied to agamic reproductions."

species can be differentiated. The soldiers, like the workers, are wingless and blind. Individuals of both castes complete their development in less than a year.

The nymphs of the reproductive form develop from larvæ that will mature the sexual organs. The term "nymph" is applicable,

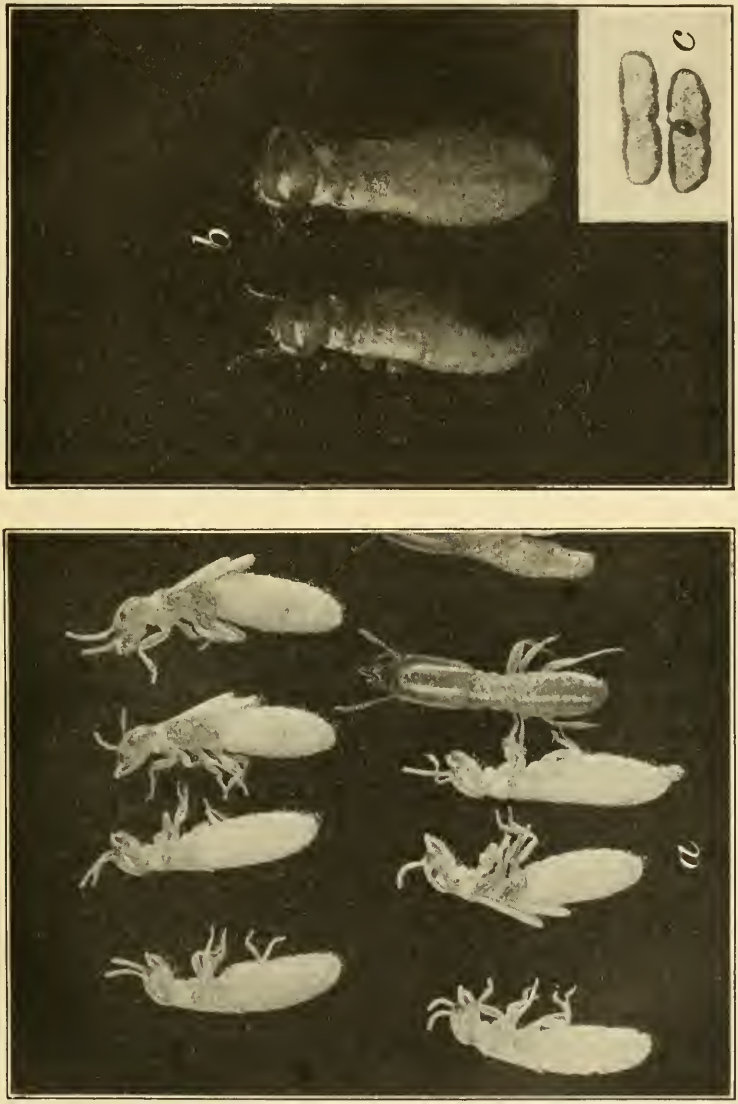

FIG. 9.—*Leucotermes virginicus*: *a*, Nymphs of the first form, and soldiers, Maryland, May 18, 1912; *b*, young nymphs, Maryland, May 18, 1912; *c*, view of brownish-black bands on dorsum of the abdomen of worker (enlarged 20 times); these bands occur on both *flavipes* and *virginicus*. (Original.)

according to Lespès and Hagen, to individuals "with the wing-rudiments easily distinguishable to the naked eye."[a] Individuals the wing-rudiments of which are present, but only distinguishable when under magnification, are termed larvæ. Nymphs are white

[a] Grassi, B., and Sandias, A. Op. cit., p. 264.

and soft-bodied, and when fully developed and ready to molt for the last time are from 7 to 7.5 millimeters in length in *flavipes* and 4.5 to 5 millimeters in *virginicus*. In *flavipes* the antenna consists of from 16 to 17 and in *virginicus* from 14 to 15 segments. The mandibles are practically the same as in the worker, and are probably very necessary in effecting an exit from the old colony. R. D. Grant states[a] that in a Missouri Pacific Railroad Co. engine house the rafters were injured and the cement of the brick walls built 14 years previously was perforated. Mr. C. L. Marlatt has specimens of plaster which was laid on metal lathing in a building at Charlotte, N. C., which had been mined in order to allow the winged adults to escape from heavy wooden beams which had been honeycombed. Also, in the establishment of the new colony the young royal couple have the excavating to do.

There are two forms of nymphs (Pl. VIII, figs. 3, *a*, *b*), namely, the primary form, with elongate wing pads, that develops into the winged sexed adult, and the "second form" (Lespès), with short wing pads—mere buds—which represents an arrested early stage of the nymph of the primary form, or even a larva. Nymphs of the secondary form are slightly more elongate, and develop the sexual organs without progressing further, instead of completing their normal development to the winged, pigmented, sexed adults that swarm. These nymphs, after becoming sexually mature and attaining a straw-colored pigmentation—normally after the nymphs of the primary form have developed to sexed adults—become supplementary royal individuals, kings, and queens, but never (?) leave the parent colony. They do not possess functional eyes.

The sexed individuals, when ready to swarm, are castaneous-black or light brown in color, have two pairs of long, filmy wings, and are so chitinized that they can bear full sunlight. They possess both functional compound eyes and simple eyes or ocelli. The body—excluding the wings, which are slightly longer than the entire insect and project some distance beyond the abdomen when "in situ"—is slightly less in length than in the case of the nymphs. The entire body of the sexed individual is from 9 to 10 millimeters in length in *flavipes* and from 7.5 to 8 millimeters in length in *virginicus*. There are from 16 to 18 segments to the antenna in *flavipes* and from 15 to 16 antennal segments in *virginicus*. The sexes are as easily distinguishable as in the case of fully developed nymphs. "(1) The seventh [abdominal sternite] (the apparent sixth) is strongly developed and semicircular, with the rounded edge posterior in the female and very short in the male. (2) The eighth sternite, which is reduced to two lateral lobes in the female, is small and entire in the male.

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[a] Grant, R. D. Jour. Proc. Acad. Sci. St. Louis, v. 3, p. cclxix, November 19, 1877.

FIG. 1.—*a*, Lateral view of fully developed nymph of primary form; *b*, lateral view of neoteinic king—compound eyes without pigmentation.

FIG. 2.—Dorsal view of same: *a*, Showing pubescence and tapering abdomen of neoteinic king; *b*, nymph of the primary form.

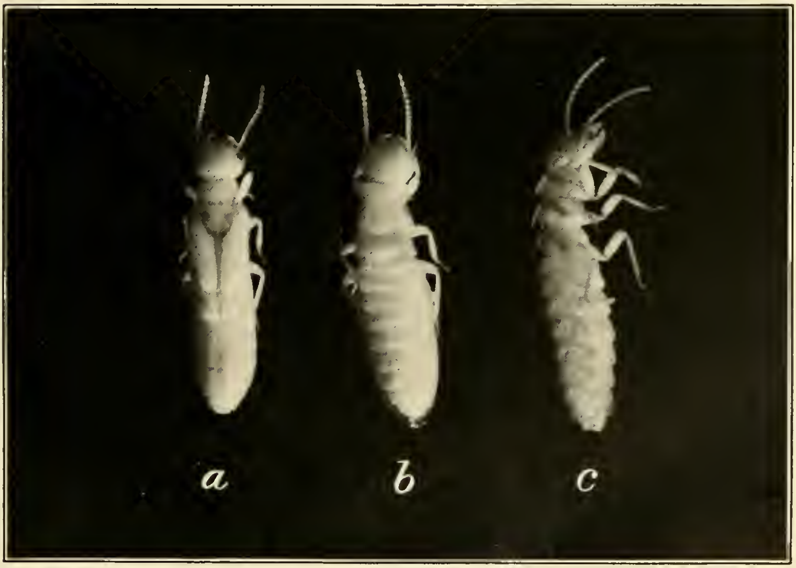


FIG. 3.—*a*, Fully developed nymph of the first form with elongate wing pads before final molt; *b*, nymph of the second form with short wing pads before final molt; *c*, neoteinic king after final nymphal molt. (Original.)

STAGES OF LEUCOTERMES FLAVIPES.

(3) The ninth sternite nearly resembles the eighth."[a] The genital "appendices" in the male are attached to "what is apparently the eighth, but is really the ninth sternite, the first being fused with the metasternum."[b] There are two segmented appendages, or cerci, attached to the abdomen. After swarming, the sexed adults become royal individuals.

Larvæ, or young, are undifferentiated individuals which, after further development, attaining chitinization and pigmentation, change to differentiated individuals. The larvæ, like all the other stages of termites, are active. When young or freshly molted the individuals are more transparent and white and the segmentation of the body at this stage is more sharply defined. "The younger the individual, or the more recent its ecdysis, the thinner is the chitin."[c] The term larva is applied (1) to any individual which has not yet attained full size, mature chitinization, and pigmentation; (2) in the case of the sexed individuals, to those with the wing-rudiments not easily distinguishable to the naked eye; and (3) in case of the soldier, to the large-headed, undifferentiated, workerlike forms.

The eggs are white, slightly reniform, and those laid by true queens (queens that have swarmed) are approximately 1 millimeter in length in *flavipes*. The eggs are usually found in clusters or scattered singly in the galleries.

THE SENSE ORGANS.

Termites are essentially subterranean in habit and in consequence all castes of Leucotermes are blind except the colonizing individuals. The soldiers have compound eyes, but without pigmentation; in some neoteinic royal individuals the pigmentation of the compound eye is not visible to the naked eye (Pl. VIII, fig. 2, *a*), but in most cases there is a slight pigmentation of variable intensity. All castes except the colonizing individuals shun the light.

Although blind, termites are known to possess other sense organs.[d] The antennæ are important tactile sense organs, and often individuals may be seen feeling their way by means of these appendages. The antennæ of the colonizing individuals are pitted, and from these pits, which appear as white depressions on the pigmented antennal segments, prominent hairs arise. A. C. Stokes, in an article entitled "The sense organs on the legs of *Termes flavipes* Koll.,"[e] describes

[a] Grassi, B., and Sandias, A. Op. cit., p. 306.

[b] Ibid., p. 271.

[c] Ibid., p. 256.

[d] Müller, Fritz. Beiträge zur kenntniss der Termiten. Jenaische Ztschr, Bd. 9 (n. F. Bd. 2), p. 241–264, pl. 10–13, Mai 8, 1875. See p. 254, pl. 12, figs. 32, 34.

[e] Stokes, Alfred C. The sense-organs on the legs of our white ants, *Termes flavipes* Koll. Science, v. 22, no. 563, p. 273–276, illus., November 17, 1893.

and figures "sensory hairs"; "sensory pits"; "tibial spurs with prominent basal apertures, across which extends a delicate membrane (auditory organs?)"; "pilose depressions"; "surface markings"; etc. Grassi[a] mentions tactile, "very long, fine, readily vibratile hairs" on the body, and states that the cerci also appear to be "essentially tactile." It is believed that there is a relation between the convulsive movements frequently observed, that is, the sudden jerking of the whole body, and these sense organs, and that individuals are thus enabled to communicate, or at least give danger or distress signals. The convulsive movements made by the workers and soldiers, when the royal pair are disturbed in the cell, are very violent and indicate great agitation.

There is a characteristic musty or acrid odor which can be easily detected in colonies of Leucotermes, and individuals frequently can be seen to follow directly in the path taken by others, but as termites usually travel in well-worn channels this may be due to tactile sense alone.

THE FUNCTIONS OF THE CASTES.

The social economy of termites is somewhat similar to that of other social insects, although in many respects totally different. Undifferentiated young hatch from the eggs, are active, and in turn transform to the differentiated individuals of the castes after a series of quiescent stages and molts.

As the name implies, the workers are those individuals that make the excavations, extend the colony, and care for and protect the royal couples and young.

The soldiers, more highly specialized workers, are of less importance functionally than the workers—just as the anther transformed to the petal in the common pond lily, *Castalia* sp., is less important functionally than the other anthers—yet both serve a purpose. Just before the time of swarming, the members of colonies become restless, and as the sexed adults emerge numerous workers and soldiers congregate on the outskirts of the colony near the exit holes with heads toward the exterior. The duty of the soldiers is apparently entirely protective, but they do not appear to be very effective, at least when the colony is opened and they are exposed to the attack of ants, etc.

The pigmented, winged, sexed adults, developed from nymphs of the first form, are the colonizing individuals which swarm in enormous numbers in the spring and found the new colonies, and when finally established at the head of a new colony, which they have reared, they become the royal couple. Unlike other social insects, the male continues to live, even after the fertilization of the female, and the king and queen inhabit the royal cell together, there

[a] Grassi, B., and Sandias, A. Op. cit., p. 267–269.

being repeated coition. Termites are sometimes polygamous, at least in incipient colonies. The young queens care for the young and carry the newly hatched larvæ in their mouths to safer places in the nest when the colonies are disturbed. (Nymphs of the first form also have been seen performing this duty in old colonies.) The workers attend the larvæ in old colonies.

In the life cycle of termites, however, there is so much variation in the development of the castes that it leads to a rather complex life history. Young are kept in a retarded, undifferentiated state and can speedily be turned into substitute reproductive forms of both sexes. These neoteinic royal individuals are used (1) as substitutes for the true royalty that have swarmed and (2) in splitting up the old colony into new and independent colonies. Fully developed nymphs of the second form are to be found in colonies in the spring. They never complete their normal development, which consists of the acquisition of wings and the mature pigmentation, but assume the characteristic pale straw color after the final molt. The sexual organs are developed after the acquisition of pigmentation. They become neoteinic reproductive forms, but always (?) remain in the parent colony.

Each caste has a distinct function, there being a well-defined division of labor, which, however, is not strictly adhered to. Termites properly represent the phenomenon of polymorphism, i. e., "species in which one or both of the sexes appear under two or more distinct forms,[a]" both sexes being equally polymorphic.

THE LIFE CYCLE.

THE METAMORPHOSIS—CASTE DIFFERENTIATION.

The metamorphosis of termites, while formerly considered to be a contrastingly simple type of insect development, is in reality very complex; indeed, there may be said to be different types of development for the castes. In the development of the worker, as in the order Thysanura, there is no external change or metamorphosis, the freshly hatched worker larva being active and of the same form as the adult worker. In the development of the soldier, however, marked changes in form occur, the mature soldier, with pigmented head and saberlike mandibles, being developed from a large-headed, white, workerlike larva (Pl. IX). The winged, pigmented, sexed adult is developed from a small-headed, white larva, there being a still more radical change. However, what may popularly be termed the "antlike" form can be distinguished in all stages in the development of all the castes, hence termites can hardly be classed with insects with "complete metamorphosis" as the true ants, where there

[a] Wheeler, W. M. Concerning the polymorphism of ants. Bul. Amer. Mus. Nat. Hist., v. 23, p. 50–93, 6 pls., January, 1907. See p. 50.

are the three successive stages of larva, pupa, and adult, although termites pass through pupalike "quiescent" stages in the molting of larvæ and nymphs, with temporary periods of inactivity. Furthermore, great variation is possible in the metamorphosis, as is seen in the development of "neoteinic" or "supplementary" reproductive forms, as the "neotenes" and "ergatoids." Therefore, in general, termites may be classed with insects having "incomplete metamorphosis," as the locusts and roaches. In this type of development the form of the body is always essentially the same as that of the adults. The development of the larva and nymph to the winged sexed adult termite greatly resembles the development of the locusts and roaches.

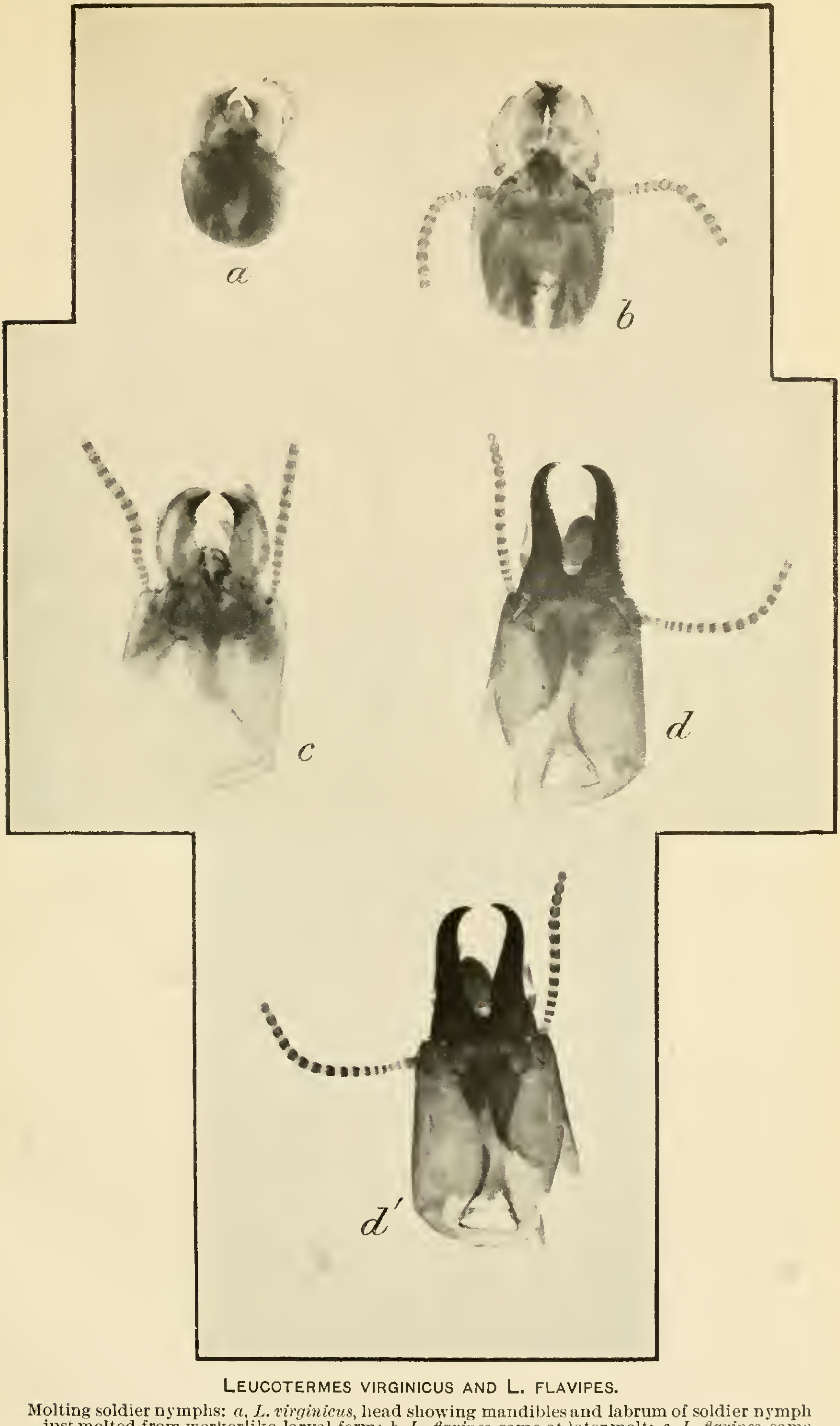
In the genus Leucotermes there is no apparent metamorphosis in the case of individuals of the worker caste. The freshly hatched worker larva is active, there being a very simple development. The

FIG. 10.—*Leucotermes flavipes:* Quiescent stage of molting larvæ. Enlarged 10 times. (Original.)

change from larva to adult is a gradual growth, the white, large-headed larva passing through a series of quiescent stages and molts. The adult worker is of a dirty grayish-white color. In the soldier caste and the reproductive forms the metamorphosis is more complicated, and marked changes in form occur during the development. Young molting larvæ in the "quiescent stage" [a] were first observed by the writer on August 11, 1911, near Jerseyville, Ill., in a large, wide, longitudinal channel in the decaying heartwood of the butt of a white cedar telegraph pole.[b] Previous to the molt the larva falls over on its side and passes through a quiescent stage, the head being bent down to lie on the ventral side of the body along which the antennæ and legs, also, lie extended in a backward direction. This gives the larva the appearance of being doubled up (fig. 10). After the skin has been shed the larva resumes its normal activity.

[a] Strickland, E. H. Loc. cit.

[b] Snyder, T. E. Changes during quiescent stages in the metamorphosis of termites. Science, n. s., vol. 38, No. 979, pp. 487–488, October 3, 1913.



LEUCOTERMES VIRGINICUS AND L. FLAVIPES.

Molting soldier nymphs: *a*, *L. virginicus*, head showing mandibles and labrum of soldier nymph just molted from workerlike larval form; *b*, *L. flavipes*, same at later molt; *c*, *L. flavipes*, same at later molt; *d*, *L. flavipes*, mature soldier; *d′*, ventral view showing convex, slender, chitinized, pigmented "menton." Photograph from specimens in balsam slides. Enlarged 16 times. (Original.)

The antennæ increase in the number of segments by the subequal division of the third segment [a] independent of the molts in *L. lucifugus* Rossi.

In the metamorphosis of the soldier, as has been shown by Grassi [a] (*Calotermes flavicollis* Fabricius and *Leucotermes lucifugus* Rossi), Knower [b] (*Eutermes* sp.), and Heath [b] (*Termopsis angusticollis* Walker), there is a radical change from a large-headed larva to the soldier caste. This change takes place during [c] a quiescent stage. The worker, like the soldier, also develops from a large-headed larva; that is, in the colony there are two types of larvæ, the large-headed and small-headed, the former normally developing to workers and soldiers, while the latter become the reproductive forms. According to Grassi there are four molts in the development of the asexual forms of *Leucotermes lucifugus*, whereas the sexed forms pass through five molts. Holmgren states [d] that in Leucotermes the soldiers are polymorphic and originate [e] from at least five different larval stages, while the polymorphic workers originate from three different larval forms. The undifferentiated larvæ present possibilities of development in all directions, but the development of Leucotermes shows that the breeding possibilities, while great, are by no means so great as in Calotermes. This would indicate progressive development toward stability, as is also indicated by the absence or rarity of neotenes and ergatoids in the more highly developed termites (Termes and Euter-

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[a] Grassi, B., and Sandias, A. Op. cit., p. 270.

[b] Op. cit.

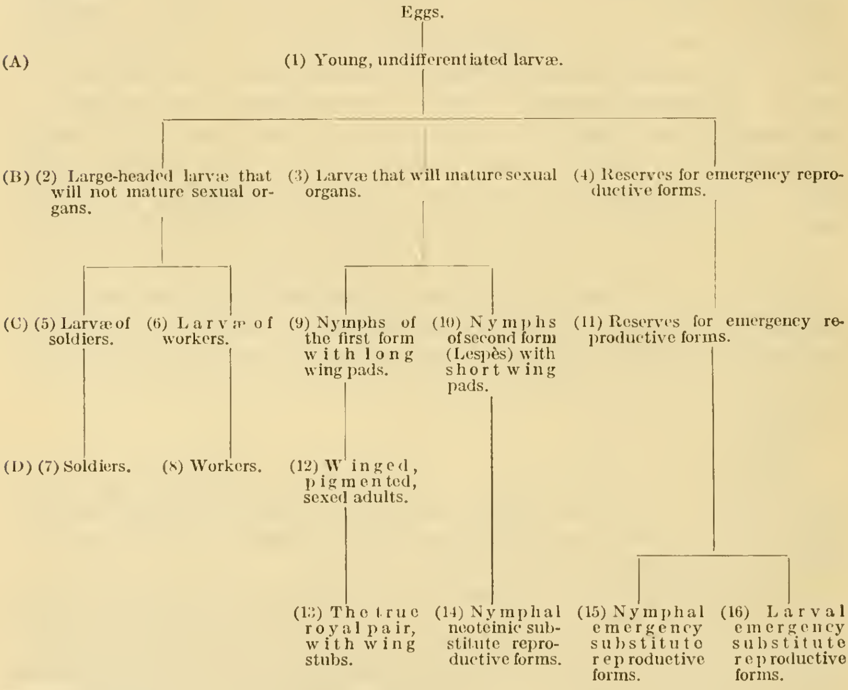
[c] Snyder, T. E. Loc. cit.

[d] Holmgren, N. Termitenstudien 3. Systematik der Termiten—Die Familie Metatermitidæ. K. Svenska Vetensk. Akad. Handl., Bd. 48, No. 4, pp. 166, 4 pls., Uppsala and Stockholm, 1912. Blick auf dem mutmasslichen, stammesgeschichtlichen Entwicklungsverlauf der Termiten, p. 129–153.

[e] The recent discovery by McClung, Stevens, and Wilson (Wilson, E. B., Heredity and miscroscopical research: Science n. s., v. 37, No. 961, p. 814–826, May 30, 1913) of the association of an odd number of chromosomes, in the divisions of the spermatocytes—that is, cells formed by the division of the "spermospore," the male germinal cell—with the determination of sex may also be applicable to caste differentiation in termites. Wheeler (Wheeler, W. M., The polymorphism of ants, with an account of some singular abnormalities due to parasitism: Bul. Amer. Mus. Nat. Hist., v. 23, p. 1–93, pls. 6, Jan., 1907), however, states, with reference to ants, that nourishment, temperature, and other environmental factors merely furnish the conditions for the attainment of characters predetermined by heredity, that is, with Weismann he believes that the characters that enable us to differentiate the castes must be represented in the egg, but with Emery he believes the adult characters to be represented in the germ as dynamic potencies or tensions rather than morphological or chemical determinants. Holmgren states (op. cit., p. 140) that in termites, as the result of the method of feeding, three potential germ plasms are released in at least three directions * * * and that there must be a germ plasm correlation which finds its expression in the caste correlation.

mes), wherein, however, there may be several true queens [a] in the one colony and where polygamy exists. In insects supposed to represent the most primitive, or lowest and least developed, types this is a rather complex metamorphosis. Here also there is much variation in the life cycle and no strict rule is followed. (See chart.) Apparently the individual development is entirely subservient to the needs of the colony. This ability of adaptation of individual to circumstance leads to a complex economy.

A representation[1] *of some of the successive stages in the development of the various forms or castes in the life cycle of Leucotermes flavipes Kollar as found in colonies in the eastern United States. All these reproductive forms are not present in the same colony at the same time.*



[1] See correlated forms of *Leucotermes lucifugus* Rossi. Grassi, B., Ein weiterer Beitrag zur Kenntnis des Termitenreiches. Zool. Anz, Bd. 12, No. 311, pp. 355-361, July 8, 1889. Übersicht der im Termitenstaate vorkommenden Formen: *Termes lucifugus*, p. 360); id., Ein weiterer Beitrag zur kenntniss der Termitenreiches. Ent. Nachr., Jahrg. 15, No. 14, pp. 213-219, July, 1889; Holmgren, N., Termitenstudien 3. Systematik der Termiten- Die Familie Metatermitidæ. K. Svenska Vetensk. Akad. Handl., Bd. 48, No. 4, p. 148, Scheme B, Uppsala & Stockholm, 1912 (table showing parallel evolution and at what molts changes or development occur).

PROGRESSIVE DEVELOPMENT OF THE NYMPHS.

Colonies of *Leucotermes* spp. in the northeastern United States are dormant during the winter, the insects retiring to the more remote

[a] John, O. Notes on some termites from Ceylon. Spolia Zeylanica, v. 9, pt. 34, p. 102–116, 1913.

Riley, C. V. Termite economy. Proc. Biol. Soc., Wash., v. 9, p. 71–74, April, 1894.

Escherich, K. Termitenleben auf Ceylon, Jena, 1911, p. 45–46.

galleries in the wood or to the subterranean passages of the nests, At Falls Church, Va., in 1912 it was not until March 11, in 1913. February 20, and in 1914, March 23 that signs of activity were observed in colonies of *flavipes*. Nymphs of the first form with "short wings" (Fritz Müller) or "wing pads" (Hagen) were present on March 11, 1912. At this time the wing pads were well developed, being about two and one-half times the length of the segment from which they originated, and had a yellowish tinge. The antennæ consisted of from 16 to 17 segments, excluding the base, and the line of demarcation between the basal segments was less distinct. On March 29, 1912, the ocelli were visible in the nymphs; antennæ, head, and thorax were acquiring a tinge of yellowish-brown, and the compound eyes were becoming pigmented—a reddish-brown. On April 18, 1912, and April 8, 1913, at Falls Church, Va., nymphs of the first form when fully developed and ready for the final molt could be readily distinguished by the opaqueness of the elongated wing pads, the filmy, yellowish-brown, loosening skin, which becomes separated from the body, particularly posteriorly, and the reddish-brown pigmentation to the compound eyes. (Pl. VIII, fig. 1, *a*.) The nymphs gradually increase in size and pass through a series of molts and quiescent stages until the final molt, when the wings are unfolded. Packard, who figures [a] the stages in the growth of the wing in *flavipes*, states that the wings are simply expansions. During the latter part of April, 1912, nymphs with short wing pads, or those of the second form (Lespès) (Pl. VIII, fig. 3, *b*), were found in colonies. Their antennæ had from 16 to 17 segments. These nymphs appear to be more active than nymphs of the first form and have but slight pigmentation of the compound eye.

During the final molt—which occurred from April 18 to 27, 1912, April 8 to 17, 1913, and April 22 to May 2, 1914, at Falls Church, Va., in case of the nymphs of the first form (*flavipes*)—nymphs of both the first and second forms pass through a "quiescent stage" [b] (Pls. X and XI), which closely approaches the pupal stage of insects with complete metamorphosis. This quiescent stage apparently serves the same purpose as the pupal stage, since the most marked changes, both external and internal, take place during this molt; it is, however, of short duration. On April 18, 1912, the first nymphs (*flavipes*) in this stage were observed in the outer layers [c] of a decaying stump. All of the nymphs in this colony were fully developed, but very few had

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[a] Packard, A. S. A textbook of entomology. New York, 1903, p. 140.

[b] Strickland, E. H. Loc. cit.

[c] Larvæ or nymphs in the quiescent state are usually to be found isolated in small but deep, transverse conical nitches or shelves in the nest where they are not liable to disturbance by the movements of the other members of the colony. Possibly they seek out such secluded places, usually near the outlying galleries, beforehand, or may be carried there while helpless, by the workers. Clusters of eggs are also found in similar nitches.

yet begun to molt. A large number were placed in a covered tin box $3\frac{1}{2}$ by 5 by $1\frac{1}{2}$ inches, with disintegrated wood and moist earth in the bottom. This was to be a check box, and the conditions here were more natural than in the small corked vials, in which over 100 other nymphs had been kept in the dark, one nymph to each vial. The development of each nymph was watched and the time necessary for the various changes from nymph to adult was noted. On June 8 fully developed nymphs of *virginicus*, with opaque wing pads, were observed to molt in a similar manner. Nymphs in all stages described for *flavipes* were observed molting until June 11.

As E. H. Strickland has already figured and described these changes in the nymphs of the first form (*flavipes*), his accurate description is here quoted in detail, with a few comments. Until this description appeared, the quiescent stage in the development from nymph to adult for this species was undescribed. His observations were made from nymphs collected in the neighborhood of Boston, Mass., May 7, 1910.

The mature nymph becomes very sluggish and finally all movement ceases; it then falls over on its side and the head is bent down till it lies on the ventral side of the body, along which also the antennæ and legs are extended in a backward direction, * * * while the wing pads are bent downward till they lie laterally along the sides of the body. * * * It will be at once noticed that while in tnis position the nymph is to all appearances a quiescent "pupa libera." There does not appear to be an ecdysis immediately prior to this quiescent period, however, so I would hesitate to describe it as a true pupal state though it undoubtedly has the same physiological function.

This quiescent stage lasted in the few specimens observed for a period varying from four to about nine hours.[a] The duration in time seems to be controlled to a large extent by the amount of moisture in the earth surrounding the pupa for when specimens were placed in perfectly dry earth they were unable to pass beyond this stage of development,[b] while the greater the amount of moisture, the shorter the period. During this stage the last nymphal skin splits across the head and along the dorsum, and is slowly worked downward and backward till a large portion of it hangs freely from the apex of the abdomen on the ventral side. The legs are the last part [c] of the body to be freed from this skin, which then becomes detached as a much crumpled mass. As soon as the wings are liberated they begin to move away from the body at their base. This is apparently due to the tracheæ in the basal portion of the wing becoming inflated. The inflation, however, does not extend beyond the suture along which the wing is subsequently broken off, and the distal portion remains tightly folded. * * *

The ecdysis described above is the last in the development of the imago, for the insect now disclosed is the sexually complete[d] adult; it does not, however, become

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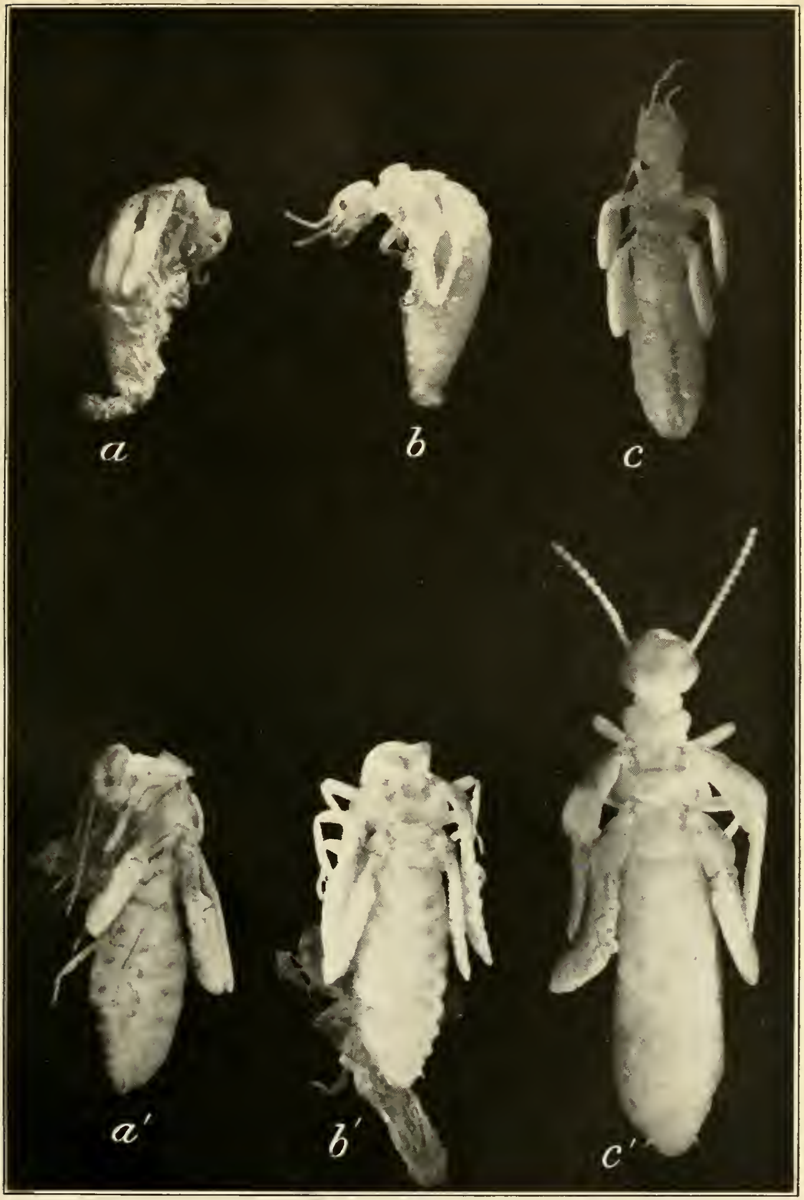
[a] Varying from about $3\frac{1}{2}$ to 12 hours at Falls Church, Va.—T. E. S.

[b] A considerable amount of moisture apparently is essential to normal development. Specimens placed in small, individual, corked vials molted normally, while others placed in vials the mouths of which were lightly plugged with cotton developed abnormally, with distortions, or not at all.—T. E. S.

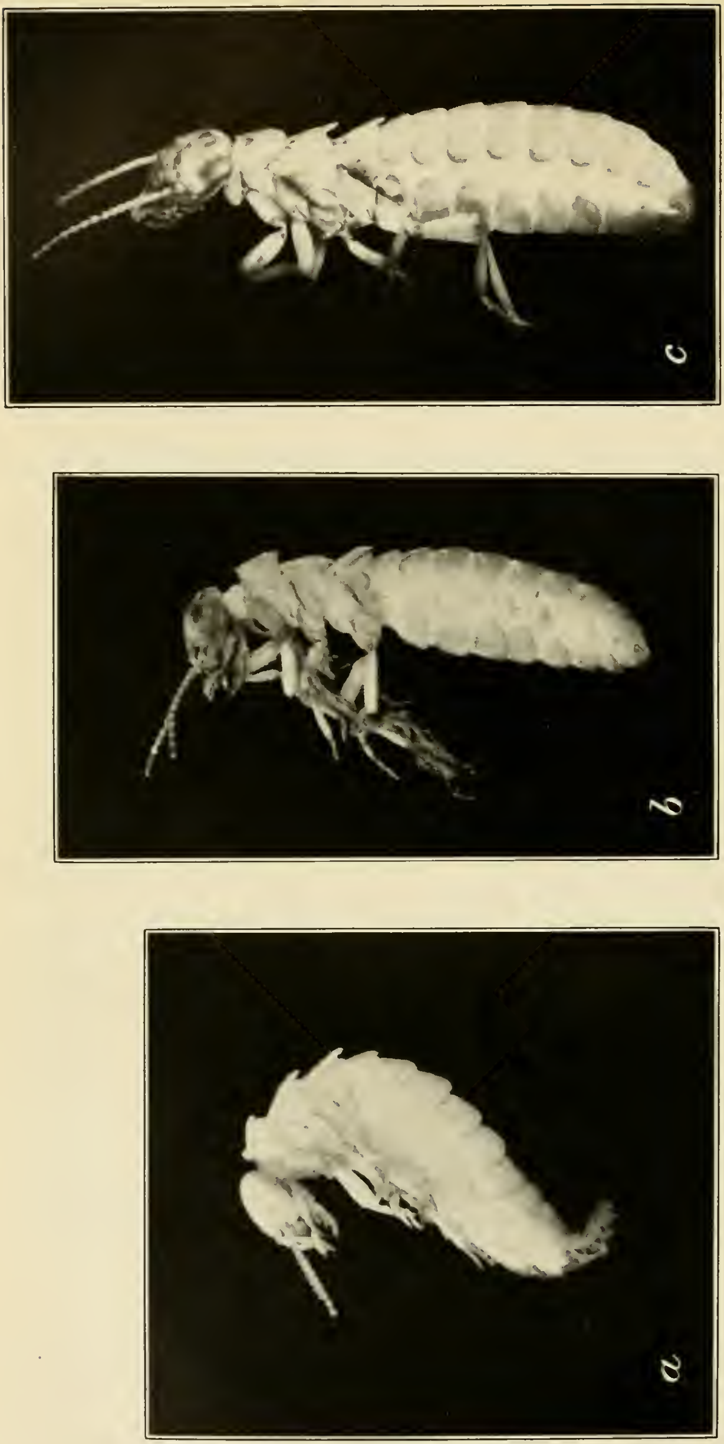
[c] Sometimes the antennæ are the last part to be freed of the cast skin in case of nymphs of both the first and second forms.—T. E. S.

[d] At this stage the sexual organs are not yet fully functionally matured.—T. E. S.



LEUCOTERMES FLAVIPES.

a and b, Lateral views of the quiescent stage of nymphs of first form; c, dorsal view of active molted nymph showing how wings are held away from the body. Photographs from etherized specimens. a′, Lateral view of quiescent stage of nymphs of the first form (skin cast); b′, dorsal view of same; c′, active molted nymph of first form with wings unfolding. From alcoholic specimens. (Original.)



LEUCOTERMES FLAVIPES.

a, Quiescent stage of molting female nymph of second form; *b*, molted male nymph of second form or neoteinic king—cast skin still attached to legs; *c*, mature neoteinic king not sexually mature and just molted. (Original.)

active as soon as it emerges but remains for about a quarter of an hour in the same position as that in which the ecdysis occurred. During this time, however, the head is slowly drawn upward to its normal position and the insect finally struggles to its feet. Its movements are at first very awkward and uncertain but after a few minutes it is actively running about. As before mentioned, the greater portion of the wings remains closely folded together so that at first sight they appear as abnormally placed wing-pads. A close examination with a hand lens shows them to consist of the very compactly folded wing. * * *

After these young adults have been running about for an hour or so the main portion of the wing begins to expand; the basal portion becomes expanded before the apical part begins to unfold, but the inflation gradually works toward the apex till the typical fully winged though pigmentless adult is produced. The wings continue to be held away from the body till this process is complete, after which they are folded from the base in an overlapping position over the abdomen. The ensuing pigmentation of the body is gradual[a] and does not appear to be affected by the presence or absence of light; the entire body turns black through shades of yellow and brown till in about twenty-four hours the sexually complete imago is ready for swarming.

FIG. 11.—*Termopsis angusticollis:* Quiescent stage of nymph of the first form. Enlarged 7 times. (Original.)

It will be seen that the whole period intervening between the normal nymphal stage and the typical pigmentless adult stage[b] occupies only some nine to ten hours, and this apparently accounts for its not having been recorded before, even though it appears to be perfectly normal,[c] for it has occurred in different localities in two successive years and all nymphs taken passed through these stages before completing their development.

An illustration of the thorax of *Leucotermes flavipes* with unexpanded wings was given by Packard in his Text-book of Entomology, but he here described it as a late nymphal wing pad, otherwise there seem to be no references to either of the stages herein figured and described.

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[a] The borders of the chitinized parts first take on pigmentation, passing through shades of gray to castaneous to the castaneous-black of the mature adult, the abdomen being the last to take on pigmentation; there are often abnormalities in development.—T. E. S.

[b] The whole period intervening between the fully developed nymph and the mature pigmented adult is about one day and one-half to two days for individuals, and about 1 week to 10 days for the colonies.—T. E. S.

[c] These stages are absolutely normal and necessary to the progressive development of nymphs of species of both the genera Leucotermes (*L. flavipes* and *virginicus*) and Termopsis (*angusticollis*) (fig. 11).—T. E. S.

During this final molt the females of nymphs of both the first and second forms normally lose the genital appendices;[a] that is, the genital appendices are present in nymphs of both sexes before this molt, but afterwards only in mature winged males and supplementary kings, developed from nymphs of the second form; these appendices can be readily seen on the cast skins. In egg laying complementary queens of *Termopsis angusticollis* (with no indication of wing pads), genital appendices were present, though absent in true queens.

On April 25, 1912, at Falls Church, Va., molting nymphs (*flavipes*) of the second form were found. The progressive development of over 100 nymphs was noted, and apparently the molting is similar to that of nymphs of the first form. Before the quiescent stage is reached, the nymphs assume a straw-colored hue. Various stages of molting nymphs were observed through April 28. After the molt, the head and prothoracic segments darken, especially on the borders. The abdominal segments also darken. Sometimes there are grayish-black, longitudinal, pigmented markings on the head. Some of the nymphs have very short wing pads, mere buds, while in others the wing pads are more elongate, the pair on the metathorax reaching down to and slightly overlapping the (apparent) second abdominal tergite. This difference can be seen in supplementary or neoteinic reproductive forms and illustrates the fact that the growth of nymphs of the first form is arrested in various stages of development, as does (?) the presence of genital appendices in complementary queens of *Termopsis*.

Sometimes, due to unfavorable moisture conditions, there is an abnormal development of nymphs of the first form. Individuals may be observed with partial pigmentation to the chitinized parts, acquired before the quiescent stage or before the wings are unfolded; that is, the wings may be in various stages of development, from the opaque-colored, elongate wing pads to partially unfolded, or unfolded but still crumpled, wings. There is great individual variation in the manner of molting. Adults with mature body pigmentation but with distorted, poorly developed wings, or even with opaque wing pads, have been observed emerging from the parent colony at swarming time. A swarm[b] of *flavipes* occurred at Falls Church, Va., on May 8, 1912, and another on April 25, 1913, while in the case of *virginicus* the swarm occurred on June 1, 1913.

This quiescent stage, or "Ruhestadium," has been described by Hagen.[c] He states (in regard to the final molt of nymphs of the first form) that the skin bursts on the prothorax; and in order to

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[a] Grassi and Sandias. Op. cit., p. 306.

[b] It is from 7 to 10 days after the last sexed adults in colonies have acquired wings and mature pigmentation that the swarm occurs.

[c] Hagen, H. A. Monographie der Termiten. Linnaea Entomologica, v. 12, p. 337–338, 1858.

get out of the old skin, the insect doubles up. The insect lies on the ground during the molt. Grassi, while he did not describe this stage, knew that during certain ecdyses in the development of nymphs and soldiers important changes took place. Odenbach, January 13 to 24, 1896, observed in an artificial nest indoors (manuscript notes) molting larvæ of *flavipes* in the quiescent stage, as if dead. He states that the molting process lasts three and one-half hours, that workers assisted, and that the skin is eaten. His observations are practically the same as those of Strickland. Holmgren describes this stage in the larva of *Rhinotermes taurus* Desneux, Escherich[a] figures larvæ of *Termes obscuripes* Wasmann, and Bugnion[b] figures a soldier of *Termes horni* Wasmann in this quiescent stage. Holmgren was the first to state that a quiescent stage occurs in connection with each molt, and to note the internal as well as external changes that occur during these molts.

The writer has observed quiescent stages of undifferentiated (?) larvæ, larvæ of nymphs of the first form, nymphs of the first and second forms, and larvæ of workers and soldiers of *Leucotermes flavipes* and *L. virginicus* and soldiers and nymphs of the first form of *Termopsis angusticollis*.[c] Differentiated nymphs of the first form of *L. virginicus* only 2.5 mm. in length have been observed. Bugnion states[d] that since he has found nasuti larvæ of *Eutermes lacustris* Bugnion 1.3 mm. in length he believes that the differentiation is effected in the embryo for the three castes. The young nasutus with the distinct "corne frontale" is figured. This is not at all in accordance with Knower's statements and drawings of the development of the nasutus of Eutermes (rippertii?) which developed from a worker-like larva, and with Grassi's description in *Calotermes flavicollis* Fabricius and *Leucotermes lucifugus* and the writer's description in *L. virginicus* of the development of soldiers from worker-like larvæ. Bugnion further states[e] that in the higher termites the differentiation of caste reaches perfect expression.

Observations by the writer of molting soldier larvæ of *Leucotermes* spp. show that the differentiation takes place during a "quiescent stage" rather late in the life cycle.

From the first to the middle of August, 1913, freshly molted pigmentless soldier nymphs of *flavipes* in the stage preceding maturity were noticeable in colonies in Virginia. From the middle of June

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[a] Escherich, K. Op. cit., p. 43.

[b] Bugnion, E. Le Termes Horni Wasm. de Ceylan. Rev. Suisse Zool., t. 21, no. 10, p. 299–330, pl. 11–13, juin, 1913. See p. 305–309.

[c] Snyder, T. E. Loc. cit.

[d] Bugnion, E. Les termites de Ceylan. Le Globe: Memoires Soc. Geog. Geneva, t. 52, p. 24–58, 1913.

[e] Bugnion, E. La differenciation des castes chez les Termites [Nevr.]. Bul. Soc. Ent. de France, 1913, no. 8, p. 213–218, April 23, 1913. See p. 217.

to the first part of July, 1914, molting large-headed soldier larvæ and nymphs of *Leucotermes flavipes* were found in colonies in Virginia. After the first part of July freshly molted, pigmentless nymphs of soldiers were common in colonies. On August 17, 1913, molting soldier larvæ were found in the quiescent stage in a colony of *virginicus* at Chain Bridge, Va. During the quiescent stage differentiation took place. Larvæ to all external appearances undifferentiated or of the worker type (as shown by the head, mandibles with marginal teeth, and labrum of the still adhering larval skin), the individuals (*virginicus*) being over 3 millimeters in length, in the quiescent condition, develop at this molt to pigmentless nymphs of soldiers (Pl. IX, *a*), with more elongate, soldier-like head, and mandibles without marginal teeth. In this stage the head, mandibles, labrum, and "menton" (Bugnion) have not attained the shape or length of those of the mature soldier, there being at least one later molt to maturity. After the first radical change, the head is not pigmented (the only pigmentation being at the inner margin at the tips and base of the mandibles, and at the tips of the maxillæ), not elongate, rounded, tapering toward the base (broad at apex), the mandibles shorter and broadening at base. The labrum is elongate, subelliptical, tapering at apex and slightly at base, wider than in the mature form; the "menton" is convex, tapering toward base, wider than in the mature form. The antennæ have 14 segments.

After the next molt the nymph is as yet shorter than at maturity, being from 4.5 to 5.5 millimeters in length in *flavipes*, and the head is more elongate but still broader at the apex, with the mandibles, labrum, and "menton" more elongate and slender. The antennæ have from 14 to 15 segments. At this stage the mouthparts and borders of the antennal sockets are slightly pigmented. (Pl. IX, *b*.) After another molt the full size of the mature nymph is attained and there is pigmentation of the chitinized parts (Pl. IX, *c*), there being three molts from the large-headed, worker-like larva to the mature pigmented soldier. (Pl. IX, *d*.)

It will be noted that there is a gradual elongation of the parts, as the mandibles, labrum, and "menton," and that these parts become more slender and loose in width as the mature form is reached.[a] In this connection it might be of interest to state that in the neoteinic individuals (neoteinic reproductive forms with short wing pads) the head, thoracic segments, and abdominal tergites and sternites are both longer and broader than in the reproductive forms that develop from nymphs of the first form; that is, the structure at this younger retarded early stage is more gross.

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[a] Snyder, T. E. Changes during quiescent stages in the metamorphosis of termites. Proc. Ent. Soc. Wash., v. 15, no. 4, p. 162–165, pl. 6–7, Dec., 1913.

Freshly molted, immature, pigmentless nymphs of soldiers of *Termopsis angusticollis*, obtained from material collected by B. T. Harvey at Ashland, Oreg., August 28, 1913, show the same stages of development. In conclusion, therefore, it may be stated that in case of *Leucotermes* spp. and *Termopsis angusticollis* the differentiation occurs during a molt and quiescent stage rather late in the life cycle of the insect, the larvæ having belonged to all external appearances to the undifferentiated group.

SEASONAL VARIATIONS IN THE COLONY.

There are wide differences in the composition of colonies of Leucotermes at various seasons of the year.

EGGS.

In well-established colonies of *flavipes*, eggs and newly hatched or young larvæ have been found by Hubbard, in Florida, in April, May, and June; by the writer, in Virginia, in April, May, June, July, August, September, and October; in Illinois, in August; and by Odenbach, in Ohio, in September. In incipient colonies, the first eggs are laid, in Virginia, by the middle of June or July in case of *flavipes* and in July or August in the case of *virginicus*. In well-established colonies of *virginicus*, in Virginia, eggs have been found in late May and early June. In cases of artificial nests or colonies of *flavipes*, kept under observation indoors, and in cases of infested buildings, eggs have been found by Odenbach and the writer in January, February, March, April, May, July, August, September, November, and December. Odenbach's nests were from South Brooklyn, Ohio.

In case of both *flavipes* and *virginicus*, in long-established colonies the period of maximum egg production is from the middle of May to early September in Virginia; that is, during the warm months.

NYMPHS OF REPRODUCTIVE FORMS.

Nymphs of the first form of *flavipes* with easily discernible wing pads were found in the quiescent stage of the molt on August 5, 1913, at Veitch, Va. By the middle of September they had well-developed wing pads—two and one-half times the segment from which they originated—and antennæ with from 16 to 17 segments. The nymphs were from 5.5 to 6.5 millimeters in length and the compound eyes had acquired the primary reddish pigmentation. There is apparently an unaccountable annual variation, since in 1913 and 1914 nymphs were very abundant in colonies in the fall, while in 1912 they were comparatively scarce. In March, up through the time of molting, nymphs of the first form are present in the outlying channels of colonies in great numbers.

In incipient colonies nymphs are not produced during the first year that the colony is established, but are developed every year in old, well-established colonies. Nor are nymphs of the first form produced the first year in "orphaned" colonies. Nymphs of the second form are commonly to be found during the latter part of April to early May in Virginia (March in North Carolina), and they occur in varying numbers associated with nymphs of the first form. Nymphs of both forms are well developed by the middle of September of the year in which sexual maturity is attained, in *flavipes*.

Colonizing individuals of *flavipes* appear from the early part of April to May in Virginia and Maryland (earlier in infested buildings). In the case of *virginicus* they do not appear till a month later, or the end of May or early June in Virginia and Maryland. After having attained the mature pigmentation they soon swarm.

The royal individuals of *flavipes*—the pairs of winged sexed adults that have swarmed—are to be found together in the royal cell. In incipient colonies of termites, unlike the other social insects, the male assists in the establishment of the colony and continues to cohabit with the queen, there being repeated coition.

NEOTEINIC REPRODUCTIVE FORMS.

Neoteinic reproductive forms are normally(?)[a] developed from nymphs of the second form after the swarm; the males continue to cohabit with the females. Immature neoteinic reproductive forms are to be found at the time the winged sexed adults are attaining mature pigmentation—the end of April in Virginia. Maturity is probably attained shortly after the swarm, namely, May to June, although mature neoteinic reproductive forms have been found before the swarm.

In case of *virginicus*, neoteinic reproductive forms, produced from nymphs of the second form, are matured, fertilized, and egg laying by July to August. In case of *flavipes*, these reproductive forms are matured by May to June. There is a seasonal variation.

WORKERS.

Workers are always present in colonies except those just established by colonizing sexed adults; they are permanently present in the colony and constitute the most numerous caste.

[a] These forms can be produced at any time necessary. On April 9, 1912, a decaying stump infested with *flavipes* was removed from the forest and placed in the termitarium; this was at a time when the nymphs of the first form were nearly mature. On November 18 the termites had entered the ground and two neoteinic ergatoid(?) forms were found about 3 to 4 inches below the surface in chambers in the earth. No nymphs of the first form were present. They could be distinguished from the workers by the larger size, distended abdomen, straw-colored pigmentation, and sharper segmentation of the abdomen. Rudimentary wing pads were present. The antennæ had 15 to 16 segments. Workers solicited drops of liquid from the female by stroking the abdomen with their palpi.

SOLDIERS.

Soldiers are also always present in colonies, except those just established by colonizing sexed adults, usually a few being present in incipient colonies; they are always relatively much less numerous than the workers. From the first to the middle of August, 1913, freshly molted, pigmentless soldiers of *flavipes* were common in colonies in Virginia, where they were found as late as the middle of October. On August 17, 1913, near Chain Bridge, Va., molting larvæ and nymphs of soldiers of *virginicus* were found.

LOCATION OF THE COLONY IN WINTER.

By the middle of November to December, depending upon the season, termites retreat to the subterranean passages of the colony, the earth under infested logs being riddled by a labyrinth of galleries. In case of very large logs, termites may remain in the more impenetrable inner galleries in the heartwood. In Virginia they remain in this retreat until the last of February or first or last part of March, depending on weather conditions.

Indeed, the center of activity in termite colonies changes with the seasons, due to the varying needs of the colonies as to conditions of warmth and moisture, which are essential to life and development. In spring when there is abundant moisture, open, wooded southern exposures are favorable, and the outlying galleries of colonies are teeming with developing nymphs, whereas during the heat of summer conditions would be too dry. Consequently in summer termites bury themselves more deeply in the wood or earth in less exposed galleries, in moist, shady sites, and in winter usually enter the ground to escape the cold.[a] In autumn, developing larvæ of the castes, and nymphs of soldiers and sexed adults, are to be found in the outlying galleries where the warmth will enable more rapid development. Therefore colonies apparently depleted at certain seasons, at others will be infested. Again, the Leucotermes colony readily migrates, and the site is liable to abandonment if conditions become unfavorable. A single colony may extend to and inhabit several adjacent stumps or trees, and it is often impossible to define the limits of a colony or the line of demarcation between different colonies in a region where termite colonies are abundant and there are many decaying stumps or logs; hence what is apparently a separate colony may be only a branch connected with the main colony by subterranean passages. If colonies are cut into and the reproductive forms removed, the colony quite frequently abandons the nest. The reproductive forms are capable of movement, and it may be that old colonies branch out by means of neo-

[a] As the higher altitudes are attained, termite colonies in the earth under stones are more common; that is, in the North Carolina mountains and in cañons in Arizona.

teinic reproductive forms which eventually establish new colonies. However, this is only a theory, but otherwise what becomes of the large number of nymphs of the second form in colonies in the spring? Surely they are not needed in the parent colony any more than the winged sexed adults, and it may be that they are impelled to leave the colony by the same irresistible force that induces the swarm. However, it is probable that workers and soldiers accompany them from the parent colony and that by means of subterranean passages they establish the new nest. Indeed, these forms may be the nucleus of the small bands of foraging workers and soldiers infesting decaying branches mentioned frequently in literature. The alternative is, of course, that such bands become isolated from the parent colony and rear the reproductive forms. It seems that both methods may be possible and necessary.

DURATION OF DEVELOPMENT AND LIFE.

The eggs of *flavipes* hatch in about two weeks after they are laid. Workers developed from eggs laid on July 15, 1912, were 4.5 mm. in length by the following December, with 13 segments to the antennæ. Both workers and soldiers complete their development within one year.

Definite data on the duration of life of any individuals of Leucotermes, not excluding even the royal pair, are lacking. However, the males or true kings of *flavipes* continue to live with the true queens after copulation, the royal individuals probably living at least five years;[a] neoteinic queens live at least one year and probably as long as true queens. Smeathman conjectures that a queen of *Termes bellicosus* Smeathman when 3 inches long is about 2 years old.

CANNIBALISM.

There are many instances to show that termites are cannibalistic in their habits; all dead or injured individuals are eaten; also, according to Odenbach, larvæ that have difficulty in molting.

It is not at all rare to find, especially in cases of workers, a narrow, grayish band, with black, scalloped, turned-up edges usually on the dorsum of the abdomen, but also sometimes present on the ventral surface and as a plate on the legs. This band is sometimes present on the abdomen of soldiers, and it also occurs on the thorax and head of workers. Possibly these black bands are healed-over wounds where the insects have bitten one another (fig. 9, *c*), or they may be due to a bacterial or fungous disease, or to both wound and disease.

These bands occur on workers and soldiers of both *flavipes* and *virginicus*.

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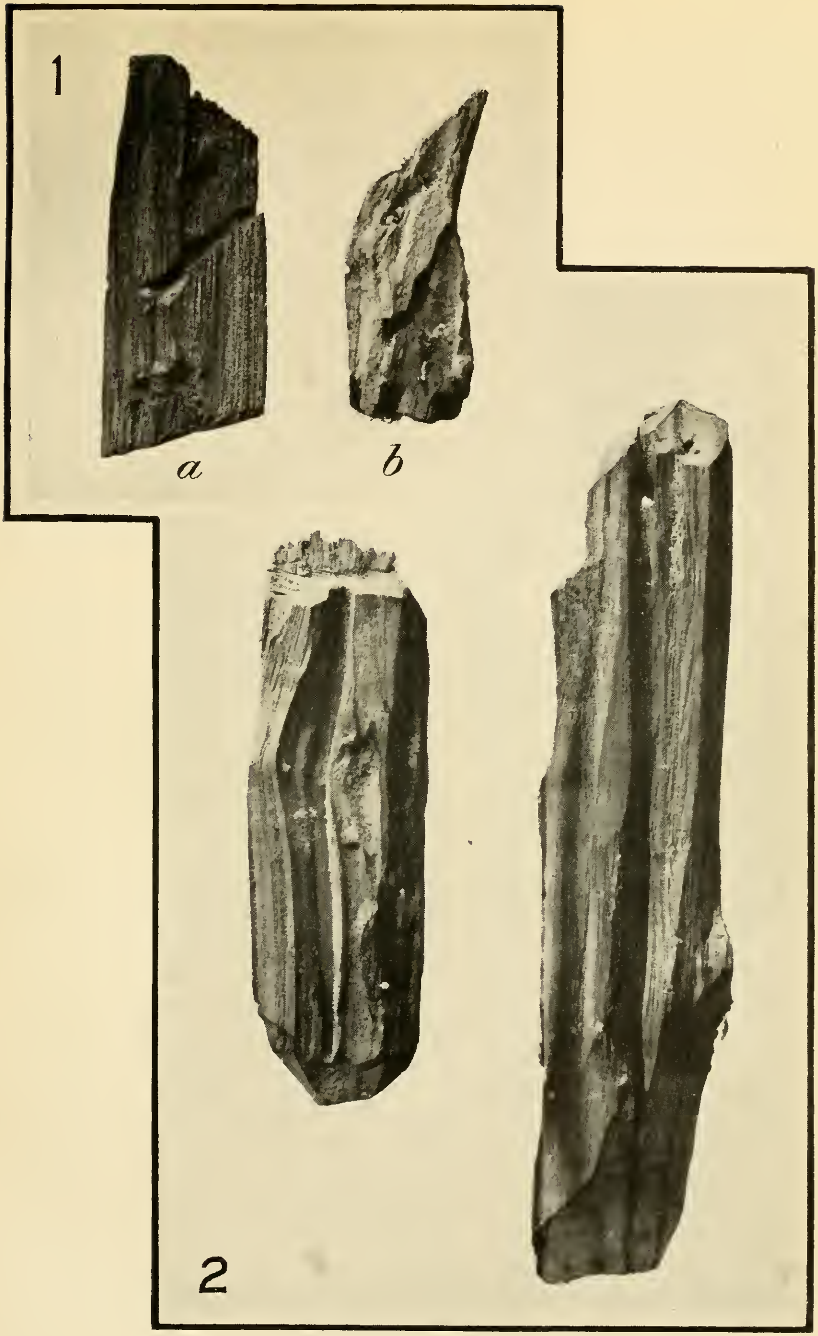
[a] Heath, H. The longevity of members of the different castes of *Termopsis angusticollis*. Biol. Bul., v. 13, no. 3, p. 161–164, August, 1907.



LEUCOTERMES FLAVIPES.

FIG. 1.—*a*, Abandoned burrow of *Lymexylon sericeum* in solid wood of chestnut telegraph pole, in which a fertilized true queen was found; *b*, cell excavated in decaying wood by young royal couple.
FIG. 2.—Royal cell in solid chestnut in which 40 neoteinic royal individuals, for the most part queens, were found. (Original.)

On August 12, 1914, several workers with these bands on the body were taken from a colony of *flavipes* at Falls Church, Va., and placed in a small tin box with decayed wood and earth. Normal soldiers were also placed in the box. On October 2, 1914, the workers with the black bands were still alive and apparently in the same condition; the soldiers had no bands.

Chanvallon, according to Hagen,[a] recommends placing arsenic in termite nests, and since the insects are cannibals and the dead are eaten, a large number can be killed in this manner.

SITUATION OF THE DIFFERENT FORMS IN THE NEST.

The reproductive forms are not necessarily to be found in a "royal" cell situated in the more remote parts of the nests, as in tropical species, but are usually in the more sound or solid wood (Pl. XII, figs. 1, *a* and 2). In colonies recently established by colonizing individuals the eggs and young are present in a definite royal cell, where they receive the care of the queen. In well-established colonies no forms are permanently present with the reproductive forms, and there apparently is no well-defined royal cell.

The royal cell, excavated in decayed wood by the sexed adults that have swarmed, is a broad, oval chamber, the entrance to which is but slightly larger in diameter than the abdomen of the queen at a period 14 months after swarming (Pl. XII, fig. 1, *b*).

Most of the 40 neoteinic reproductive forms found at Falls Church, Va., May 27, 1912, were congregated in a single chamber in the solid wood of a chestnut slab. This chamber was a broad but shallow longitudinal cell in the solid, sound wood. The entrances to this chamber were but slightly larger in diameter than the abdomens of the fertilized queens. Other neoteinic individuals were found in shallow, broad, oval cells in the wood and in earth under the slab (Pl. XII, fig. 2).

The nymphs are usually present in the more remote passages of the nest, except during the spring, when they are in the outlying channels,[b] where the warmth of the sun will hasten their development.

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[a] Hagen, H. A. Monographie der Termiten. Linnæa Entomologica, Bd. 10, 1855, p. 35.

[b] Developing larvæ, nymphs, or immature adults are normally to be found, temporarily at least, in that part of the nest where there are the most favorable conditions of heat and moisture for their rapid development—changing with the seasons. In the spring and autumn these forms occur under the bark on decaying stumps and under decaying wood or bark sunken in the ground in open sunny sites, always being in the outlying galleries where the warmth will enable more rapid development.

There are apparently no permanent sites used as "nurseries," as is the case in tropical species of termites. However, young larvæ are seldom found in the main unpartitioned runways, but rather in partitioned galleries, where they will not be disturbed by the activities of the other members of the colony. Often they are in broad but shallow unpartitioned galleries in the more sound wood of the interior heartwood of logs, etc.

Unpartitioned channels or runways usually contain only workers and soldiers; the partitioned channels contain larvæ and nymphs besides. The young, freshly hatched, developing larvæ are often found in broad but shallow moist galleries in the interior of the heartwood. Extensions of an old colony, consisting of subterranean passages leading to small pieces of decaying wood, contain only workers and soldiers.

As previously stated, during the winter all the castes seek the more remote or subterranean passages of the nest.

THE SWARM OR SO-CALLED NUPTIAL FLIGHT.

Under normal conditions in the Southern States,[a] in early April and May, in the case of the more common species, *flavipes*, and in June in the case of *virginicus*, the colonizing individuals emerge in enormous numbers from small holes in the wood of stumps, logs, poles, fence posts, foundation timbers in buildings, and the roots of trees and from the ground. It is 7 to 10 days after the last sexed adults have acquired wings and mature pigmentation that the swarm occurs. The winged insects usually crawl upon some elevation before taking flight; before swarming they teem over the tops of infested stumps (fig. 12) and festoon brush lying on the ground in order to get a start. If a sexed adult loses its wings while at a height above ground (as on the top of a stump) it jerks itself up in the air in endeavoring to get down. Numerous workers and soldiers are congregated in the outer layers of the wood near the exit holes at the time of emergence. These colonizing individuals differ from the other soft-bodied castes in that they are larger, of a castaneous color, and are highly specialized and developed for the purpose of swarming and starting new colonies. In addition, they are sexed and have eyes and wings. While it is true that they are weak fliers and are preyed upon by many insectivorous animals—birds, lizards, insects, etc.—yet some escape to found new colonies.

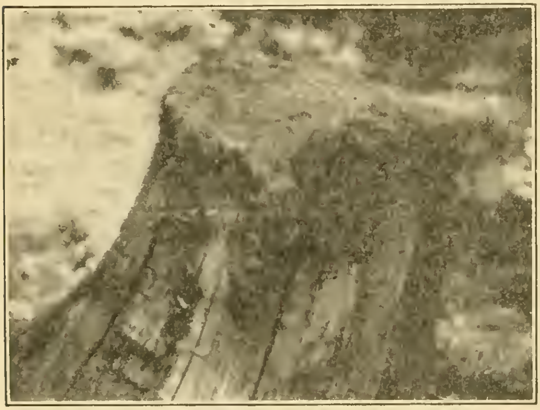

FIG. 12.—*Leucotermes flavipes:* View of a swarm of sexed adults emerging from a stump at Falls Church, Va.; a portion of the enormous numbers constituting a swarm. (Original.)

[a] The first swarm which contains the greatest number of individuals does not occur outdoors until the ripening of the pollen of the flowers of dogwood (*Cornus florida*), which is also influenced by seasonal and geographical variations.

After the adults have flown a short distance in an irregular "wobbly" manner, they fall to the ground, and by catching the tips of the wings against some object and turning sideways they pry them off at a suture or line of weakness near the base, leaving stubs. This triangular, basal portion of the wing, or stub, is thickened and more chitinized than the wing and is also pubescent up to the suture, a possible aid in breaking off the wing after flight.

The male follows the female tirelessly and persistently, with head close to her abdomen, and touches her abdomen with the antennæ. Often the male and female run in a circle of small diameter, and sometimes the pursued turns pursuer, apparently attracted by some secretion at the posterior end of the body.[a] Sometimes as many as three individuals may be seen running off together. This is apparently due to sexual attraction, an amatory procedure preliminary to pairing, which accomplishes the purpose of bringing the sexes together. This continues for several days after the flight. The sexes are attracted to each other at a period several days before swarming, as is evidenced by the fact that when a colony is broken into there is a short flight, followed by loss of the wings, after which the male follows the female in the same manner as after normal swarming.

Neither of the terms "swarm" or "nuptial flight" is appropriate in referring to the emergence of the colonizing sexed adult termites, since the insects after a short flight separate into pairs, or the males and females may even "pair" (but do not "mate" sexually till later) with individuals of other colonies, and never congregate again in the same colony, but form many new colonies. In the case of bees, on the contrary, after the swarm subsides the insects all together form one new colony. Furthermore, copulation does not take place at the time of the swarm, which is not a "nuptial flight."

THE ESTABLISHMENT OF NEW COLONIES.

Many investigators have considered that the foundation of new colonies by winged sexed adults was impossible, and was not the purpose of the swarm, but Perris (1876), Pérez (1894), and Heath (1903) disproved this.

For several days after swarming the now wingless sexed adults can commonly be found together under small pieces of decaying wood, lying on the ground, ultimately disappearing, either to excavate shallow cells in the ground, in decaying wood (Pl. XII, fig. 1, *b*), or to take possession of an old abandoned insect burrow. The entrance to this now royal cell is but slightly wider than the abdomen. It

[a] Heath, H. The habits of California termites. Biol. Bul., v. 4, no. 2, p. 47–63, figs. 3, January, 1903. See p. 54.

is here that copulation probably takes place. Doubtless many colonizing pairs, even after escaping their numerous enemies at the time of the annual swarm, fail to become established in a new colony owing to unfavorable moisture conditions. Sometimes several pairs are found together in the same cell in a piece of wood, or perhaps one male and two females, or vice versa, but these reproductive forms, unlike the neoteinic forms, are not normally polygamous. The young royal couple, after finding suitable shelter, forage for themselves and the abdomens of both sexes increase slightly in size, becoming swollen. This is probably due to feeding [a] and development of the sexual organs.[b] Heath states that "everything is apparently sacrificed to lightness of body" at the time of the swarm. This results in wider dispersal.[a] Copulation probably does not take place till about a week after the swarm, when the couples are established together in the royal cell, as sexed adults of *flavipes* that swarmed on May 8, 1912, were in royal cells on May 15, the male no longer following the female about.

While it is not essential that the colonizing pairs, the young kings and queens, be adopted by foraging workers and soldiers, it is possible that this sometimes occurs. It is significant that small branch colonies of workers and soldiers are to be commonly found under decaying pieces of wood and in the ground after the swarm.

COPULATION AND THE RATE OF EGG LAYING.

Actual copulation was not observed during these investigations, but observations indicate that copulation does not take place till after the male and queen are established in the royal cell, and copulation at the time of swarming outside the nest is not very probable, as the genitals of the males are in a very imperfect stage of development.[c] Other observers have noted the process in the case of *flavipes*.

Haviland states,[d] "In *Termes malayanus* I have reason to think that the king fertilizes the eggs after they are laid; indeed, copulation in the case of kings and fully grown queens of most species of the genus *Termes* is apparently impossible." [?]

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[a] Heath, H. Loc. cit.

[b] Müller, Fritz. Beiträge zur kenntniss der Termiten. Jenaische Ztschr. f. méd., Bd. 7, Heft 3, p. 333–358, figs. 11, pls. 19–20, März 7, 1873. See p. 337–351.

I. Die Geschlechtstheile der Soldaten von Calotermes.

II. Die Wohnungen unserer Termiten, p. 341–358.

[c] Hagen, H. A. Some remarks upon white ants. Proc. Boston Soc. Nat. Hist., v. 20, p. 121–124, December 4, 1878.

[d] Haviland, G. D. Observations on termites, with descriptions of new species. [Read 3d June, 1897.] Jour. Linn. Soc. (London), Zool., v. 26, p. 358–442, pl. 22–25, April 1, 1898.

Grassi states:[a] "On April 17, 1891, about 11 a. m., I detected the king and queen in coitu in a glass containing a small Calotermes nest * * *. They stood end to end in a straight line with the tips of their abdomen applied to each other * * *. It is therefore certain that the connection takes place in the nest, and is repeated at intervals." Sandias states[b] that he observed what appears to be a similar process between substitute forms still far from maturity, being only about a fortnight old.

The Rev. F. L. Odenbach, of St. Ignatius College, Cleveland, Ohio, has noted (MSS.) the copulation of neoteinic royalty (*Leucotermes flavipes*), namely, the mating of supplementary queens, time and again in artificial nests. On March 11 and 29, 1898, he observed many sexed adults pairing, coitu lasting about three minutes. He further states that the same queen has connection repeatedly with different males. On December 27, 1899, in describing the pairing of neoteinic royalty with short wing pads, he states: "The introduction is a lively play with feet and feelers, heads looking in opposite ways, the bodies curved together so as to make a circle, then the male slips along the body of the female until the organs meet; then they stand in one line, heads looking in opposite directions. The body is moved backward and forward, hinging on the legs and finally to both sides, as if they wished to telescope the abdomens. Time of connection, about one minute."

Heath states[c] * * * "almost a fortnight after swarming, I have on several occasions seen the royal pair of Termopsis in coitu. With their bodies closely appressed end to end in a straight line they remain from one to ten minutes in contact."

Egg laying in the case of *flavipes* begins about the middle of June or July, varying with the season, or about one and one-half months after the swarming. While the eggs hatch in about 10 days after they are laid, larvæ of varying sizes are often present, since they do not all hatch uniformly. Most of the first broods develop workers and a few soldiers, as the workers constitute the caste most necessary to the conduct of the young colony. At this time the queen and the male still occupy the royal cell together and the queen, with abdomen only slightly distended, cares for and carries about the eggs and later the young larvæ in her mouth, when the colony is disturbed. The royal cell is kept clean and the sides are now smoothed.

Recently hatched larvæ are fed on prepared food and do not eat wood until later in their development. On January 8 and 15, 1896, Odenbach observed workers to draw a white substance of the consistency of butter from the anus of neoteinic queens and devour it.

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[a] Grassi, B., and Sandias, A. Op cit., p. 285–286.

[b] Ibid., p. 386.

[c] Heath, Harold. Op. cit., p. 52.

On November 18, 1912, workers were observed to solicit liquid from the anus of a larval or ergatoid (?) queen, at Falls Church, Va. On August 5, 1913, a fertilized, fully developed queen, collected at Veitch, Va., about 14 millimeters in length, ejected a clear white liquid from the anus, when disturbed.

The rate of egg laying of the young and active queen is not very rapid, as clusters of eggs in varying numbers from about 6 to 12 were observed in several cells with single pairs. The new colony at first is very small, and even after the rearing of the first brood of workers and soldiers the increase in numbers is not rapid. In July, 1912, at Falls Church, Va., about 12 small white eggs in a cluster were observed in a royal cell with young royal individuals of *flavipes*. At least three were observed, probably 2 males and 1 female. These had been captured after the swarm on May 8, in the earth under a small piece of decaying wood. On July 29 the newly hatched larvæ were observed, and on October 30 seven workers and one soldier surrounded a single royal pair. Fragments of the chitinized parts of another adult were found near the royal cell. The abdomen of an egg-laying female under observation, 13 months after swarming, was oblong and somewhat distended, the segments of the abdomen being slightly separated and showing white between. On October 30, when the female in the royal cell was disturbed, she continually moved the end of the abdomen, curving it ventrally under the body. This alternate rising and falling of the abdomen has been described by Smeathman as a constant "peristaltic" movement, in the case of tropical species. No eggs had been laid since the first were deposited in July, and it is believed that this so-called "peristaltic" movement in case of Leucotermes is merely the result of alarm, and has no direct bearing on egg laying. During this time the male still occupied the cell with the female and both were active. Eventually the abdomen of the female becomes immensely distended through the development of the ovaries, but in the case of certain species of Leucotermes the queen still retains the power of locomotion.

It will thus be seen that development under the foregoing conditions is at best a slow process and not at all comparable to that which takes place in tropical species, where growth of the queen and the rate of egg laying is correspondingly rapid.

On February 21, 1913, nine or more additional eggs were observed in a cluster near the royal cell of the above-mentioned pair. This cell was in a small decayed branch, placed on moist earth, and isolated in a tin box. On February 24 the first freshly hatched larva was observed. The abdomen of the queen at this time was not markedly distended. On May 16 freshly hatched larvæ were again present in this colony. On August 15 six eggs, as well as newly hatched young, were present in the royal cell. The male still cohabited with the queen, and the abdomen of the queen was not as yet markedly distended.

While the recently hatched young are active, they are dependent on the care of the parents or upon the workers for food.

Wheeler[a] states, "In incipient ant colonies, the queen mother takes no food, often for as long a period as eight or nine months, and during all this time is compelled to feed her first brood of larvæ exclusively on the excretions of her salivary glands. This diet, which is purely qualitative, though very limited in quantity, produces only workers and these of an extremely small size (micrergates)." In incipient termite colonies (Leucotermes and Termopsis[b]) the young royal couple share the royal cell, excavated in decaying wood, at which time the abdomens of both the sexed adults increase slightly in size, and they take food—that is, wood. The first larvæ develop to workers and a few soldiers, both forms being smaller than normal individuals or those in well-established colonies. No nymphs of sexed adults are produced during the first year. The rate of egg laying of a fully developed true queen is much more rapid. On August 5, 1913, at 5 p. m., a true queen, about 14 millimeters long, which had been taken in the root of a dead chestnut tree above ground, was isolated with the king in a cell in wood. By 9 a. m. on August 6, more than 12 eggs had been laid. When captured in the tree there were several hundred eggs as well as numerous recently hatched larvæ near by.

The antennæ of some true royal pairs that have swarmed are apparently entire at a period of seven months after swarming; however, the segments were not actually counted. In other pairs the antennæ of both sexes are mutilated.

THE ROYAL PAIR AND OTHER REPRODUCTIVE FORMS.

OCCURRENCE IN THE UNITED STATES.

Feytaud[c] gives a historical account of the frequency of occurrence of reproductive forms of *L. lucifugus* in Europe and figures the reproductive forms. Between April and September in the eastern United States the several types of reproductive forms of our common species of termites are to be found in colonies in decaying wood above ground; that is, the pigmented, true royal pair with wing stubs, developed from the sexually mature adults; the supplementary neoteinic forms, with pale straw-colored pigmentation and short wing pads, developed from nymphs of the second form; and the ergatoids and neoteinic larval forms, with straw-colored pigmentation and no wing pads or rudiments, developed from mouldable larvæ. It is believed that since these forms are mobile and that in

[a] Op. cit., p. 68. [b] Heath, H. Op. cit., p. 57. [c] Loc. cit.

old, well-established colonies there is apparently no definite permanent royal cell, these forms inhabit the subterranean passages in wood or in the earth below the frost line during the winter. During the warm months, probably to facilitate the processes of reproduction and development of the young, they inhabit the passages in decaying wood above ground. The occurrence of true royal pairs is not rare,[a] but supplementary or neoteinic reproductive forms are apparently more common in colonies.

HISTORICAL.

The following is a historical record, in chronological sequence, of the occurrence of reproductive forms in colonies of *Leucotermes flavipes* and *L. virginicus* in the United States, together with notes on the conditions under which they were found.

The first queens of *flavipes* taken [b] in the United States were found by the late H. G. Hubbard in a colony in Florida and were of the neoteinic type, or supplementary form, with short wing pads. Hubbard also found the first neoteinic kings, although he makes no mention of them and may not have recognized the fact that he had found both sexes of neoteinic reproductive forms. Some of the neoteinic queens that Hubbard collected are deposited in the Hagen collection at Cambridge, Mass., but most of the specimens are in the collection of the United States National Museum. The number of specimens now present in the vials at the museum is probably not as great as when originally collected, since Hubbard gave certain of the royal individuals to Hagen. Hubbard's note, dated "Enterprise, Fla., May 19, 1875," recording the finding of the first reproductive forms in the United States, reads: "*Termes flavipes* (determined by Hagen), females with their eggs from small, rotten log in road near lake shore; females not in separate cells, several together." [This vial also contained two supplementary kings and nymphs of the first form.] Another note dated April 4, 1882, Crescent City, Fla., reads: "*Termes flavipes*, nymphs, queens, and eggs from galleries in pine log; Trichopsenius and Anacyptus were found in this nest." [A neoteinic king was also present in the vial.] A note dated "May 11, 1883, Crescent City, Fla., in pitch pine," is in a vial containing 11 neoteinic queens, 5 neoteinic kings, and 631 eggs with the embryos in various stages of development. [Nymphs of the first form were also present in this vial.]

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[a] It was formerly thought that true queens did not exist in colonies in the United States and Europe (proper). According to E. A. Schwarz (Termitidæ observed in southwestern Texas in 1895. Proc. Ent. Soc. Wash., v. 4, no. 1, p. 38–42, Nov. 5, 1896), there are but few permanent nests, headed by true royalty, of Leucotermes, due to the wandering habit of the genus; that is, the frequent moving of colonies would necessitate such rarity.

[b] Hagen, H. A. The probable danger from white ants. Amer. Nat., v. 10, p. 401–410, July, 1876. See p. 405.

Mr. Louis H. Joutel,[a] of New York City, found a number of fertilized, egg-laying neoteinic queens occupying the same cell, 9 in one colony and 14 in another. The number varies with the colony, as has since been ascertained, and many neoteinic royal individuals may be present in a small colony, where they would be more needful. Mr. Joutel spent several years in the study of termites, and in correspondence with the writer states that on two separate occasions he has found true queens—the first shortly after the finding, in 1893, of the above-mentioned neoteinic queens. This would be the earliest record of the finding of a true queen of *flavipes* in this country. He further states that on a later occasion he found two true queens at Peekskill, N. Y., on the same day, July 14, under about the same conditions. The queens were located in a "* * * dead hickory stump, about 12 inches diameter, and were in the upper part of the tunnels among the workers. There was nothing to suggest a queen cell and no eggs to be found, although I looked over them carefully. They were found in stumps about 20 to 30 feet apart." In commenting on a statement made by the writer[b] that a true queen was inactive in a burrow when discovered, Mr. Joutel states: "The three [true queens] that I found were very active, and while they did not move quite as fast as the larvæ [workers], it was due only to their size." Mr. Joutel is quite right, as I have since found out, and the instance cited was probably due to the queen being caught in a burrow too narrow for her distended abdomen, in trying to escape, rather than being confined in a cell the entrance to which was narrower than the size of her abdomen. While Mr. Joutel was the first actually to find a true queen, Mr. C. Schaeffer,[a] of Brooklyn, N. Y., was the first to record the finding of a fertilized, true queen of *flavipes*, at Moshulu, N. Y., July 16, 1902. He has kindly loaned the specimen to me for study. This queen is approximately 8 millimeters in length, the abdominal tergites and sternites not being widely separated, is markedly pubescent, and the antennæ are mutilated.

In describing the true queens which he found, Mr. Joutel states that they resembled the queen that Mr. Schaeffer found. He further states, "* * * they were all apparently broader than the one you figure in relation to its length. The heavy chitinized parts looked like little dots on the surface and did not take up as much space in relation to the rest of the surface as those parts do in the one you figure. [True, in living specimens.] The first one had its antennæ complete; of the other two, one had two segments missing on one antenna and the other had three segments wanting—

[a] Loc. cit.

[b] Snyder, T. E. Record of the finding of a true queen of *Termes flavipes* Kol. Proc. Ent. Soc., Wash., v. 14, no. 2, p. 107–108, June 19, 1912.

these happened to be on the same side." He also says, "I have repeatedly taken a pair at swarming time and bred the eggs from them, but have never got them to colony size," and that "* * * in stating that I found only three queens, I had reference to the fully developed ones. On Staten Island, in company with Mr. W. T. Davis, I came across a small log that had eight separate cells with a king and queen in each. A few had three and one four (individuals). They had eggs but no young. Some had perfect antennæ and others had segments missing." He states: "One small colony that I kept alive several years that had only about two or three dozen workers *swarmed* each year, a few individuals only, but I broke up and examined each fragment of wood and sifted the ground several times but never found a trace of either kind of queen; the whole colony was contained in a gallon jar. Other colonies that had thousands of workers, which I kept alive about 22 months from time of collecting, never swarmed or had young, but finally died of old age, I presume. They got smaller and seemed to have more fat in their makeup." Mr. Joutel also says, "Light, I found, was not objected to by termites, unless it was too strong, as long as they felt that they were *covered*, that is, they worked under cover, not necessarily in the dark." This is true, but even in metal termitariums with sliding, thick, red glass covers, termites, while at first they actively wandered about on the surface of the earth, and were apparently unaffected, soon sought cover under decaying pieces of wood or in the earth.

The Rev. F. L. Odenbach, S. J., has, since 1895, made observations on the habits of *Leucotermes flavipes* in artificial colonies. He has roughly sketched in his notes two types of neoteinic queens that he has found. The neoteinic kings he describes as being compressed laterally, and therefore seeming to have a ridged back. One neoteinic queen, with short wing pads, that he found pairing was 10 millimeters in length and had a markedly distended abdomen. Another gravid queen that he figures is apparently adapted from a nymph of the first form, since long, well-developed wing pads are present. The abdomen is distended and the abdominal tergites are separated. He states:

These reproductive forms were from a very large nest I took up in South Brooklyn, near Cleveland, Ohio, in the fall of 1895.

I placed the termites in a large glass globe. In September, 1897, I discovered a large mass of eggs from which were developed all the different nymph forms known to me, *true winged males and females* also in large numbers. These latter chased about the nest in such wild disorder for a few days that the workers fell upon them and destroyed them to the very last one. It reminded me of the slaughter of drones in a beehive. At the time it seemed to me that the wild orgies, [?] which as a rule occur outside of the nest in midair, disconcerted the workers and soldiers who did the next best thing to restore order and quiet in their household.

From the above large nest I caused a colony to migrate into a Lubbock nest, and in this nest I found the different neoteinic reproductive forms. First, the nymph with the long wing pads. She laid eggs, and I repeatedly induced her to do so by the same means by which I first caused ant workers to lay eggs (1885).

If they seem numb with cold, I place my hand on the glass plate and this induces the activity.

This queen was quite different in shape and color from those I will mention below, being larger and of a lighter color. She was slow in her movements and did not change her location very often. She was tended by the workers, which could hardly be said of the others, since they were too restless.

The others, reproductive individuals, were nymphs of different kinds, with different shaped wing pads, but none with as long ones as those of the individual mentioned above. They also laid eggs, but during one of their wild rushes around the nest were given their quietus. I now had only the above nymph and the one with no visible wing pads left. This latter I thought to be a true queen (?), since the treatment of her was nothing like that accorded to the nymph with long wing pads. She laid eggs, but seemed to be disregarded by the workers.

On March 26, 1895, at Haw Creek, Fla., Hubbard found an imago (a male) with the wings gone, in a colony. The antennæ have segments missing. His note reads, "In old, rotten pine log in swamp hummock; soldiers, larvæ, and imago with wings gone."

King [a] also states that he has found a black form (male) with wing stumps in a colony and that it is a swift runner. "Again, there is associated with *Termes flavipes* a clear black form, variable in size, some with wing stumps, and others, so far as I can see now, without being cleared, appear to have none. [?] I have only met with five of these forms so far; one measured 6 mm. in length, another 5 mm., and two of these measure 4 mm." He states that the fifth form was sent, not long since, to Dr. L. O. Howard, with notes, who referred it to Mr. E. A. Schwarz, the latter stating that it was a fully developed male with wing stumps.

Mr. King further says:

"* * * When I first observed its appearance with *Termes flavipes*, and in the nest with it, I supposed it to be a species of a staphylinid beetle, so swift were its movements that they made them quite deceptive. They are very swift runners and hard to capture. Further observations will be necessary to determine whether these are new species or not. It is my impression, however, that they are of a different type."

He does not state at what period of the year he found this form.

These forms found by Hubbard and King were possibly royal individuals, and in the case of the specimens collected by Mr. King they were possibly of both species, *flavipes* and *virginicus*.

H. G. Hubbard found a true queen of Leucotermes, probably *lucifugus* (a species very similar to *flavipes* [b]). As in *virginicus* the ocelli are nearer to the compound eyes than in *flavipes*. *L. virginicus*

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[a] King, G. B. *Termes flavipes* Kollar and its association with ants. Ent. News, v. 8, No. 8, p. 193–196, October, 1897. See p. 194.

[b] Hagen, H. A. Monographie der Termiten. Linnæa Entomologica, v. 12, 1858, p. 174–180 and 182–185.

Banks has as yet been found only in Virginia, West Virginia (Hopkins), Maryland, North Carolina, and Illinois (Snyder). *Leucotermes lucifugus* Rossi occurs in the United States and "is found in Texas, Kansas, Colorado, and southern California, and perhaps elsewhere."[a] The species *lucifugus* of Mediterranean Europe, according to E. A. Schwarz,[b] is probably native to America (Mexico). According to Dr. Knower, *flavipes* has been introduced into Japan and is firmly established. This species has also been introduced into Europe and has been destructive in the vicinity of Vienna.

This true queen, found by Hubbard, is slightly over 13 millimeters in length, has the abdominal tergites and sternites more projecting, and has not as greatly distended an abdomen as the true queen found in Virginia; that is, the chitinized parts are less fused than in the older queen. (Pl. XIII, *b*.)

The note in Hubbard's field diary recording the discovery of the first fertilized true queen reads as follows:

June 20th, 1898, Santa Rita Mountains, Madera Cañon (Southern Arizona). We ascended a ravine filled with majestic sycamore trees under which the ground was wet with numerous springs, but entirely tramped by cattle and devoid of smaller vegetation. * * * I found under a stone in a little dry mound in a wet springy spot on the mountain side, a colony of true Termes, among which, in a cell cavity just beneath the stone was a single matured gravid female, or queen, which certainly had been winged; took eggs, larvæ, workers, and soldiers with the queen. This is the first instance known of a true queen in the genus Termes. There were no supplementary or nymphal queens in this colony and no male was found. I explored the entire colony, which was not a large one.

Prof. Harold Heath, of Stanford University, Cal., has described the life cycle of *Leucotermes lucifugus* in California,[c] which is very similar to that of our common species of the East. He figures a true "primary" queen, as only 8 months old, however, that has a markedly distended abdomen and the abdominal tergites separated—probably an error, due to transposed descriptions under the figures, according to observations by Feytaud [d] and the writer.

A true queen, with wing stubs (*flavipes*), found by the writer was in an abandoned burrow of *Lymexylon sericeum* Harr. (Pl. XIII, *b*) in the decaying butt of a chestnut telegraph pole near Portsmouth, Va., on August 12, 1910. This queen was inactive, since the burrow was no wider than her abdomen, and apparently she was unattended. The abdomen was greatly distended and oblong in shape, the abdominal tergites and sternites being widely separated. In the bright sunlight the abdomen appeared to have a yellowish green tinge. The length of the queen was approximately 14 millimeters. The antennæ were mutilated.

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[a] Howard, L. O. The Insect Book. p. 356. New York, 1901.

[b] Loc. cit. See p. 39.

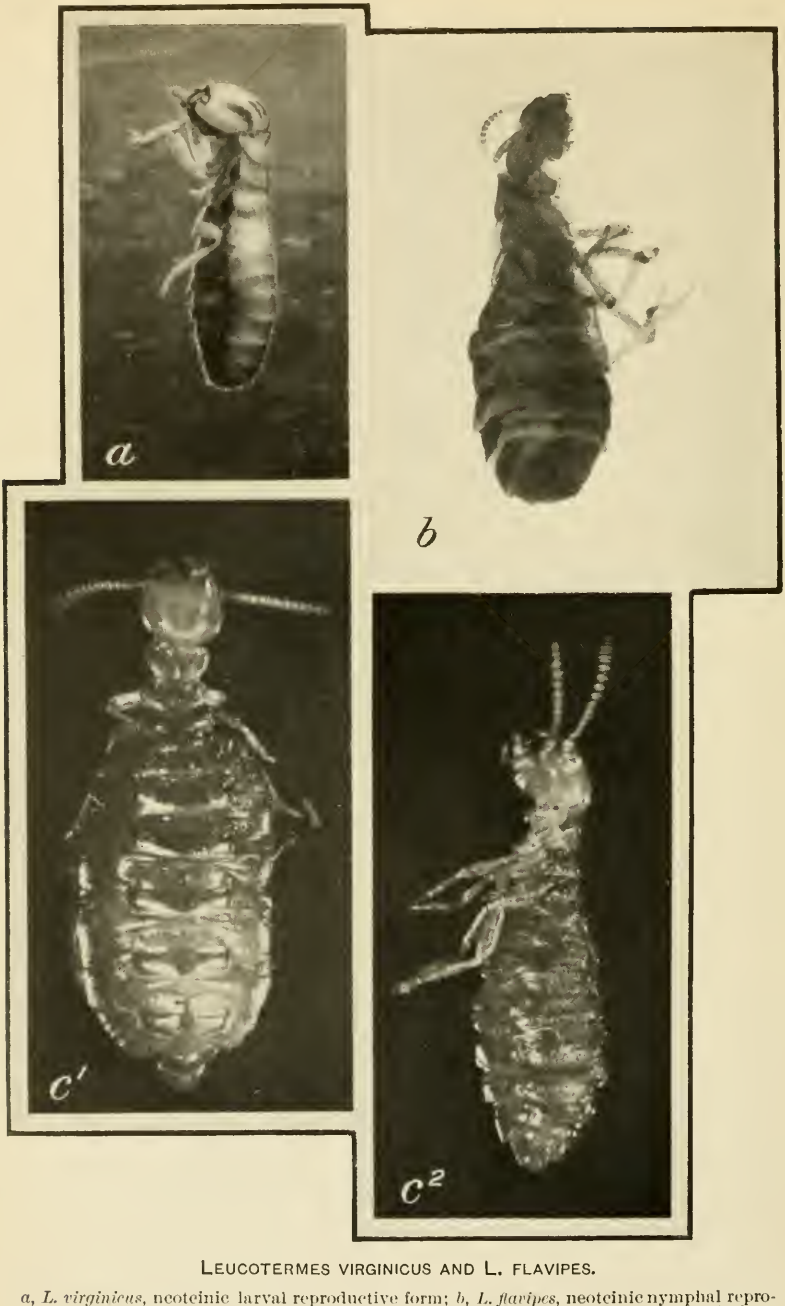
[c] Heath, Harold. Loc. cit.

[d] Feytaud, J. Op. cit., p. 567, fig. 21.

FIG. 1.—*a*, Supplementary queen with straw-colored pigmentation to chitinized parts; *b*, true queen with castaneous pigmentation to chitinized parts. (Original.)

FIG. 2.—Supplementary and true queen, showing deeper pigmentation of chitinized parts of the true queen. (Original.)

LEUCOTERMES FLAVIPES.



LEUCOTERMES VIRGINICUS AND L. FLAVIPES.

a, *L. virginicus*, neoteinic larval reproductive form; *b*, *L. flavipes*, neoteinic nymphal reproductive form (queen); c^1, c^2, *L. flavipes*, neoteinic larval queens, dorsal and ventral views (note absence of wing pads). From etherized specimens. Enlarged 10 times. (Original.)

Mr. W. B. Parker, of the Bureau of Entomology, has found two large fertilized true queens of *Leucotermes lucifugus* in redwood hop-poles in California. These queens were found in May, one being approximately 8 millimeters in length, with 11 segments to the antennæ, the other approximately 6 millimeters in length, with antennæ broken. Like the queen found by Mr. Schaeffer, the abdomens were not fully distended.

At Falls Church, Va., during the seasons of 1912, 1913, and 1914, numerous nymphs of the second form, in stages before, during, and after molting, were found by the writer; also young and mature neoteinic reproductive forms and young and mature true royal individuals.

On April 23, 1912, at Falls Church, the first colony of *flavipes* was found with a nymph of the second form present. The abdomen was noticeably broader, and this nymph was active and associated with nymphs of the first form. The nymphs of the first form were fully developed and in various stages to the sexed adults with immature pigmentation. Freshly hatched young larvæ were present. The day was sunny and warm.

On the same day a colony of *flavipes* was found in a decaying tulip tree stump, established well in the heartwood. Sexed adults with mature castaneous-black pigmentation were present and flew when the colony was disturbed. They were not present in large numbers, and all were in the outer layers of the wood. No fully developed nymphs in the stage just before the final molt were present, which is remarkable, as they were apparently present in all other near-by colonies. Very young nymphs and half-grown nymphs, as well as larvæ just hatched and young to medium-sized larvæ, workers, soldiers, and two neoteinic males (mature kings?) were present. They were active and in the outer layers of the wood. The abdomens of these males tapered markedly, being narrower at the end of the abdomen. They had a yellowish brown pigmentation, and in one king the compound eyes were without a trace of pigmentation. (Pl. VIII, fig. 2, *a*.)

A small colony of *flavipes* was found on April 25, 1912, under a small chestnut slab lying on the ground, exposed but sunken compactly into the moist earth. The day was sunny and warm. Fully developed nymphs of the first form were the most abundant stage, although some few transforming nymphs and a few sexed adults with dark pigmentation, as well as a few soldiers and workers, were present. The next most abundant caste to nymphs of the first form was nymphs of the second form, of which 90 were present and 4 were molting. They were active, much more so than nymphs of the first form. Most of these forms were either in shallow tunnels in the earth or on the earth, but a few were found in the decaying wood.

On the same day a single nymph of the second form was taken in a small colony under a strip of chestnut bark compactly pressed into the ground; this nymph was associated with nymphs of the first form. In two other colonies single nymphs of the second form were found associated with sexed adults under the bark on decaying chestnut stumps. Normally, but relatively few nymphs of the second form, as compared to nymphs of the first form, are present in colonies.

In another colony about one dozen nymphs of the second form, one of which was molting, were found associated with adults with pigmentation in various stages of development to maturity. A few of the latter with mature pigmentation had only one pair of wings unfolded, whereas others were present with the wings at the tips still compactly folded.

In a near-by colony, nymphs of the second form that had completed the final molt were present with sexed adults, but unlike the foregoing they are darker, some being pigmented. Very young larvæ were present in the outer layers of the wood. The acquisition of pigmentation in neoteinic royalty apparently is a sign of maturity and old age.

On May 27, 1912, 40 neoteinic forms, for the most part fertilized queens, together with females in which the abdomen was not greatly distended, were found in the more solid wood of a decaying chestnut slab on the ground. (Pl. XII, fig. 2.) Smaller forms, males, with the abdomen not oblong or distended were present in the colony. Most of these forms were congregated in the longitudinal royal chamber, in which young were also present. According to Grassi,[a] in case of *lucifugus*, "The colony must therefore rear fresh (complementary) kings every year [?], which become mature in August and September, fertilize the queens, and die." In colonies in Virginia neoteinic reproductive forms of *flavipes* are being developed from nymphs of the second form during April and May and are matured by May to June. In case of *virginicus* these reproductive forms are matured by July to August. There is a seasonal variation. There is no conclusive evidence that the kings do not live as long as the queens. They are not always present with the queens in colonies, but being so much more active are more likely to elude capture.

Two sexed adults, a royal couple, were captured by C. T. Greene at Falls Church, on November 12, in the frass in an old burrow of *Prionoxystus robiniæ* Peck, in the base of a living chestnut tree. Three royal individuals were present in the frass, and were located from 2 to 3 inches deep in the burrow. Four to six (at most) young were present, and, according to Mr. Greene, apparently all were workers.

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[a] Grassi, B., and Sandias, A., op. cit., p. 298.

On November 18, 1912, two larval (ergatoid?) reproductive forms with a yellowish pigmentation and rudimentary wing pads were found in passages in the ground under a decayed stump at Falls Church.

Nymphs of the second form greatly outnumbered nymphs of the first form in a colony of *flavipes* taken in a decaying oak limb on the ground on March 22, 1913, at Black Mountain, N. C.

On April 17, 1913, at Falls Church, molting nymphs of the second form of *flavipes* were found together with molting nymphs of the first form, some of the former of which had already molted and attained the characteristic yellowish pigmentation.

Molting nymphs of the first and second forms of *virginicus* were found on April 30, 1913, at Falls Church, under decaying slabs of wood on the ground.

Mr. H. S. Barber, of the Bureau of Entomology, on May 30, 1913, on the Virginia shore of the Potomac River, opposite Plummers Island, Md., found a neoteinic reproductive form of *flavipes*. This was a queen exceeding 6 millimeters in length, with wing buds and 17 segments to the antennæ. This queen was associated with workers, soldiers, and young in decaying pine wood on the ground. (Pl. XIV, *b*.)

On May 26, 1913, nine neoteinic queens of *flavipes* with distended abdomens and one king were found near Charteroak, Pa., in the interior of a decaying maple stump. Freshly hatched young and young larvæ were numerous. The queens were not in separate cells, but were active and associated with workers and soldiers. (Pl. XV.)

Mr. H. G. Barber, under the title "Another Queen of the White Ant Found," states:[a]

> While on a collecting excursion last Fourth of July with Mr. Charles E. Sleight, at Lake Hopatcong, N. J., I found a small colony of white ants beneath a small log where they had made some tunnels along the ground beneath the log. Among the individuals was captured a fully developed queen, which was preserved and presented to the local collection of insects, at the American Museum of Natural History.

A large fertilized true queen and a king of *flavipes* were found on August 5, at Veitch, Va., in a large colony associated with workers, soldiers, and young and several hundred unhatched eggs in the sound outer layers of wood, about 1 inch in from the exterior, near the base of a dead standing chestnut tree. This tree had died at least two years previous, but this may not approximate the age of the colony, since termites often infest the bases of living trees by obtaining entrance through old abandoned insect burrows. The king was hidden beneath the queen, which was about 14 millimeters in length. The antennæ of the queen in this instance were mutilated

[a] Barber, H. G. Another queen of the white ant found. Jour. N. Y. Ent. Soc., v. 22, no. 1, p. 73, March, 1914.

and the workers and soldiers were very solicitous. It is evident that the queen is fed on food prepared by the workers, since her abdomen became markedly shrunken when she was isolated.

On August 7, 1913, another true royal couple of this species was found near Chain Bridge, Va., in the interior of a decayed yellow poplar (tulip tree) log lying on the ground. The colony was small and the abdomen of the queen was not fully distended, being more flat than oblong. (Pl. XVI, *b*, king.)

On August 15, 1913, at Falls Church, a young neoteinic reproductive form? (female) of *virginicus* was found in an experimental stake of decaying yellow pine which had been set in the ground a year previous. The queen (?) was of a dirty yellow color with four grayish-black longitudinal markings on the epicranium, and grayish-black markings between the coxæ and mesothoracic and metathoracic tergites. The length was 4.5 millimeters. The segments to the antennæ were mutilated, one antenna having 11 segments. (Pl. XIV, *a*.) There was no pigmentation to the compound eyes.

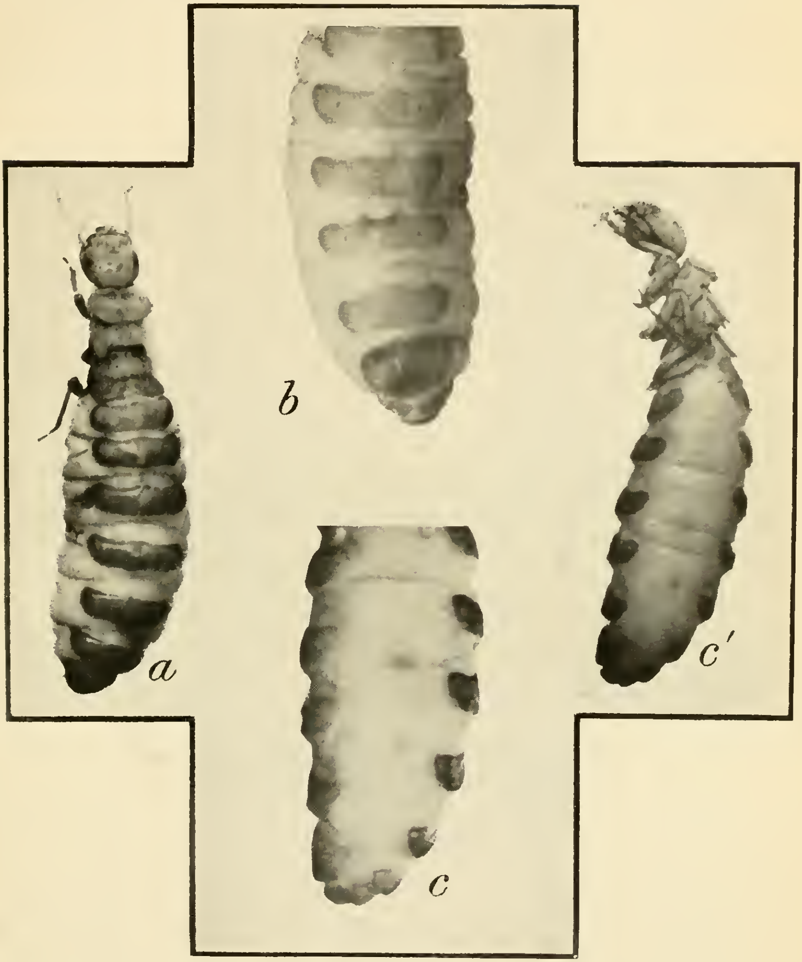
On September 17, 1913, near Chain Bridge, Va., numerous nymphs of the second form of *flavipes* of mature size were found associated with nymphs of the first form in the sound heartwood of a decaying black locust stump. The nymphs of the first form had well-developed wing pads.

On November 3, 1913, at Falls Church, nymphs of the second form of *flavipes* were found associated with those of the first form in the sound wood of a decayed oak stump near the ground. Young were present in this colony.

In 1914, on April 17, the first fully developed nymphs of the second form of *Leucotermes flavipes* were found in colonies at Falls Church, Va.

A large true queen of *flavipes* was found in a decayed oak stump about 5 feet high on July 17, 1914, at Falls Church. The tree had been dead for at least three to four years, and the stump was about 14 inches in diameter and still had the bark on. This queen, which was oblong but somewhat quadrate—4 millimeters in width—was 14½ millimeters in length (measured while alive [a]), and in color had a slight tinge of greenish-yellow or opaqueness. The antennæ had segments missing. The colony was very large. Numerous eggs were present in the galleries in the decayed wood, and the queen was found in an elliptical cell about 2 inches in the wood from the exterior; the sides of the cell were cleanly eaten out. The royal cell was situated about 1½ feet above the surface of the ground. The male was not found.

[a] The abdomens of queens become further elongated during the killing and fixing process, and hence in photographs of preserved specimens there is an apparent loss in width.



LEUCOTERMES FLAVIPES.

a, Dorsal, *b*, ventral, and *c*, *c′*, lateral views of abdomen of fertilized nymphal neoteinic queens. *a* and *c′*, Enlarged 7 times; *b* and *c*, enlarged 10 times. (Original.)

LEUCOTERMES FLAVIPES.

a, Mature king, nine months after the swarm and cohabitation with a true queen that had reared a brood of young—abdomen of queen not markedly distended; *b*, mature king, probably several years old, cohabiting with fertilized queen with abdomen markedly distended and tergites and sternites separated; *c*, fertilized true queen that swarmed April 25, 1913, and by September 25, 1913, was rearing a brood of young; *d*, Same, dorsal view. *a*, Enlarged 7 times; *b*, *c*, *d*, enlarged 10 times. (Original.)

In a near-by dead oak tree about 1 foot in diameter, which had been dead probably for two years, another true queen of this species was found on the same day. This queen was oblong and approximately 12½ millimeters in length (measured while living). The royal cell was in the decayed wood about one-half inch from the exterior at the base of the tree near the roots. The colony was large in numbers. Hundreds of eggs in clusters were in shallow galleries under the bark. The male was not found. Sometimes eggs in large clusters were found in deep, transverse, conical ledges or notches, attended by workers.

When the royal cell is cut into and the queen removed, the large number of attending soldiers and workers become very much excited, as evidenced by constant convulsive movements or sudden jerking of the whole body.

In this same woodland, on July 20, four neoteinic queens of *flavipes* were found in the more solid wood of a low (the wood above ground being nearly disintegrated) decayed oak stump, near the surface of the ground. One queen was of the normal neoteinic type, developed from a nymph of the second form, being 9 millimeters in length, with wing pads present. The compound eyes were pigmented, and the antennæ consisted of 16 segments. The other three neoteinic queens were of a type not previously found in colonies by the writer. These queens, of a straw-colored pigmentation, were 7, 6, and 5 millimeters in length (measured while alive), respectively. In shape the abdomens are oblong quadrate, like those of the true queens. The antennæ comprise 15 segments, which have a tinge of grayish-brown pigmentation to the dorsal surface. No wing-pads or rudimentary buds are present. The compound eyes are without pigmentation. The head, thoracic segments, and tergal and sternal "nota" (chitinized tergal and sternal areas) are not as broad as in neoteinic reproductive forms developed from nymphs of the second form. In these larval queens, as in true queens, the segments of the abdomen are less projecting than in normal neoteinic queens, and the "nota" are less semicircular. The mouth parts and legs are also less gross in structure. Indeed, these queens more nearly approach the true queens as to these points. (Pl. XIV, *c*.) They were probably developed from larvæ of the sexed forms. The outline of rows of numerous eggs in various stages of development could be seen through the body tissue under a high-power Zeiss binocular. The body tissue of normal neoteinic queens is coarser and thicker. This is the first time that reproductive forms of apparently different types have been found in the same colony of this species. The colony of termites in which these queens were found was small in numbers.

All the queens found by the writer in July, 1914, at Falls Church were captured within an area of ground less than an acre in extent.

It is believed that the spread or distribution of a colony may be largely dependent on the supply of decaying wood near by; that is, if there is a large amount near by (as colonies in large dead trees) the colony will not branch out over a large area.

On August 5, 1914, at Falls Church, a true royal pair of *flavipes* was found in a cell in the more solid wood of a decaying oak chopping block, that is, a section of a log that had been put to this use in the woods. The cell was in a knotty area of solid wood about 1½ feet from the ground but in the outer layers. The king was hiding beneath the queen, and is 6 millimeters in length. The abdomen is distended and the antennæ mutilated. The queen was of large size (probably 10 to 12 millimeters in length) but was crushed in cutting into the royal cell. The colony was large, and galleries extended from the ground up through this block and another similar block placed on top of it. The termites had filled in the crevices between the two blocks with clay, and larvæ, pupæ, and adults of *Homovalgus squamiger* Beauvois, a scarabæid beetle, were present in the termite galleries in the clay or in pupal cells.

In the same woods several young royal pairs of *flavipes* were found established in incipient colonies in the outer layers of a decaying chestnut slab partially sunken in the ground. Each pair was in a shallow cell excavated in the wood and was surrounded by a few young larvæ (a half dozen to a dozen). A few unhatched eggs were present in some of the cells. In one of the cells three adults were present instead of simply one pair. This is quite often the case in incipient colonies.

At Veitch, Va., on August 12, eight neoteinic reproductive forms of *flavipes* were found in a decaying yellow pine stump. They were in the more solid wood about 1 foot from the ground, but in the outer layers. Five were females and three were males or kings. The females were all about 7 millimeters in length, with abdomens distended with eggs, but with the segments not markedly separated except near the end of the abdomen, where the latter was lumpy and distorted, due to distension. The males, with narrow, slender abdomens, were all about 6½ millimeters in length, but had, instead of the straw-colored pigmentation of the females, a darker pigmentation streaked with grayish-black markings on the head and borders of the tergites and sternites and between the coxæ and the mesothoracic and metathoracic tergites. The antennæ of these reproductive forms consisted of 16 to 17 segments. These forms were developed from nymphs of the second form. The colony was not very large, but numerous unhatched eggs and young larvæ were present.

At Lake Toxaway, N. C., on August 27, 1914, an ergatoid queen of *Leucotermes virginicus* was found under a large flat rock in a shallow cell in the earth. Workers, soldiers, and young were aggregated under the stone, but the colony was not large. This queen had no trace of wing pads or pigmentation to the compound eyes, if present. The abdomen is oblong-ovate, being distended; its length is 5 millimeters. The antennæ are mutilated. Workers and soldiers surrounding the queen ran up and touched her with the antennæ and then evidenced excitement and alarm by the convulsive jerking of the body backward and forward.

This locality is a wooded, rocky hillside at an elevation of about 3,400 feet above sea level. There had been surface fires through the forest. It was noted that termite colonies were unusually abundant in the earth under stones in this locality, which is apparently the case as the higher elevations are reached.

On September 15, 1914, near Chain Bridge, Va., well-developed nymphs of both the first and second forms of *flavipes* were found in a colony in the more solid wood of a decaying chestnut stump. There is an annual seasonal variation in the degree of development the nymphs of the first form have attained by late fall; sometimes the wing pads are long and the nymphs apparently nearly mature; in other years in March these nymphs will still have comparatively short wing pads. There is sometimes also a variation in the different colonies.

DESCRIPTION OF THE REPRODUCTIVE FORMS.

As has been previously stated, the abdomens of both the young queen and male increase slightly in size and become distended after swarming. The abdomen of queens (*flavipes*) that had laid eggs during July, in January (9 months after swarming) were oblong and somewhat distended, the segments of the abdomen being slightly separated and showing white tissue between. The queens are dark castaneous in color and the males more blackish. The legs, tarsi, and tibiæ are markedly light yellowish in color in both sexes. After the swarming the abdomens of the males become only slightly distended.

The gradual distension of the abdomen of the queen, brought about by ovarian development, necessitates the separation of the abdominal tergites and sternites, and the connecting tissue between the abdominal tergites, pleurites, and sternites becomes remarkably distended, or more probably, according to Hagen,[a] as stated by Riley, there is actually further growth after the insect has reached the imaginal stage. It may be noticed from the illustration of the true queen found by the writer on August 12, 1911 (Pl. XIII, *b*), that there are two brownish scars located on the pleural tissue on the right side of the abdomen. These were not noticed until the queen was

[a] Riley, C. V. Termites, or white ants. Proc. Biol. Soc. Wash., v. 9, pp. 31–36, Apr., 1894.

removed from the cell, and were probably due to injury received in shipment, as the queen was not taken from the royal cell, but a small block of wood was cut out of the pole, the whole having been placed in a vial of alcohol. The queen was partly out of the cell and the scars were probably due to abrasions by small fragments of jagged, projecting wood. This is stated in detail, because it might be thought that the wounds were "battle scars."

Attached to the mesothorax and metathorax in true queens are the stubs of wings, lost at the time of swarming. The head, thorax, and scutellar area ("nota") of the abdominal segments of true queens are more heavily chitinized and more deeply pigmented with castaneous brown than in the neoteinic queens, developed from nymphs of the second form, which are straw-colored (Pl. XIII, *a*); consequently, the nonfunctional eyes and ocelli are not so prominent in neoteinic queens, which never develop wings and which always[a] (?) remain in the parent colony. The head, thoracic tergites, and abdominal tergites and sternites are both longer and broader than in the true queens, which same differences are apparent in the nymphs. (Pl. VIII.) In true queens the mesothoracic and metathoracic tergites have a distinctively irregular shape. The chitinized "nota" of the abdominal tergites and sternites more markedly approach the semicircular in shape and are much more projecting in neoteinic queens developed from nymphs of the second form. However, in younger (smaller) true queens (*flavipes* and *lucifugus*) the tergites and sternites are slightly more projecting than in older queens. Furthermore, the legs are more slender and the mouth parts slightly smaller (less gross) in true queens. The mesothorax and metathorax and pigmented, chitinized "nota" have a distinctive shape in the neoteinic larval queens. (Pl. XIV, *c*.)

In matured true queens (of both *flavipes* and *lucifugus*) ribbons of parallel ovules of various sizes and stages of development are visible (under high-power Zeiss binocular) through the tissue of the abdomen, where there are no deposits of fat. Sections through the body show an enormous ovary development, with ribbons of ovules in progressive stages of development. In a lateral or dorsal view of the abdomen of the true queen, small, round spiracles can be seen, set in at the base of the lateral slope of the tergites. (Fig. 13, *a* and *c*.) The spiracles are approximately similarly placed on queens of species in the genera Calotermes Hagen, Termopsis Heer, and Eutermes Fr. Müller. In some tropical species, as in *Termes bellicosus*, the spiracles are located in the pleural tissue of queens with enormously

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[a] It may be possible that subcolonies or offshoots of large old colonies are established by these mobile queens and workers and soldiers by means of subterranean passages to decaying wood.

distended abdomens, an indication of displacement by actual post-adult growth (?). In tropical species of Eutermes the enormous development of the ovaries in old queens crowds the digestive and excretory organs to the ventral surface of the abdomen.

Situated on the vertex of the epicranium is a small depression which appears as a rather prominent white spot, under the binocular microscope, in workers, nymphs, and neoteinic royal individuals of *flavipes*. This depression, slightly larger in diameter than an ocellus, is also present in the soldiers and in colonizing individuals. This is the "retrocerebral gland"[a] mentioned by Grassi,[b] as a "* * * [gland of unknown function," [existing in *lucifugus*] "(only?) in the nymph of the first form, the perfect insect, and the soldier. It eliminates a transparent secretion which can be squirted out for some distance."]

While the abdomens of neoteinic queens apparently never become as elongate as in true queens, they become as much distended, but have not the oblong or quadrate shape, being more oval, or wider near the end of the abdomen, which tapers markedly. At the end of the abdomen of true queens the chitinized parts are more compressed or fused than in the neoteinic forms.

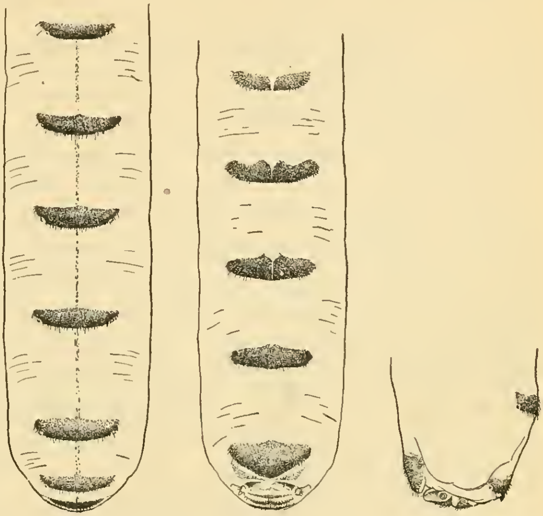

FIG. 13.—*Leucotermes flavipes:* Fertilized, true queen; dorsal (*a*), ventral (*b*), and lateral (*c*) views of abdomen. Drawn from specimen preserved for three years in alcohol. Note position of spiracles. (Original.)

Fertilized, neoteinic queens, developed from nymphs of the second form, range in length from 9 to 12 millimeters. The males are of the same length as the nymphs from which they develop; their abdomens are compressed laterally and taper toward the end, and "therefore seem to have a more narrow ridged back" (Odenbach).

Neoteinic or supplementary royal individuals are obtained from an arrested early stage in the development of the nymphs of the first

[a] Homologous to the small head gland of worker-like larvæ of Eutermes, which larvæ develop to nasuti, with a nose-like process (?).

[b] Grassi, B., and Sandias, A. Op. cit., p. 317.

form, or even larvæ, as young are kept in an undifferentiated state, which can be speedily turned into reproductive forms that serve as substitutes. Fritz Müller[a] compares the modes of diffusion and reproduction to those of plants which continue the species by means of cleistogamic as well as perfect flowers, the neoteinic forms corresponding to the cleistogamic flowers which are supplementary, emergency forms for use in case the perfect flowers (or winged colonizing forms) should fail. The winged forms would furnish a possible, but not probable, escape from interbreeding, since, usually, males and females from the same colony pair. Neoteinic supplementary forms are produced not only to counterbalance the loss of true royalty but also for the purpose of extending the colony.

DATES OF THE SWARMING OF LEUCOTERMES.

Colonizing individuals of *Leucotermes flavipes* usually swarm in the forenoon during the first part of April and May in the southern part of the eastern United States. Farther north the swarm occurs later, usually the last of May or early June. Hagen [b] mentions an exceptionally large swarm which occurred in Massachusetts. The sexed adults normally emerge earlier in infested buildings. According to E. A. Schwarz, sexed adults swarmed from infested beams in the floor in the basement of the old United States National Museum on March 15, 1883, the second year after the opening of the museum. The following year they swarmed during the latter part of March.

On April 16, 1910, sexed adults, possibly from the same colony, swarmed from crevices between the bricks in the sidewalk opposite the old National Museum.

On March 30, 1908, sexed adults came up through cracks in the floor in a building at Philadelphia, Pa.

Mr. Schwarz states, in an article entitled "Termitidæ Observed in Southwestern Texas in 1895": [c]

> *Termes flavipes* Kol.—Common throughout southwestern Texas and very destructive to woodwork in houses. An immense swarm of winged individuals [*lucifugus?*] issued from several houses at San Diego [Tex.], on October 25. I was informed that in early spring another flight takes place in buildings infested by termites [*flavipes?*]. What appears to be the same species is also common in sticks and branches lying on the ground in the chaparral, but I failed to get the winged form from such situations.

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[a] Müller, Fritz. Beitrage zur Kenntniss der Termiten. III. Die Nymphen mit kurzen Flügelscheiden (Hagen), "nymphes de la deuxième forme" (Lespès). Ein Sultan in seinem Harem. Jenaische Ztschr., Bd. 7, Heft 4, p. 451–463, figs. 3, November 18, 1873.

[b] Hagen, H. Some remarks upon white ants, Proc. Boston Soc. Nat. Hist., vol. 20, p. 121–124, December 4, 1878.

[c] Proc. Ent. Soc. Wash., vol. 4, no. 1, p. 38–42, November 5, 1896. See p. 38.

W. D. Hunter states [a]:

> *Termes flavipes* K. is not uncommon in Texas, where swarms occur ordinarily during the early part of the season. In 1911, however, the insect did not come into notice until about the middle of October [*lucifugus?*]. At that time much more than usual numbers were to be seen throughout the State.

Often several swarms emerge from the same colony in the same year. At McDonogh, Md., in April, 1913, according to a correspondent, sexed adults swarmed from the woodwork of a house, the beams being honeycombed. A very large swarm issued on April 6, another on April 13, a third on April 18, and a fourth swarm issued April 25, comprising in all four distinct swarms. In size, however, the first swarm, from my observations, is usually the largest. (Fig. 12.)

Leucotermes virginicus swarms during the forenoon in the vicinity of Washington, D. C., usually one month later than *flavipes*, or in early June. However, on August 11, 1913, at Falls Church, Mr. William Middleton observed a large swarm to emerge from a small chestnut corner stake which was set in the ground. The colony, which was not large, swarmed at 12.30 p. m.

Leucotermes lucifugus, according to Heath,[b] swarms "* * * at different times between the months of October and April * * *." "It usually takes place about 11 a. m."

During the early part of May, 1909, sexed adults of *Leucotermes* sp. (probably *flavipes*) were observed by the writer emerging in great numbers from the ground in the fenced yard of an old house located in a pine grove near Woodville, Tyler County, Tex. The swarm occurred in the forenoon of a warm, sunny day.

The following notes were made by members of the branch of Southern Field Crop Insect Investigations, in charge of Mr. W. D. Hunter:

> On September 12, 1910, a light shower fell, and before the rain had entirely stopped the air was full of flying termites; this lasted one hour. On December 16, 1910, there was a swarm [*lucifugus*] at Dallas, Tex. After a rain at Dallas, October 13, 1911, there was a swarm; another rain brought them out on October 16, 1911. On October 18, 1912, there were swarms of termites at Dallas, following a two-day's rain.

It will be seen from the foregoing that reliance, in the determination of species, can be placed on the dates of swarming, since the species *flavipes* never swarms in the fall in the eastern United States. Apparently rainfall has no influence on the time of swarming, as is the case in Texas.

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[a] Hunter, W. D. Some notes on insect abundance in Texas in 1911. Proc. Ent. Soc. Wash., vol. 14, no. 2, p. 62–66, June 19, 1912. See p. 63.

[b] Op. cit., p. 52.

ASSOCIATION WITH ANTS.

Grassi [a] and Escherich [b] have given interesting accounts of the relations between termites and ants. S. A. Forbes [c] states that *flavipes* has been found associated with *Formica schaufussi* Mayr. H. C. McCook [d] states that *flavipes* occurring under stones in the neighborhood of the Alleghenies were seized and carried off by the mound building ants (*Formica exsectoides* Forel) when disturbed. J. C. Branner [e] refers to the common ants as being enemies of the termites. King [f] has noted the association of termites with ants. The following brief notes have been made while investigating damage by termites to trees and forest products:

Termites and ants are commonly to be found inhabiting the same log or stump, yet ants are the enemies most to be feared by termites, as they will capture and carry away the members of a disorganized colony. Ordinarily the relations between termites and ants seem to be neighborly and peaceful. If the termite colony is opened up and disorganized, the ants at once take advantage of the opportunity and carry away the termites, which offer but little resistance. Ants of several species may be attracted to such a helpless colony from a distance. The soft-bodied soldiers are apparently not very effective in such emergencies, although in the narrow channels of the colony, where the powerful head with open mandibles is the only front presented to the marauding ants, they afford some protection to the colony.

Two species of carpenter ants (*Camponotus pennsylvanicus* Mayr and *Cremastogaster lineolata* Say [g]) are the ants which more commonly have been found associated with termites in the eastern United States. The latter species, due to its small size and rapidity of movement, is a most formidable enemy.

Ants greatly diminish the number of the colonizing individuals at the time of the swarm, carrying them away as they are running about on the ground. Soldiers and workers guard the breaches from which the sexed adults have emerged, possibly to keep the greedy ants from following their prey to the parent nest.

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[a] Grassi, B., and Sandias, A. Op. cit., p. 282–283.

[b] Escherich, K. Die Termiten oder weissen Ameisen. Eine biologische Studie, p. 122–126, Leipzig, 1909.

[c] Forbes, S. A. Nineteenth Report of the State Entomologist on the Noxious and Beneficial Insects of the State of Illinois, p. 198, Springfield, Ill., 1895. The white ant in Illinois (*Termes flavipes*, Kollar), p. 190–204.

[d] McCook, H. C. Note on mound-making ants. Proc. Acad. Nat. Sci. Phila. for 1879, p. 154–156, August 12, 1879.

[e] Branner, J. C. Geologic work of ants in tropical America. Bul. Geol. Soc. Amer., v. 21, p. 449–496, figs. 11, pl. 35, August 20, 1910. See p. 478–479.

[f] Loc. cit.

[g] Identified by Mr. Theodore Pergande, of the Bureau of Entomology.

TERMITOPHILOUS INSECTS.

The presence of termitophilous insects or "guests" in colonies of *Leucotermes flavipes* in the United States has been recorded by several writers on termites. Mr. E. A. Schwarz[a] has published an extensive list of Coleoptera associated with *flavipes.* Inquilines, or guests, are found only in permanent colonies and, as brought out by Mr. Schwarz,[b] might be of importance in establishing the original habitat of a species; that is, if a termite species had peculiar inquilines (guests that do not occur among other species of termites) in one country and none in another, it would indicate that the termite species was native to the country where the inquilines occur in its colonies. Mr. H. G. Hubbard found the staphylinid beetles *Trichopsenius* and *Anacyptus* in a colony with supplementary royalty, April 20, 1882, near Crescent City, Fla. He also found peculiar wingless psocids which resemble young termites in a colony of the latter, near Haw Creek, Fla., March 26, 1895. The note in his field diary reads:

> Termitophilous psocid found with termites in large log of pine, swampy hummock of Prairie Farm. Several specimens in alcohol, together with worker of termite. * * * The resemblance to a young termite is perfect, especially in mature specimens. * * * The psocid is, however, much more active than the termite and very difficult to capture. Immature specimens were not rare. * * * The immature specimens inhabit the galleries of the termites, but are not so apt to be found among the termites as in their immediate vicinity.

King[c] records three inquilinous staphylinid beetles as associated with *flavipes, Philotermes pilosus* Kraätz, *Homalota* sp., and *Tachyporus jocosus* Say.

All stages of small scarabæids, *Homovalgus squamiger* Beauvois and *Valgus canaliculatus* Fabricius, are commonly found associated with termites in decaying wood in Maryland, Virginia, West Virginia, and North Carolina, and are probably truly inquilinous. From the middle of July, 1914, prepupal larvæ and pupæ of *Homovalgus squamiger* were commonly found in decaying wood infested by termites and in the galleries of termites in Virginia. Adults of this beetle begin to mature about the middle of August. The larvæ construct oval pupal cells in the decayed wood or make them of earth; the interior is smooth and glossy. This beetle is probably a true inquiline.

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[a] Schwarz, E. A. Termitophilous Coleoptera found in North America. Proc. Ent. Soc. Wash., vol. 1, no. 3, p. 160–161, March 30, 1889.

Schwarz. E. A. Additions to the lists of North American termitophilous and myrmecophilous Coleoptera. Proc. Ent. Soc. Wash., vol. 3, no. 2, p. 73–78, January 8, 1895.

[b] Schwarz, E. A. Termitidæ observed in southwestern Texas in 1895. Proc. Ent. Soc. Wash., vol. 4, no. 1, p. 38–42, November 5, 1896.

[c] Op. cit., p. 196.

Beetles of the family Pselaphidæ are frequently found in decaying wood near termite nests, and some are known to be their guests. Adults of *Tmesiphorus carinatus* Say [a] were found in decaying wood in which colonies of *flavipes* were present at Falls Church on March 18, 1912. Mr. E. A. Schwarz has included this species in his list of myrmecophilous beetles as "often found among ants of various species." [b] Adults of *Batrisus virginiæ* Casey [a] were found in decaying wood infested with *virginicus* on the same day.

Adults of the staphylinid, *Philotermes pennsylvanicus* Kraätz [a] were collected with *flavipes* near Kane, Ill., August 11, 1911, in the butt of a decaying white cedar telegraph pole. The species is a true inquiline, and the beetles are very active. On August 16, 1913, near Chain Bridge, Va., an adult of *Philotermes* sp. (possibly *fuchsii* Kraätz) (determined by Mr. H. S. Barber of the Bureau of Entomology) was found in a colony of *virginicus*. Blatchley [c] records *Philotermes pilosus* Kraätz and *P. fuchsii* Kraätz in the nests of *flavipes* in Indiana.

PARASITES.

Termites are infested externally with mites and internally with protozoan parasites, but no internal or external feeding insect parasites have been recorded by Leidy,[d] Grassi,[e] or Porter.[f] Grassi states that the presence of these protozoa in the intestine retards sexual development, as evidenced in the case of workers and soldiers. He further states that they are normally absent in the reproductive forms and newly hatched larvæ.

SUMMARY AND CONCLUSIONS BASED ON THE RESULTS OF THE EXPERIMENTS.

The following conclusions are based on observations of colonies in the termitarium, colonies in small tin boxes, and other colonies in the forest at Falls Church.

Colonizing individuals of both sexes swarm together from colonies of *Leucotermes flavipes* and *L. virginicus* from about 11 a. m. to 1 p. m., the length of time occupied by the adults in emerging being about one hour. No evidence of the separate swarming of the sexes

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[a] Identified by Mr. E. A. Schwarz.

[b] Schwarz, E. A. Myrmecophilous Coleoptera, found in temperate North America, Proc. Ent. Soc. Wash., v. 1, No. 4, p. 237–247, May 15, 1890.

[c] Blatchley, W. S. The Coleoptera or beetles of Indiana, p. 343–344, Indianapolis, 1910.

[d] Leidy, J. On intestinal parasites of *Termes flavipes*. Proc. Acad. Nat. Sci. Phila. [v. 29] for 1877, p. 146–149, June 26, 1877.

Leidy, J. The parasites of the termites. Jour. Acad. Nat. Sci. Phila., ser. 2, v. 8, p. 425–447, pls. 51–52, February, 1881.

[e] Grassi, B., and Sandias, A. Op. cit., p. 11–13.

[f] Porter, J. F. Trichonympha and other parasites of *Termes flavipes*. Bul. Mus. Comp. Zool., v. 31, no. 3, p. 45–68, pls. 6, October, 1897.

or seasonal dimorphism has been observed. However, all the individuals do not necessarily emerge from the same colony at the same time, since there may be several swarms from the same nest. On May 14, 1912, at Falls Church sexed adults of *flavipes* emerged, although not in great numbers, from colonies, whereas there was evidence, by the discarded wings on the ground, of an earlier swarm. Most of the colonizing individuals had swarmed from other colonies on May 8; yet some individuals, not in the enormous numbers of the first swarm, were observed swarming from the same colonies on May 14. While there may be as many as four swarms, the first is usually the largest. This may be explained by the fact that there is an uneven development of individuals. Indeed, a few retarded, winged, sexed adults (*virginicus*) may remain in the colony till July 24 (near Kane, Ill.) and early August (District of Columbia) or be found, as individuals, flying. A large swarm of *virginicus* has emerged from a colony as late as August 11, 1913, at Falls Church.

The winged insects usually crawl up to some elevated place before taking flight. There is an enormous mortality of the colonizing individuals, and insectivorous animals destroy them in great numbers. The swarm is not a "nuptial flight."

The so-called "amatory passages" possess a sexual significance, and there is a mutual attraction between the sexes several days before the normal period of swarming. This can be observed if the colony is disturbed and the colonizing forms emerge prematurely, and is evidenced even before the loss of the wings. This attraction, probably due to some secretion, continues till after the royal pair is established in the royal cell and copulation has taken place. Copulation probably occurs a week after the swarm of *flavipes;* that is, on May 15 adults that had swarmed on May 8 were in the royal cell and apparently no longer following each other about, head close to abdomen, as previously. There is evidence that individuals of neither sex are sexually mature at the time of swarming, and that there is further development before copulation, as can be noted in the increase in size of the abdomen of both sexes.

The colonizing individuals are not all irretrievably lost.[a] The establishment of new colonies by these forms is a normal process. Although there is an enormous mortality at the time of the swarm, and a still further diminution in numbers due to inability to become established under favorable conditions, yet some pairs do become established. These sexed adults are not necessarily monogamous.

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[a] Perris, E. Nouvelles promenades entomologiques, *Termes lucifugus*. Ann. Soc. Ent. France, sér. 5, t. 6, p. 201–202, 1876.

Pérez, J. Sur la formation de colonies nouvelles chez le termite lucifuge (*Termes lucifugus*). Compt. Rend. Acad. Sci. (Paris), t. 119, No. 19, p. 804–806, Nov. 5, 1894.

Heath, Harold. Loc. cit.

True royal pairs are independent of workers in the foundation of new colonies; that is, it is not necessary that they be found and established in royal cells by foraging workers and soldiers, although it is possible that this occurs, which would then constitute an independent colony. New colonies established by sexed adults that swarmed were found both in the termitarium (where conditions were similar to those in nature) and in the forest. The king and queen are equally important; they continue to cohabit and coition is repeated. The first brood reared by young true queens that have swarmed consists of workers and soldiers of smaller size than the normal form.

Neoteinic royal individuals are to be found commonly in colonies of *flavipes* in the eastern United States; they are "ergatoids" or "neotenes" and are developed by retarding the normal development of nymphs of the first form at an early stage, and from young larvæ; sometimes as many as 40 or more, consisting of many queens and a few males, may be present in the same colony. The males are polygamous. It is believed that these forms are provided (1) when overcrowded old colonies are split up and new, independent colonies are to be established, or (2) through the actual loss of the true royalty or by the accidental separation of some members of the colony from the royalty. This method of the formation of new colonies is sure, and probably much more rapid in the case of establishment by the true colonizing forms, as the royalty would receive the care of the workers, would not have to forage for themselves, and their only function would be reproduction. The number of eggs laid and the rate of increase would necessarily be much more rapid, due to the following facts: (1) The abdomens of mature, fertilized, supplementary queens are nearly as fully distended as in the case of true queens; (2) the large number of supplementary royalty possible to be present in a single colony and consequent increase in the number of eggs laid, and (3) the proper care and nourishment the royalty would receive.

It is often noted that the antennæ of the reproductive forms are mutilated, that is, have a greater or less number of segments missing. However, this is not always the case in young reproductive forms. The loss of the segments in individuals in long-established colonies might be due to the treatment the latter receive from the workers, or from being dragged about by them, but the antennæ are sometimes mutilated in individuals in incipient colonies.

There is a series of molts and "quiescent stages" in the development of the larvæ of the castes; caste differentiation occurs during such a stage, which corresponds somewhat to the pupal stage in insects with complete metamorphoses.

In conclusion, the more important facts may be summarized as follows: There is great variation in the life cycle of Leucotermes;

FIG. 1.—Chestnut telephone pole, with base charred but basal area untreated. This pole has been standing near Dover, N. J., for eight years. (Photograph loaned by United States Forest Service.)

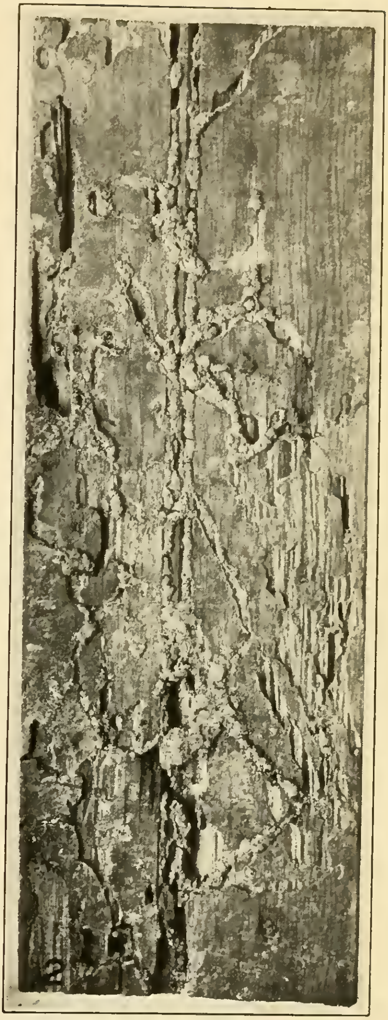

FIG. 2.—Pine flooring honeycombed by termites at New Iberia, La. (Original.)

DAMAGE BY TERMITES.

these insects are adapted to meet emergencies successfully and overcome obstacles without the disorganization of the colony. New colonies may be established (1) by the sexed colonizing adults that invariably swarm and leave the parent colony; (2) by neoteinic royal individuals, produced from nymphs of the second form which never (?) leave the parent colony, or from young larvæ, as in colonies orphaned after the nymphs of the first form have nearly completed their development; (3) by neoteinic reproductive forms supplied to orphaned colonies, which may be derived from nymphs of the first or second forms, or larvæ. Nests headed by true royalty are not rare, but many difficulties are to be surmounted in their establishment by sexed adults; such recently established colonies are small in number. Nests headed by neoteinic reproductive forms are more commonly to be found, as this is a more sure and more rapid method of establishment. Colonies established by neoteinic reproductive forms necessarily increase in size more rapidly due to the numerous egg-laying queens and the care and food they receive from the workers. Subcolonies or temporary colonies are frequently found with only workers and soldiers present; these subcolonies, which furnish increased facilities for habitation and food supplies, are possibly offshoots from the parent colony or nest and are established by means of subterranean passages, which are extended for long distances by foraging workers and soldiers.

THE DAMAGE TO FOREST PRODUCTS.

Termites seriously injure construction timbers in bridges,[a] wharves, and like structures; telephone and telegraph poles[b] (Pl. XVII, fig. 1), hop poles,[c] mine props,[d] fence posts and rails or boarding; lumber piled on the ground, railroad ties set in the ground (not where there is stone or slag ballast or heavy traffic), woodwork (Pl. V; Pl. XVII, fig. 2) in new and old buildings,[e] and especially seriously damage the wooden boxing or "conduits" of insulated cables placed in the ground (to the detriment of the insulation); tent pins and ridge poles, wooden

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[a] Hagen, H. A. The probable danger from white ants. Amer. Nat., v. 10, no. 7, p. 401–410, July, 1876.

[b] Snyder, T. E. Insects injurious to forests and forest products. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent., Bul. 94, pt. 1, pp. 12, figs. 3, pls. 2, December 31, 1910. See p. 9–10.

[c] Parker, W. B. California redwood attacked by *Termes lucifugus* Rossi. Jour. Econ. Ent., v. 4, no. 5, p. 422–423, October, 1911.

[d] Snyder, T. E. Insect damage to mine props and methods of preventing the injury. U. S. Dept. Agr., Bur. Ent., Circ. 156, pp. 4, July 13, 1912. See p. 2–3.

[e] Marlatt, C. L. The white ant. (*Termes flavipes* Koll.). U. S. Dept. Agr.. Bur. Ent., Circ. 50, rev. ed., pp. 8, figs. 4, January 27, 1908.

Hopkins, A. D. Insect injuries to forest products. U. S. Dept. Agr. Yearbook 1904, p. 381–398, 1905. White ants, or termites, p. 389–390.

beehives and tree boxes; wooden electrotype blocks, and books (Pl. IV) and documents stored in damp, dark places, etc.; timber in contact with the ground being especially liable to serious damage. Often the damaged material has to be removed and replaced, or rebuilt. The wood of no species of native tree of commercial importance is "immune" to attack, although some are relatively more resistant than others. Such damage has occurred as far north as Boston and the shores of the Great Lakes, but greatly increases as the Tropics are approached. In the Southern States termites are especially destructive to wooden underpinning, beams, and flooring (Pl. XVII, fig. 2), and all other material of wood accessible in buildings. They enter buildings by means of tunnels through the ground, by way of wooden joists, or by means of covered paths (minute "sheds" constructed of earth and excrement of the superficial consistency of sand), leading to the woodwork over the surface foundations of stone or other material which they can not penetrate. This enables them to avoid the light. Thus termites silently, secretly, and ceaselessly work their insidious damage, instinctively never perforating the exposed surface of timber, except to enable the sexed adults to swarm. Sometimes the emergence of these winged forms is the first indication of their presence, but at other times joists and floors collapse without warning.

PREVENTIVES, REMEDIES, AND "IMMUNE" WOODS.

Forest products in contact with the ground should be impregnated with coal-tar creosote, which is a permanent preventive against attack by our native termites. Coal-tar creosote has many properties which would recommend its use in this respect, for it is also a fungicide, and, being insoluble in water, will not leach out in wet locations. These requirements furnish objections to many chemicals that otherwise are very effective insecticides. The various methods of superficially treating timber, as by charring, by brushing, or by dipping with various chemical preservatives, among which are creosotes, carbolineums, etc., have proven to be temporarily effective in preventing attack,[a] if the work is thoroughly done. If not thoroughly done, termites enter through the untreated or imperfectly treated portions, especially through weathering checks and knots. Where the bases of poles, mine props, etc., are left untreated termites enter the timber from below, and, avoiding the treated portions, come up through the interior. Charred timber is effective against termite attack for a period less than a year, although it is not seriously damaged at the end of one year. It will readily be seen that neither brushing nor spraying the exterior after place-

[a] Snyder, T. E. Insects injurious to forests and forest products. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent., Bul. 94, pt. 1, pp. 12, figs. 3, pls. 2, Dec. 31, 1910. See p. 9-10.

ment, as is sometimes practiced, is effective in keeping out termites, since the portion that sets in the ground could not be treated, and it is usually at this point that termite attack occurs.

Before treating timber with chemical preservatives, especially where the brush method is employed, it is essential that the timber be thoroughly seasoned, otherwise penetration by the preservative will be retarded.

A treatment with "blue oil" is recorded as apparently effective in protecting wood against the attacks of "white ants," or termites, besides acting as a preservative (fungicide) generally. "Blue oil"[a] is the residue left in the distillation of mineral oils after the isolation of kerosene (petroleum) and paraffin; (*a*) the oil to be a shale product; (*b*) its specific gravity (at 60° F.) to be 0.873 to 0.883; (*c*) its flashing temperature to be not lower than 275° F. (close test).

Many patented wood preservatives, advertised as effective against wood borers, often merely contain simple preservatives, as for instance, linseed oil, to which a slight odor of oil of citronella has been imparted, or contain simple poisons. For timber to be set in the ground, brush coatings with linseed oil are not effective against termites.

An English firm manufactures a saccharine solution which probably contains a salt as arsenic[b]; this patented treatment is supposed to be efficient against wood-boring insects, especially termites. The wood is seasoned by immersing in the saccharine solution at 120 to 140° F. This process is being tested.

Impregnation with chlorinated naphthalene may prove effective against termites, as a preservative for woodwork, in interior finish, where a requirement is that the preservative should not "sweat" out, or stain the wood. Treated wood blocks buried in the ground with termite-infested logs were not attacked after a test of nearly six months.[c] Impregnation with paraffin wax was not effective (fig. 14). If the wood is not in contact with the ground, impregnation treatments with bichlorid of mercury and zinc chlorid are effective. The mercury and zinc in this form are both soluble in water.

H. W. Bates, in a paper entitled "On the prevention of destruction of timbers by termites," Transactions of the Entomological Society of London, 1864, Vol. I, p. 185, cites preventive measures. M. J. Berkeley, in The Technologist, (London), 1865, Vol. V, p. 453, gives remedies based on the report by the committee of inquiry into

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[a] The protection of timber against white ants. Trans. Roy. Scot. Arbor. Soc., v. 23, pt. 2, p. 227–228, July, 1910.

Dixon, W. B. Protection from "white ants" and other pests. Nature, v. 85, no. 2148, p. 271, December 29, 1910.

[b] Chemical abstracts, v. 7, no. 2, p. 408, January 20, 1913.

[c] Impregnation of wood to resist insect attack. Amer. Lumberman, no. 2009, p. 32, November 15, 1913.

the ravages by white ants at St. Helena. Froggatt gives[a] preventive measures applicable in New South Wales.

FIG. 14.—Red oak block, impregnated with paraffin wax, honeycombed by termites after five months' test. This was buried in the ground with termite-infested logs. (Original.)

[a] Froggatt, W. W. White ants, with some account of their habits and depredations. Misc. Pub. no. 155, Dept. Agr., Sydney, N. S. Wales, Sydney, 1897. See p. 6–8, account of depredations and methods of prevention.

The wood-pulp products and various patented "composition boards" used as substitutes for lath, etc., might be made termite proof by adding during their manufacture such poisons as white arsenic, antimony, bichlorid of mercury, zinc chlorid, etc; tests are being conducted.

In general, serious damage by termites to the wood of fire or insect killed, standing, merchantable timber can be prevented if the timber is utilized within from one to two years from the time that it was killed, depending on the species of wood and the locality—one year for pine (less in the Southern States) and two years for chestnut.

Forest tree nursery stock should be planted in ground that has been plowed deep late in the fall of the year in a region where injury by termites is common.

Marlatt [a] states regarding white-ant infestation in buildings that setting foundation beams or joists in concrete is only a partial protection, since in the settling of the house the concrete will crack and afford entrance to the insects. Some protection is afforded by removing decaying stumps or posts, etc., adjacent to buildings, by drenching infested timbers with kerosene, and by removing infested joists in cellars and drenching the ground where they were set with kerosene (or carbon bisulphid). Where the injury is confined to exposed woodwork in buildings, hydrocyanic-acid gas fumigation [b] is to be recommended, the infested beams and joists beneath being exposed, if possible, by opening up the floors.

Certain species of wood appear to be naturally highly resistant to termite attack. Species of wood that, so far as determined by test,[c] have been resistant to attack by our native termites are all tropical species and woods too expensive for ordinary use, including teak (*Tectonia grandis*) from Siam and Burma, greenheart (*Nectandra rodiæi*) [d] from South America and the West Indies, "peroba" (several species of *Aspidosperma*) from South America, and mahogany (*Swietenia mahoghani*) from tropical America. Hagen[e] states that, according to Kirby, "Indian oak" or teak (*Tectonia grandis*) and "ironwood" (*Sideroxylon*) of India are immune to attack by termites. This immunity (?) or relative resistance of ironwood is not due to hardness, since Asiatic termites attack the hardest wood, *Lignum-vitæ*, but to the presence in the wood of substances (as oils or alka-

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[a] Op. cit.

[b] Howard, L. O., and Popenoe, C. H. Hydrocyanic-acid gas against household insects. U. S. Dept. Agr., Bur. Ent., Circ. 163, p. 8, November 29, 1912.

[c] Impregnation of wood to resist insect attack. Amer. Lumberman, no. 2009, p. 32, November 15, 1913.

[d] This wood has been superficially attacked by termites after 12 months' test; the wood was eaten to the depth of one-eighth inch.

[e] Hagen, H. A. Monographie der Termiten. Linnæa Entomologica, Bd. 10, p. 44–45, 1855.

loids) repellent or distasteful to termites.[a] The presence of tyloses or of gums may be factors in determining[b] the durability and resistance of hardwood species. Hagen further states that, while teak is not destroyed by termites, he believes that even teak will be attacked when it has become old or been long exposed to the air. Hagen states that it is useless to consider tannin as a preservative, since, according to Williamson, termites will destroy leather. Some species of woods native to the Philippine Islands are apparently immune to termite attack.

Capt. Ahern, Chief of the Philippine Forestry Bureau, quotes Foreman, p. 390, as stating[c] that the "anay," or native termite, "eats through most woods (there are some rare exceptions, such as 'molave,' 'ipil,' 'yacal,' etc.)." Capt. Ahern states that—

The following woods are not subject to attack by anay: "Dinglas" [*Eugenia bracteata* Roxb., var. *roxburghii* Duthie, family Myrtaceæ], "ipil" [*Afzelia bijuga* Gray, family Leguminosæ], "molave" [*Vitex littoralis* Dcne, family Verbenaceæ], and "yacal" [*Hopea plagata* Vidal, family Dipterocarpeæ].

"Tindalo" [*Afzelia rhomboidea* Vid.] is attacked by "anay" when there is no other wood in the vicinity.

"Baticulin" [*Litsea obtusata* B. and H., F. Vill, fam. Laurineæ] is attacked by "anay," but is not damaged or destroyed, except such parts as are buried underground.

TEST WITH THE WHITE ANT.

Mr. D. N. McChesney, master mechanic at the depot quartermaster shops in Manila, found last February that his trunk (made of an American spruce) had been invaded by white ants and was almost entirely destroyed; the clothes contained in the trunk were also eaten. He placed the trunk on the ground and near it pieces of the following woods:

Result of 30 days' contact with ants.

American woods:	
Oregon pine	Entered and eaten; a mere matter of time for complete destruction.
Bull pine	Eaten more readily than Oregon pine.
Spruce	Do.
Western hemlock	Not touched.
California redwood [*Sequoia sempervirens*].	Ants tried, but discontinued after a slight effort.
California white cedar	Do.
Native woods:	
Molave	Ate a little of it; deepest hole about one-fourth inch.
Narra [*Pterocarpus indicus* Wild., family Leguminosæ].	Ate a little of it; deepest hole about one-half inch.
Painted wood	Ants worked under paint and ate the wood readily.

[a] The quality of hardness in wood, while not rendering a species of wood immune to termite attack, is an important factor in determining the relative resistance of species of woods. Hardness is a factor in the grading of mahogany lumber.

[b] Gerry, M. "Tyloses: Their occurrence and practical significance in some American woods." Jour. Agric. Research, vol. 1, no. 6, p. 462–464, March 25, 1914.

[c] Ahern, G. P. Important Philippine woods. 112 pp., col. pls. Forestry Bur., Manila, P. I., January 2, 1901. See p. 91.

Hemlock and redwood[a] are badly honeycombed by our native species of termites on the Pacific coast, and California white cedar is honeycombed by the termites of the Pacific coast.

European cypress (*Cupressus sempervirens* Linn.) is reported[b] damaged by termites at Rochefort, France.

Cedrus deodar, from India, and *Cedrus atlantica*, of the mountains of northern Africa, are reported to be immune (?) to termite attack.

Red "deal" is less liable to attack than white "deal."[c]

The following three species of wood remained untouched by termites for three years in the District of Pretoria, Transvaal:[d] "Leadwood" (*Combretum prophyrolepsis*), "black ironwood" (*Olea laurifolia*), "vaalbosch" (*Brachylæna discolor*).

In case of certain species of pines, with an extremely resinous heartwood, as the "fatwood" of the longleaf pine (*Pinus palustris*) of the Southern States, while termites honeycomb the sapwood, the heartwood apparently is resistant. Odenbach states that turpentine is very repellent to termites in artificial nests. In southern Rhodesia[e] the wood of the "mopani" tree (*Copaifera mopani*) withstands termite attack for years, and is therefore very suitable for straining posts for fences, though unfortunately not a timber that can be cut and squared.

Tests of the relative resistance of various native and exotic woods have been begun, but as yet no definite conclusions can be drawn. The heartwood of the following native species of wood is relatively more resistant to attack by our native termites: Black locust; black walnut[f] (cases on record where heavy beams supporting flooring in a building in Baltimore, Md., were completely honeycombed); eastern white cedar (*Chamæcyparis thyoides*); eastern red cedar or juniper; bald cypress of the Southern States; western red cedar (*Thuja plicata*) of Washington, Oregon, and California; incense cedar (*Libocedrus decurrens*) of Oregon and California; and Monterey cypress (*Cupressus macrocarpa*) of California. All these species of woods, however, are attacked by termites.

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[a] Parker, W. B. Loc. cit.

[b] Hagen, H. A. Monographie der Termiten. Linnaea Entomologica, Bd. 10, p. 1–144, 1855. See p. 133.

[c] French, C. Handbook of the destructive insects of Victoria, pt. 2, p. 141, Melbourne, 1893.

[d] Howard, C. W., and Thomsen, F. Notes on termites. Transvaal Agr. Jour., v. 6, No. 21, p. 85–93, illus., October, 1907; v. 7, No. 27, p. 512–520, April, 1909; v. 8, No. 29, p. 86–87, October, 1909.

[e] Jack, R. W. Termites or "white ants." Rhodesia Agr. Jour., v. 10, No. 3, p. 393–407, pl., February, 1913.

[f] Impregnation of wood to resist insect attack. Amer. Lumberman, No. 2009, p. 32, November 15, 1913.

Hagen [a] briefs the records of various travelers as to the immune (?) or termite-resistant wood species of the countries of the world. Froggatt [b] states that in Australia red pine is more resistant than clear pine; that "jarrah" is said to be resistant, though not immune; and that desert cypress when sawn up appears to be resistant, but in the form of logs is not immune. The Rev. Joseph Assmuth, S. J.,[c] of Bombay, India, states that "deal" and "pukka" teak are injured by termites; he gives photographs of the damaged specimens of wood. In answer to a letter of inquiry he states:

The "pukka" teak is what is called here in India "Burmese teak," *Tectonia grandis* L. "Pukka" means genuine; it is used here in opposition to the less reliable timber of "Malabar teak," though both come from the same species of wood. The difference of both lies, I am told, in the seasoning of the timber, or rather in the different mode of felling the trees. In Malabar they cut off a ring of bark from near the base of the tree, so that the tree dries up while standing still erect, and is then felled. This seems to cause a gradual withdrawal of the oils contained in the wood, which makes the wood more liable to the attack of white ants. In Burmah the tree is felled as it stands and allowed to dry up lying on the ground. Thus the peculiar oils remain in the wood and are preserved in it, and consequently this timber is less palatable to the white ants, and shunned by them until in course of time the oils evaporate also. Then the white ants go for it too. Such, at any rate, is my theory. I can't explain otherwise why the one sort is at once attached by white ants, whereas the other remains for a longer period, at least, immune. The case therefore is briefly this: Malabar teak (here also called "jungle teak") is attacked by the white ants from the beginning. Burmah or "pukka" teak remains safe for a certain period, sometimes longer, sometimes shorter, but it is not absolutely safe either.

"Dealwood" is the common European wood used for boxes and the like; it is usually timber of Abies, Picea, or Pinus. It is the wood most readily attacked by termites of different species.

Kanehira,[d] tabulates the results of experiments with a large number of species of woods as to their relative resistance to termite attack in Formosa, Japan. Reasons are advanced as to the probable causes which render the wood "termite proof" (?). The conclusions he draws can not be accepted without further details as to how the tests were conducted and after a longer period of experimentation. Certain of the woods he lists as "immune" are known to be attacked by termites.

METHODS OF OBTAINING PHOTOGRAPHS FOR THE ILLUSTRATIONS.

The photographs of the insects reproduced in this paper were made after a method devised by Mr. H. S. Barber, of the Bureau of Entomology. The specimens were placed either between horizontal

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[a] Loc. cit.

[b] Froggatt, W. W. White ants. (Termitidæ.) Misc. Pub. 874, Dept. Agr. N. S. Wales, Sydney, 1905, p. 43–44.

[c] Assmuth, J. Wood-destroying white ants of the Bombay presidency. Jour. Bombay Nat. Hist. Soc., v. 22, no. 2, p. 372–384, 4 pls., September 30, 1913.

[d] Kanehira. On some timbers which resist the attack of termites. Indian Forester, v. 40, no. 1, p. 23–41, January, 1914.

glass slides submerged in alcohol or immersed in water in a chamber made by gluing glass slides to thin slips of rectangular cover glass with heated balsam. In this water-tight compartment the specimens can be placed in vertical or horizontal positions. Ether is used to clear out the cell, which is filled with boiled water, thus avoiding the formation of air bubbles. If the specimens are placed head downward, movements of the antennæ, due to vibration, can be avoided. Cells of various sizes are used, or one large cell can be utilized by placing thin slips of cover glass back of the specimens to hold them firmly in position. By clamping the cell to the lens holder of a dissecting microscope placed horizontally, focusing can be conveniently accomplished by adjustments of the screw.

The best results are obtained by etherizing recently killed specimens that have not been placed in alcohol. A 72 millimeter focal length lens brings out the characters to the best advantage, if the enlargement is 6 to 8 diameters.

Many of the photographs were taken by Mr. H. S. Barber and some by Mr. H. B. Kirk at the eastern field station. Most of them, however, were made by the photographic laboratory of the United States Department of Agriculture.

BIBLIOGRAPHY.[a]

This bibliography consists mainly of publications on our native termites or closely allied species; some little-known publications are included. Hagen, up to 1860, Froggatt, Holmgren, Escherich, and Feytaud give extensive bibliographies.

Andrews, E. A., and Middleton, A. R. Rhythmic activity in termite communities. Johns Hopkins Univ. Circ., n. s., 1911, no. 2 (whole no. 232), p. 26–34, illus., February, 1911.

Atkinson, G. F. Some Carolina insects. 1st Rpt. So. Car. Exp. Sta. for 1888, p. 19–56, 1889.

Banks, N. Two new termites. Ent. News, v. 17, no. 9, p. 336–337, illus., November, 1906. *Cryptotermes cavifrons*, from Florida, and *Termopsis laticeps*, from Arizona, described.

Bidie, G. White ants—termites eroding glass. Nature, v. 26, no. 675, p. 549, October 5, 1882.

Buckley, S. B. Description of two new species of termites from Texas. Proc. Ent. Soc. Phila., v. 1, p. 212–215, May, 1862 (1863). *Hamitermes* (*Termes*) *tubiformans*, from Texas, p. 212, and *Eutermes cinereus*, from Texas, described.

Casey, T. L. A new genus of termitophilous Staphylinidæ. Ann. N. Y. Acad. Sci., v. 4, p. 384–387, March, 1889.

Coryell, J. R. The termite pest of the old world. Sci. Amer., v. 59, no. 10, p. 151, September 8, 1888, illus.

Derry, D. E. Damage done to skulls and bones by termites. Nature, v. 86, no. 2164, p. 245–246, April 20, 1911.

Dixon, W. A. Protection from "white ants" and other pests. Nature, v. 85, no. 2148, p. 271, December 29, 1910.

[a] The references in the bibliography, as well as those in the footnotes, have been verified by the librarian of the Bureau of Entomology, Miss Mabel Colcord.

FITCH, A. Fourth Report on the Noxious and Other Insects of the State of New York, 1858, p. [8] or Trans. *Termes frontalis.* N. Y. State Agr. Soc., v. 17 (1857), p. 694, 1858.

FORBES, S. A. The white ant in Illinois. (*Termes flavipes* Kollar.) 19th Rpt. State Entomologist . . . of Illinois for 1893 and 1894, p. 190–204, 1895. Lists economic publications on termites.

GRANT, R. D. [Ravages of *Termes flavipes*.] Trans. Acad. Sci. St. Louis, v. 3, Jour. of Proc., p. cclxix, November 19, 1877.

HAGEN, H. A. Report on the Pseudo-Neuroptera and Neuroptera collected by Lieut. W. L. Carpenter in 1873 in Colorado. Ann. Rpt. U. S. Geol. Survey Ter. for 1873, by F. V. Hayden, p. 571–606, 1874.

White ants destroying living trees and changing foliage in Cambridge, Mass. Canad. Ent., v. 17, no. 7, p. 134–136, July, 1885.

The female of *Eutermes rippertii.* Psyche, v. 5, no. 157–159, May–July, 1889, p. 203–208.

HAVILAND, G. D. Observations on termites; with descriptions of new species. Jour. Linn. Soc. [London], Zool., v. 26, no. 169, p. 358–442, pls. 22–25, April 1, 1898.

Observations on termites or white ants. Ann. Rpt. Smithsn. Inst. for year ending June 30, 1901, p. 667–678, pl. I–IV, 1902.

HUBBARD, H. G. Notes on the tree nests of termites in Jamaica. Proc. Boston Soc. Nat. Hist., v. 19, p. 267–274, December 26, 1877, printed March, 1878.

Insects affecting the orange, Washington, 1885. Chap. IX, p. 121–125, White ants or "wood-lice."

KELLOGG, V. L. Are the Mallophaga degenerate psocids? Psyche, v. 9, no. 313, p. 339–343, May, 1902.

KNOWER, H. McE. The development of a termite—*Eutermes* (*Rippertii?*). A preliminary abstract. Johns Hopkins Univ. Circ., v. 15, no. 126, p. 86–87, June, 1896.

The embryology of a termite, *Eutermes* (*Rippertii?*). Jour. Morphol. [Boston], v. 16, no. 3, p. 505–568, pl. 29–32, August, 1900.

A comparative study of the development of the generative tract in termites. Johns Hopkins Hospital Bul., v. 12, no. 121–122–123, p. 135–136, 2 figs., Baltimore, April–May–June, 1901.

LINTNER, J. A. Entomology. Proc. Albany Inst., v. 2, p. 48–50, 1878.

OSBORN, H. On the occurrence of the white ant (*Termes flavipes*) in Iowa. Proc. Iowa Acad. Sci., v. 5, for 1897, p. 231, 1898.

OSTEN-SACKEN, C. R. Extract from a letter by Baron R. Osten-Sacken, on the specimens of Termes found by him in California. Proc. Boston Soc. Nat. Hist., v. 19, p. 72–73, for January 3, 1877, June, 1877.

PACKARD, A. S. Third Report U. S. Entomological Commission, Washington, 1883, p. 326–329.

On the systematic position of the Mallophaga. Proc. Amer. Philos. Soc., v. 24, p. 264–272, 13 figs., September 2, 1887.

A Textbook of Entomology, New York, 1903.

PARKER, W. B. California redwood attacked by *Termes lucifugus* Rossi. Jour. Econ. Ent., v. 4, no. 5, p. 422–423, October, 1911.

RILEY, C. V., editor. Amer. Ent., v. 3 (n. s., v. 1), p. 15, January, 1880. Termitophilous insects collected by E. A. Schwarz recorded.

RILEY, C. V., and HOWARD, L. O. Termites swarming in houses. U. S. Dept. Agr., Div. Ent., Insect Life, v. 6, no. 1, p. 35, November, 1893.

SCAMMELL, E. H. White ants. Knowledge, n. s., v. 4, p. 10–12, January, 1907. Protection of wood by a newly devised process.

SCHWARZ, E. A. Staphylinidæ inquilinous in the galleries of *Termes flavipes.* Amer. Ent., v. 3 (n. s., v. 1), p. 15, January, 1880.

Termitophilous Coleoptera found in North America. Proc. Ent. Soc. Wash., v. 1, no. 3, p. 160–161, 1889.

SCUDDER, S. H. Remarks upon the American white ant. Proc. Boston Soc. Nat. Hist., v. 7, p. 287–288, 1860.

Further injury to living plants by white ants. Canad. Ent., v. 19, no. 11, p. 217–218, November, 1887.

More damage by white ants in New England. Psyche, v. 6, no. 177, p. 15–16, January, 1891.

The fossil white ants of Colorado. Proc. Amer. Acad. Arts and Sci., v. 19 (n. s., v. 11), p. 133–145, 1884.

SMITH, E. F. White ants as cultivators of fungi. Amer. Nat., v. 30, p. 319–321, April, 1896.

SNYDER, T. E. Record of the finding of a true queen of *Termes flavipes* Kol. Proc. Ent. Soc. Wash., v. 14, no. 2, p. 107–108, pl. 3, June 19, 1912.

Changes during quiescent stages in the metamorphosis of termites. Proc. Ent. Soc. Wash., v. 15, no. 4, p. 161–165, December, 1913.

STOKES, A. C. The sense-organs on the legs of our white ants. *Termes flavipes* Koll. Science, v. 22, no. 563, p. 273–276, November 17, 1893.

WARREN, E. Some statistical observations on termites, mainly based on the work of the late Mr. G. D. Haviland. Biometrika, v. 6, no. 4, p. 329–347, illus., March, 1909.

WHEELER, W. M. The embryology of *Blatta germanica* and *Doryphora decemlineata*. Jour. Morphol., Boston, v. 3, no. 2, p. 291–386, pl. 15–21, September, 1889.

The phylogeny of the termites. Biol. Bul., v. 8, no. 1, p. 29–37, December, 1904.

The fungus-growing ants of North America. Bul. Amer. Mus. Nat. Hist., v. 23, p. 669–807, pl. 49–53, September, 1907. Including Pt. IV, 1, The fungus-growing termites, p. 775–786.

RELATION OF TERMITES TO THE ORIGIN OF HOG-WALLOWS AND PRAIRIE MOUNDS.

BARNES, G. W. The hillocks or mound-formations of San Diego, California. Amer. Nat., v. 13, no. 9, p. 565–571, September, 1879.

BRANNER, J. C. Decomposition of rocks in Brazil—Burrowing animals—Ants. Bul. Geol. Soc. Amer., v. 7, p. 295–300, February 4, 1896.

Ants as geologic agents in the Tropics. Jour. Geol., v. 8, p. 151–153, February–March, 1900.

Natural mounds or hog-wallows. Science, n. s., v. 21, no. 535, p. 514–516, March 31, 1905.

Geologic work of ants in tropical America. Bul. Geol. Soc. Amer., v. 21, p. 449–496, fig. 11, pl. 35, August 20, 1910.

FORSHEY and COPES. Mounds. Proc. New Orleans Acad. Sci., v. 1, no. 1, p. 18–20, March 1, 1854.

HILGARD, E. W. Physico-geographical and agricultural features of the State of California. U. S. Dept. Int., Census Off. 10th Census U. S., v. 6. Report on cotton production in the United States, Part II, p. 663–741. Hog-wallows, p. 676–677, 693.

LE CONTE, J. Prairie mounds. Proc. Cal. Acad. Sci., v. 5, p. 219–220, January, 1874.

Hog-wallows or prairie mounds. Nature, v. 15, p. 530–531, April 19, 1877.

McCOOK, H. C. Note on mound-making ants. Proc. Acad. Nat. Sci. Phila., 1879, p. 154–156, 1880.

TURNER, H. W. Hog-wallow mounds. U. S. Geol. Survey, Ann. Rept. 17, 1895–96, Pt. I, p. 681–683, pl. 33, 1896.

VEATCH, A. C. Formation of natural mounds—Ant-hill theory. U. S. Geol. Survey, Prof. Paper no. 46, p. 55–56 and 58–59, 1906.

WALLACE, A. R. Glacial drift in California. Nature, v. 15, p. 274–275, January 25, 1877.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 95.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS

CONTENTS AND INDEX.

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BUREAU OF ENTOMOLOGY—BULLETIN No. 95.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

I. THE TIMOTHY STEM-BORER, A NEW TIMOTHY INSECT.

By W. J. PHILLIPS, *Entomological Assistant.*

II. THE MAIZE BILLBUG.

By E. O. G. KELLY, *Entomological Assistant.*

III. CHINCH-BUG INVESTIGATIONS WEST OF THE MISSISSIPPI RIVER.

By E. O. G. KELLY, *Entomological Assistant,*

AND

T. H. PARKS, *Entomological Assistant.*

IV. THE SO-CALLED "CURLEW BUG."

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

V. THE FALSE WIREWORMS OF THE PACIFIC NORTHWEST.

By JAMES A. HYSLOP, *Agent and Expert.*

VI. THE LEGUME POD MOTH. THE LEGUME POD MAGGOT.

By JAMES A. HYSLOP, *Agent and Expert.*

VII. THE ALFALFA LOOPER IN THE PACIFIC NORTHWEST.

By JAMES A. HYSLOP, *Agent and Expert.*

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BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
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D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *in charge of library.*

Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

Geo. I. Reeves, W. J. Phillips, C. N. Ainslie, E. O. G. Kelly, T. D. Urbahns, H. M. Russell, Geo. G. Ainslie, J. A. Hyslop, W. R. Walton, J. T. Monell, J. J. Davis, T. H. Parks, H. L. Viereck, R. A. Vickery, Henry Fox, J. R. Malloch, V. L. Wildermuth, W. R. McConnell, Herbert T. Osborn, Philip Luginbill, W. R. Thompson, Harrison R. Smith, E. G. Smyth, C. W. Creel, E. J. Vosler, R. N. Wilson, Vernon King, Philip B. Miles, E. H. Gibson, L. P. Rockwood, *entomological assistants.*
Nettie S. Klopfer, Ellen Dashiell, *preparators.*
Chas. Petty, *collaborator.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 11, 1912.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 95, seven papers dealing with cereal and forage insects, and methods for their control. These papers, which were issued separately during the years 1911 and 1912, are as follows: The Timothy Stem-Borer, by W. J. Phillips; The Maize Billbug, by E. O. G. Kelly; Chinch-Bug Investigations West of the Mississippi River, by E. O. G. Kelly and T. H. Parks; The So-Called "Curlew Bug," by F. M. Webster; The False Wireworms of the Pacific Northwest, by James A. Hyslop; The Legume Pod Moth and The Legume Pod Maggot, by James A. Hyslop; The Alfalfa Looper, by James A. Hyslop.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The articles included in this bulletin relate to insects more or less destructive to cereal and forage crops in the United States. They represent investigations largely completed during the fiscal year 1911–12.

The timothy stem-borer, the subject of Part I, has not during our observations been especially injurious, but is likely to become so should several favorable conditions result in increased abundance. The maize billbug (Part II) and the so-called "curlew bug" (Part IV) are two very closely related insects, the latter being especially destructive in Virginia and the Carolinas, while the former is occasionally quite injurious in the West. The paper relating to chinch-bug investigations west of the Mississippi River (Part III) is exceedingly timely and serves to make more clear the difference in conditions, as regards the chinch bug, between the country west of the Mississippi River and that lying east of it. Parts V, VI, and VII relate to species more or less destructive in the extreme northwestern portion of the United States, a section of the country somewhat peculiar in that it differs greatly in insect fauna from more southern and eastern sections of the country.

All of these papers relate to insects that the farmer must, to a greater or less extent, encounter and control in a successful carrying out of his business.

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

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[1] The seven papers constituting this bulletin were issued in separate form on March 31, April 22, and December 14, 1911, and April 10, April 22, May 31, and October 16, 1912, respectively.

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ERRATA.

Page 2, line 18 from bottom, for *this year* read *in 1910.*

Plate I, facing page 8, after line at bottom, insert: *a, Work of larva in bulb of plant; b, larva ascending stem to pupate; c, pupa in cell, the gallery plugged with frass below. Much enlarged.* (*Original.*)

Page 12, line 19 from bottom, before *corn borer* insert double quotation mark in place of single quotation mark.

Page 15, line 16, for *were* read *was.*

In Plate IV, facing page 24, the cut of figure 1 is upside down.

Page 46, line 16 from bottom, after *4* insert *per cent.*

Page 74, last line, insert superior figure 1 (¹) before *Bureau.*

Page 76, line 16 from bottom, for *littorale* read *aviculare.*

Page 77, line 12 from bottom, for *littorale* read *aviculare.*

Page 81, line 4, after *monograph* insert comma.

Page 81, line 5 from bottom, before *Dr.* insert *of.*

Page 82, line 5 from bottom, for *littorale* read *aviculare.*

Page 83, line 8, for *littorale* read *aviculare.*

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE TIMOTHY STEM-BORER,

A NEW TIMOTHY INSECT.

BY

W. J. PHILLIPS,
Entomological Assistant.

ISSUED MARCH 31, 1911.

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W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*
Nettie S. Klopfer, *preparator.*

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U. S. D. A., B. E. Bul. 95, Part I. C. F. I. I., March 31, 1911.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE TIMOTHY STEM-BORER, A NEW TIMOTHY INSECT.

(*Mordellistena ustulata* Lec.)

By W. J. Phillips,
Entomological Assistant.

INTRODUCTION.

The writer's attention was first attracted, in 1904, to the interesting little insect which is the subject of this paper. On November 29 of that year, at Rives, Tenn., while examining timothy for joint-worms (Isosoma), a curious little larva, unknown at that time to the writer, was found tunneling the stems. In many cases it had traversed the entire length of the stem, from the top joint to the bulb. Although nothing was reared from this material it served to arouse interest. Since that time, however, it has been reared and some interesting facts learned concerning its habits and manner of living.

Thus far it has not proved a serious pest, having been found only in small numbers at any given point. In large numbers it would scarcely do any perceptible injury to the hay crop, although it could probably very materially lessen seed production. For this, as well as other reasons, it deserves more than passing notice.

HISTORY.

The adult (fig. 1) was described by Le Conte in 1862, but there is no reference in literature to its larval habits, although as early as 1877 it was known that larvæ of other species of this genus inhabited plant stems of different kinds.

During the early part of November, 1904, Mr. Geo. I. Reeves, of this Bureau, found larvæ tunneling timothy stems at Richmond and Evansville, Ind., and at Nicholsville, Ohio, but none was reared. In the latter part of the month the writer found a larva working in timothy stems at Rives, Tenn. Nothing could be reared, but in the light of recent observations it is very probable that they were *Mordellistena ustulata* in each instance.

In 1905 the writer found numbers of larvæ inhabiting timothy at Richmond, Ind. Some time in the fall infested stems were collected and sent to the Department for rearing, but it was the same story—nothing issued.

Early in the spring of 1906 observations were begun with a view to rearing the adult. Infested stems were collected in May, and on June 8 the first adult appeared. Specimens were later submitted to the Department and were found to belong to the above species. Since that time they have been reared repeatedly.

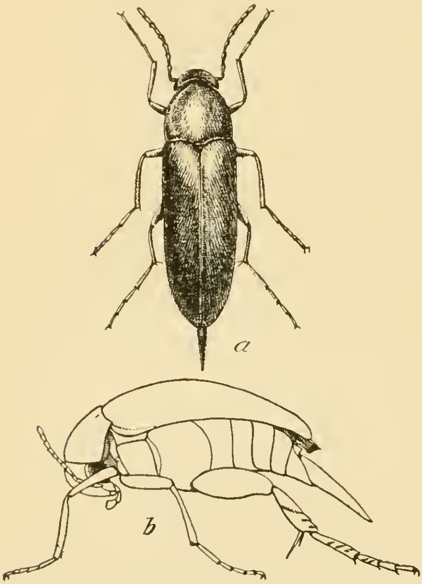

FIG. 1.—The timothy stem-borer (*Mordellistena ustulata*): *a*, Adult or beetle, dorsal view; *b*, same, lateral view. Greatly enlarged. (Original).

DISTRIBUTION.

The habitat of this insect has been given as the middle and southern United States. Adults have been captured as far east as Pennsylvania, and they have been reared from material collected in Indiana, Ohio, and Virginia. Timothy stems containing mordellid larvæ that were not identified, but which were probably *Mordellistena ustulata*, were found in Kentucky, Tennessee, Illinois, and, this year, Mr. T. H. Parks, of the Bureau of Entomology, found them at Chillicothe, Mo.

CHARACTER OF ATTACK.

As a rule the egg is deposited at or slightly below the center of the first or second joint in timothy, but much farther down the stem in other grasses. From here the larva bores into the center of the stem and then begins its downward journey to the bulb or root. It feeds upon the pith and the walls of the stem as it passes downward, and when it encounters a joint it tunnels completely through it, leaving a mass of detritus behind. Plate I is an illustration of its workmanship.

HOST PLANTS.

This species has been reared from timothy, orchard grass (*Dactylis glomerata*), quack grass (*Agropyron* sp.), and *Agrostis alba*, while larvæ that were supposedly this species have been found in bluegrass (*Poa* spp.) and cheat (*Bromus secalinus*).

DESCRIPTION OF THE DIFFERENT STAGES.

THE EGG.

(Fig. 2.)

Length 0.65 mm., diameter near center 0.16 mm. Color milky white. Acuminate-ovate, apparently smooth; one side convex and the other slightly concave; large end broadly rounded, small end acutely rounded.

Described from specimens dissected from gravid females.

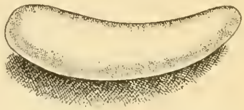

FIG. 2.—The timothy stem-borer: Egg. Highly magnified. (Original.)

THE LARVA.

(Fig. 3, *a*.)

Length 6 mm., diameter 0.875 mm. Color varying from creamy to white, shading into a very faint tinge of salmon near center. None of the segments appears to be corneous, although each bears a number of setæ; last segment feebly bifid, ending in a two-pointed spear, and covered with stout bristles. Dorsal surface of abdomen with six pairs of fleshy tubercles which will be described later.

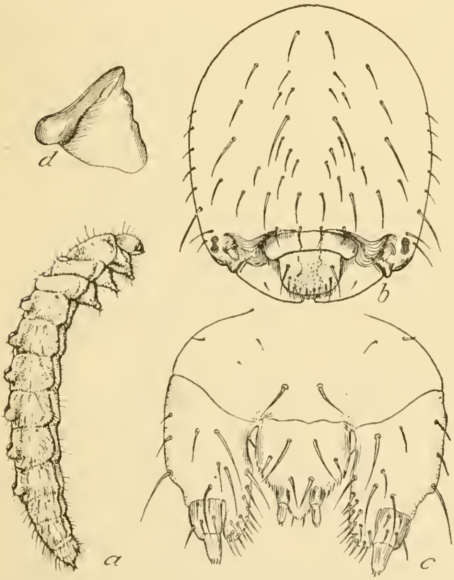

FIG. 3.—The timothy stem-borer: *a*, Larva, lateral view: *b*, head of same, dorsal view; *c*, maxillæ and labium of same; *d*, mandible of same. *a*, Greatly enlarged; *b*, *d*, more enlarged; *c*, still more enlarged. (Original.)

Head (fig. 3, *b*) narrower than thorax and arranged almost vertically with reference to it; ovoid, smooth, and bearing a number of large and small setæ, a very faint suture extending from the occipital area almost to the epistomal area.

Antennæ represented by two fleshy tubercles, situated laterad of and near insertion of mandibles; somewhat cone-shaped and bearing several small setæ on their summits.

Eyes represented by two tiny, slightly fused black dots situated slightly ventro-laterad of the antennæ.

Epistoma sublunate; anterior margin concave and posterior convex; about twice as broad as long and apparently inclosed by base of mandibles and a chitinous ridge extending from insertion of mandibles almost entirely across the face; ridge amber-colored.

Labrum tonguelike, lying directly over the mandibles, rectangular, longer than broad; distal margin rounded and densely fringed with setæ or bristles; upper surface pappose; two large setæ near center and two on each lateral margin; six smaller ones on distal margin.

Mandible (fig. 3, *d*) short, very broad at base, almost as broad as long, tapering abruptly to a sharp point; outer face convex and smooth, with a small seta near center; ferruginous at base and black at extremity, strongly curved; inner face concave, with two small notches midway of superior margin and one small notch near extremity of inferior margin.

Maxillæ (fig. 3, *c*) inserted far to the rear, large, fleshy, curving considerably, thus inclosing the labium; extending considerably beyond tips of mandibles; distal extremity bearing the two-jointed palpus and the lacinia. Each maxilla bears a number of setæ, one large and two small ones occurring on outer face, a large one at outer and one at inner angle of base of palpus, and two small ones and one large one caudad of these. The lacinia is a brushlike organ bearing a fringe of stout bristles. Maxillary palpi (fig. 3, *c*) two-jointed; first joint slightly obconical, about as thick as long, bearing several setæ on the outer face; the second joint is a slightly truncated cone, and much smaller than the first joint, and bears a number of minute setæ at the apex.

The *labium* (fig. 3, *c*) is a very simple organ inserted between bases of maxillæ, fleshy, rectangular; distal extremity sharply rounded and fringed with minute setæ, with two larger setæ at tip; four setæ forming a semicircle near center, the two in the center much the largest; a large seta at inner angle of base of each palpus. Labial palpi (fig. 3, *c*) very minute, two-jointed; first joint cylindrical; second joint almost cylindrical but much smaller than the first and slightly rounded at tip, bearing several minute setæ.

Prothorax as large as the two following segments combined; viewed from side triangular in form; not wrinkled or folded but finely striate; dorsally the posterior margin extends back for a considerable distance into the mesothorax. The mesothorax and metathorax lie at quite an angle with the abdominal segments; posterior margin of dorsum of mesothorax extending back to center of metathorax. Metathorax about same width as mesothorax, except on dorsum, where it is somewhat narrower.

Legs fleshy, cone-shaped, four-jointed; first joint very large and more like a projection of the thorax than a joint of the leg; second joint obconical, very short, and very much smaller than the first; third joint cylindrical, short, and very small; fourth joint the smallest of all, obconical, rounded at apex, and bearing three spines at tip; a whorl of spines at each joint on outer face; segments very imperfectly defined in most cases.

Abdomen composed of nine segments, all of which are broader than the mesothorax or metathorax. First six segments bearing on their dorsal surface two round, fleshy, somewhat retractile elevations or tubercles (M. Perris, in his Larves des Coléoptères, calls them "ampoule ambulatoire.") These tubercles are almost circular in form and the apex is crumpled and folded and bears several small setæ. Dorsum of the seventh segment with a slight transverse ridge bearing a number of recurved bristles; eighth segment bearing a number of bristles, which are more numerous near posterior margin, all directed backward. First eight segments with a large fold extending their full length on each lateral face, most prominent near center of segments, at which points there are a number of bristles directed slightly to the rear. Ninth segment somewhat cone-shaped, densely covered with stout bristles, ending posteriorly in a two-pointed, chitinous projection; just below this, dorsally, are two chitinous spurs or tubercles.

Stigmata: Nine pairs of stigmata, one pair in mesothoracic region just above and slightly in front of insertion of legs and a pair to each of the first eight abdominal segments, very near the anterior margin and just above the lateral fold. They are circular in form, the thoracic being slightly the larger.

THE PUPA.

(Fig. 4.)

From the lateral aspect: Length 5 mm., diameter in thoracic region 1.125 mm. Pale cream color, somewhat acuminate-ovate, broadly rounded at head and thorax. Prothorax, from the lateral view, triangular, the dorsal surface being the base of the triangle, which is very broad and convex. Antenna passing upward at side of eye, between margin of prothorax and front femora, thence to dorsum, curving backward over base of wings. Wing-pads long and narrow, covering posterior legs, with the exception of the last three tarsal joints; front wings nearly covering hind ones.

From the ventral aspect (fig. 4): The front of head is in almost direct line with the body; mandibles small and not closed; palpi widely separated and extending beyond front tibiæ. Femora of first pair of legs directed dorsally, tibiæ resting on middle femora; first tarsal joints resting under tip of palpus; tarsal joints then extending caudad, almost parallel, except last two joints, which slightly diverge. Femora of second pair of legs parallel to femora of first pair, second tibiæ, however, forming a greater angle with their femora than tibiæ of first pair of legs; second femora and tibiæ resting upon wings for a part of their length; tarsal joints gradually converging until the last two, which nearly touch between wing pads. Third pair of legs covered by wing pads, with exception of last two joints and a part of third; last two parallel, touching, and extending to middle of sixth abdominal segment.

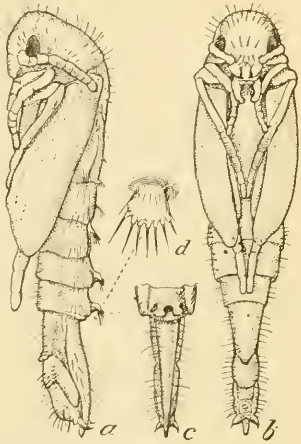

FIG. 4.—The timothy stem-borer: *a*, Pupa, lateral view; *b*, ventral view of same; *c*, ninth segment of same; *d*, setigerous tubercle of sixth segment. *a*, *b*, *c*, Greatly enlarged; *d*, more enlarged. (Original.)

Dorsal surface of the first six abdominal segments almost flat, and in the third, fourth, fifth, and sixth segments the surface produced laterally into a fleshy fold projecting over side of abdomen, the anterior margin of which is rounded and the posterior square, giving the abdomen a notched appearance; in center of each projection laterally is a group of rĕcurved bristles.

Seventh abdominal segment (fig. 4), from a lateral view, cylindrical anteriorly; posteriorly the dorsal surface is drawn out into a long cone-shaped projection, the tip of which extends beyond the last abdominal segment, resting between its two chitinous spurs; ventral surface extending backward into a fleshy fold or lip, beyond insertion of following segment.

Eighth segment (fig. 4) somewhat cylindrical anteriorly, telescoping into seventh; dorsal surface extending backward into a large fleshy projection or lip, almost filling space between cone-shaped projection of preceding segment and Y-like chitinous projection of following segment; a deep lateral notch or incision, but ventral projection much shorter than dorsal.

Ninth segment (fig. 4) smallest, telescoping into eighth, and extending posteriorly into a Y-like projection, the tips of which, inclining forward, are amber-colored, chitinous, and spinelike.

Setæ: Numerous setæ on ventral surface of abdomen, on head, and on prothorax. First abdominal segments bearing a few setæ on dorsal surface; there is a small transverse ridge on dorsum of second segment, bearing a row of setæ; following four segments bearing each two recurved, fan-shaped, fleshy elevations or tubercles, increasing in size with each successive segment (fig. 4, *d*); each elevation simple and bearing a fringe of bristles directed to the rear.

Last three segments bearing a number of bristles; cone-shaped projection of seventh rather thickly studded and last segment densely covered with stout bristles, all directed to the rear.

THE ADULT.

(Fig. 1.)

The description by Le Conte is as follows:

Hind tibia with two oblique ridges on the outer face; ridges parallel, the anterior one extending almost across the outer face of the tibia; first joint of the hind tarsi with three, second with two oblique ridges; elytra ferruginous, with the suture and margin blackish; ferruginous, black limb of the elytra very narrow; abdomen, and sometimes the hind coxæ and pectus, blackish. 9–11.

LIFE HISTORY AND HABITS.

THE EGG.

Females have never been observed in the act of oviposition and the period of incubation of the eggs has never been determined. The latter would be rather difficult to obtain, as eggs that are deposited in living plant tissue rarely hatch after they have been exposed to the air.

As stated above, the egg is usually deposited at and slightly below the center of the first or second joint from the top, within the plant tissues.

The number of eggs that one individual is capable of depositing has not been ascertained. Upon dissection females have never been found to contain more than four fully developed eggs and several immature ones, but they probably deposit a much greater number than this.

THE LARVA.

Upon hatching, the young larva apparently destroys the tissue immediately surrounding it, thus forming a minute cell or cavity. It then eats its way into the center of the stem and starts downward, tunneling the joints as it reaches them, and at harvest time the earlier ones are below the fourth joint, where they will be out of danger of the mower. By fall they have reached a point just above the bulb.

THE MOVEMENTS OF THE LARVA IN THE STEM.

The manner in which the larva propels itself up and down the stem is very interesting. It can ascend or descend the stem, forward or backward, apparently with equal facility. The maxillæ, which extend beyond the mandibles, the true legs, the dorsal tubercles or feet, and the anal segment all play a part in its movements. In going forward the abdomen is advanced by means of the dorsal tubercles, which act as feet; the body is then braced by fixing the spines of the anal segment against the opposite wall of the stem; the maxillæ and true feet then advance the thorax and head. By executing these movements almost simultaneously the larvæ can move quite rapidly. In going backward the movements are reversed. The dorsal feet or tubercles and the anal spines enable the larva to support itself in the stem.

THE MOVEMENTS OF THE LARVA OUTSIDE THE STEM.

Naturally enough, as the larva seems peculiarly adapted for movement in a small hollow stem, when it is placed on a flat surface it appears wholly at a loss how to proceed. It arches its body and turns on its side, going through the same movements as though it were in a stem, but it moves very slowly. It then turns on its back and tries to walk on its dorsal feet. By bringing all of its knowledge of the different ways of walking to bear on the problem, it moves slowly, in a drunken way, to a protecting object, if any be near.

THE PUPA.

When ready to pupate, the larva (Plate I, *a*) reverses its position in the stem and ascends to a point anywhere between the first joint from the root and the first or second joint from the top, depending upon whether the timothy has been cut or not. Plate I, *b*, shows a larva ready to pupate, just below the second joint from the root. It probably locates most often just above the first or second joint from the root. It then seals up the stem above and below with detritus, making a cell of from 1 to 2 inches in length. It will reseal a stem if interfered with, but if its burrow be molested many times it will live for weeks and not pupate, finally dying.

After inclosing itself within this cell the larva becomes sluggish, contracts slightly, and thickens perceptibly in the thoracic region. It soon casts its larval skin and becomes a fully developed pupa. In Plate I, *c*, is seen a pupa in its cell just above the second joint from the root. After pupation it is a pale cream color, gradually changing to a brownish tint.

THE MOVEMENTS OF THE PUPA IN THE STEM.

The movements of the pupa in ascending and descending the stem are fully as complicated and interesting as in the case of the larva. In moving up the stem, the spurs of the last segment are planted firmly in the wall; the body is then bowed ventrally and the spines of the dorsal tubercles are brought forward and fixed in the wall; then by quickly releasing the anal spines, with the long pointed pygidium of the eighth segment, they and the dorsal tubercles act as levers and thus propel it up the stem. By executing these evolutions quickly they can move with considerable rapidity.

They can, apparently, descend with equal rapidity. By releasing the anal and dorsal spines they are lowered by gravity. If the stem be placed in a horizontal position, the pupa makes slow progress backward. The organs of locomotion are apparently not so well fitted for moving backward on a horizontal plane.

THE MOVEMENTS OF THE PUPA OUTSIDE THE STEM.

When removed from the stem and placed upon a flat surface, the pupa moves as uncertainly as the larva in the same position. It wriggles constantly, trying in vain to fix its "climbers" into something firm, whereby it can gain leverage and propel itself forward. It will fix the anal spines into the surface upon which it rests, but as there is no surface opposite and near it moves very slowly and uncertainly.

THE ADULT.

When ready to issue, the pupa is quite brown. The thin pupal envelope is ruptured along the dorsum of the thoracic region and the insect gradually forces its way out, after which it gnaws an irregular opening at some point in the stem and emerges.

The adult beetles are about 5 mm. in length, of a brownish color, and have pointed abdomens. From the lateral aspect they are somewhat crescent shaped. They are abroad from the latter part of May to the latter part of June, depending upon temperature conditions in early spring.

There is but one brood or generation during the year.

LIFE CYCLE.

LENGTH OF THE SEVERAL STAGES.

The larval stage covers a period of about 11 months. Nothing could be learned about the number of molts, as the larvæ will not develop if their galleries are disturbed.

The pupal stage varies from 11 to 16 days, depending, apparently, upon the temperature.

The adult beetles will live from 5 to 6 days in confinement, but they will probably survive a much longer period in the open.

HIBERNATION.

The insect hibernates in the larval stage. About the time freezing begins in the fall the larvæ are down to the bulb or crown of the root, where they are well protected from cold. They are nearly full grown by this time. Whenever a few warm days come, they apparently start feeding again. In the spring they burrow down into the juicy bulb, where they continue feeding until they become full grown.

THE TIMOTHY STEM-BORER (MORDELLISTENA USTULATA): LARVÆ AND PUPA IN STEMS.

PARASITIC ENEMIES.

This insect is apparently a very attractive host. Three species of parasitic Hymenoptera have been reared from it, all of them new, representing three genera—two braconids and one a chalcidid. Messrs. H. L. Viereck[a] and J. C. Crawford[b] have kindly described these parasites, giving them the following names: *Heterospilus mordellistenæ* Vier., *Schizoprymnus phillipsi* Vier., and *Merisus mordellistenæ* Crawf. The descriptions appear elsewhere over the names of their respective authors.

In May of this year, *Mordellistena ustulata* was found to be very abundant at Wilmington, Ohio, in timothy; material was collected and sent in to the laboratory at La Fayette, Ind., for rearing. Two species of parasites were reared from it, *Heterospilus mordellistenæ* and *Merisus mordellistenæ*. *Schizoprymnus phillipsi* and *Heterospilus mordellistenæ* were reared from material collected at Richmond, Ind., in 1906 and 1908, respectively. The latter species and *Merisus mordellistenæ* were reared at La Fayette, Ind., in 1910.

It is very probable that the parasitic enemies keep the beetles pretty well in check and that this accounts for the appearance of the beetles in small numbers only in any given locality.

REMEDIAL MEASURES.

As this insect has never appeared in destructive abundance, so far as known, there has been no occasion to devise means of combating it. If a serious outbreak should occur, however, a short crop rotation should be adopted, allowing a field to remain in timothy sod not more than two or three years, thus preventing this stem-borer from becoming well established. The borders of the fields and waste places should be mowed frequently during the months of June and July. If this is done, the larvæ will not be able to reach maturity.

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[a] Proceedings of the U. S. National Museum, vol. 39, pp. 401–408, 1911.

[b] Proceedings of the Entomological Society of Washington, vol. 12, no. 3, p. 145, 1910.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 95, Part II.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE MAIZE BILLBUG.

BY

E. O. G. KELLY,
Entomological Assistant.

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE MAIZE BILLBUG.

(*Sphenophorus maidis* Chittn.)

By E. O. G. Kelly,
Entomological Assistant.

INTRODUCTION.

There are several species of the genus Sphenophorus that have been reported as being enemies to young corn in early spring. Heretofore these reports have always been made in connection with fields of grass, timothy sod, or lands recently reclaimed by drainage, and the depredations were on the first cultivated crop following these conditions.

Dr. S. A. Forbes[a] records eight species of Sphenophorus the adults of which are known to attack young corn. Dr. C. V. Riley, in the report of the Commissioner of Agriculture for 1881 and 1882, records Dr. L. O. Howard's observations on the habits and natural history of *S. robustus* and gives a description of the imago, larva, and pupa, Dr. Howard having found and reared these from specimens taken from young corn plants at Columbia, S. C. Dr. F. H. Chittenden, however, in a paper entitled "On the species of Sphenophorus related to *pertinax* Oliv., with descriptions of other forms,"[b] with reference to *S. robustus*, says:

This species ranges from Indiana and Michigan through Wisconsin, Minnesota, and western Kansas to California. It is a northern form, not occurring in the East. Nothing appears to be known of its habits, reference to *robustus* and its injuries to corn being due to a distinct species, my *S. maidis*.

Dr. Chittenden had before him, while describing *S. maidis*, among numerous other specimens, the one specimen from Columbia, S. C., reared by Dr. Howard. According to his statement *maidis* is a valid species and quite distinct from *S. robustus*.

[a] Twenty-third Report of the State Entomologist of Illinois, 1905.
[b] Proc. Ent. Soc. Wash., vol. 7, p. 57, 1905.

Dr. Chittenden informs the writer that since 1895 complaints have been made every few years in localities in Kansas, South Carolina, Georgia, and Alabama of injuries to corn by what he believes to be this species of billbug. The species has been quite generally confused with *Sphenophorus pertinax* Oliv. and *S. robustus* Horn, by both of which names it has been mentioned in economic literature, more especially by the latter. It is, however, quite distinct from either, in fact, different from any billbug known to inhabit the United States, and has only recently been described as new to science, although Dr. Chittenden states that it is by no means new as an agricultural foe.

The observations on the maize billbug (*Sphenophorus maidis* Chttn.) given herein were made by the writer between June and December, 1910.

HISTORY OF THE SPECIES.

The history of this species, the writer is informed by Dr. Chittenden, is, in brief, that it first attracted attention in Alabama as early as in 1854; again in the same State in 1880; in South Carolina in 1881; in Kansas in 1895; in 1901 it again did injury in Kansas, and in 1903 in Georgia. The fact that the insect is injurious to corn in both of the active stages, larva and beetle, indicates that it is a more or less permanent pest, whereas several of our equally common corn billbugs will eventually disappear with the reclamation by draining and the cultivation of the soil and the consequent destruction of their breeding places.

In the opinion of Dr. Chittenden, this is the species described and figured by Townend Glover in 1855 [a] as the "billbug" or "corn borer (Sphenophorus ?)," since both description and figure do not apply to any other billbug known to breed in corn. Glover describes the beetle as from four-tenths to six-tenths of an inch in length, and of a reddish-brown or reddish-black color, and the rostrum or snout in the figure can not belong to any other Sphenophorus. None of the specimens which served as models of the drawing remains in the Government collections. The billbug was reported as very destructive to corn in many parts of the South and Southwest, more particularly along the Pedee River. Injuries were reported by Senator Evans, Gen. Fitzpatrick, and Col. Pitchlynn. Senator Evans's report is as follows:

> The perfect insect eats into the stalk of the corn, either below or just at the surface of the ground, where it deposits its egg. After changing into a grub, the insect remains in the stalk, devouring the substance, until it transforms into the pupa state, which occurs in the same cavity in the stalk occupied by the grub. It makes its appearance the following spring in the perfect state, again to deposit its eggs at the foot of the young corn plants. These

[a] Agricultural Report of the Patent Office for 1854 (1855), p. 67, pl. 4.

insects destroy the main stem, or shoots, thus causing suckers to spring up, which usually produce no grain, or, if any, of very inferior quality to that of the general yield. Swamp lands or low grounds are the places most generally attacked.

Senator Evans thus is, according to Chittenden, to be credited with the discovery that the larva develops in the stalk of corn below the ground, and not in decaying wood, as contended by Messrs. Walsh and Riley in later years. The insect was said to be very destructive in Alabama, from which State the specimens chosen for illustration doubtless came, and on the Red River in Arkansas. With little doubt it was the same insect operating in Arkansas, as it is now known that this species ranges between South Carolina and Missouri.

This insect was observed in the spring of 1881 by Dr. L. O. Howard, at that time assistant to Dr. C. V. Riley, Entomologist of the Department of Agriculture. Dr. Howard was at once sent to Columbia, S. C., to investigate the injury being done to corn by "billbugs," and the following account of these investigations is taken from the report of his observations:[a]

The species found near Columbia, S. C., is *S. robustus* [now *S. maidis*]. In the plantations along the bottom lands of the Congaree River much damage is done by the adult beetle every year, and the corn not infrequently has to be replanted several times, as the earlier plantings are destroyed. The beetles are first noticed in the spring after the corn is well up. Stationing themselves at the base of the stalk, and also burrowing under the surface of the earth slightly, they pierce the stalk and kill many plants outright, others living to grow up stunted and dwarfed.

With *S. sculptilis* [*zeæ*], in spite of the damage it has done, the earlier stages remain unknown, Walsh surmising that the larva breeds on rotten wood, so situated that it is continually washed by water. With this statement in my mind I was prepared to doubt the statement of Mr. W. P. Spigener, of Columbia, who informed me that the "grub form of the billbug" was to be found in the corn, but a couple of hours in the field convinced me that he was right, my previous idea having been that he had mistaken the larva of *Chilo saccharalis* for the weevil grub. I searched a field on Mr. Spigener's plantation, which was said to be the worst point in the whole neighborhood for bugs, for some time before finding a trace of the beetle in any stage, but at last, in a deformed stalk, I found in a large burrow, about at the surface of the ground, a full-grown larva. After I had learned to recognize the peculiar appearance of the infested stalks I was enabled to collect the larvæ quite rapidly.

They were present at this date (Aug. 20) in all stages of larval development, but far more abundantly as full-grown larvæ. A few were preserved in alcohol and the remainder forwarded alive to the department, but all died on the way. Two pupæ were found at the same time; one was preserved in alcohol and the other forwarded to the department. The beetle issued on the way, and from this specimen we have been able to determine the species. From an examination of a large number of injured stalks it seems evident that the egg is laid in the

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[a] Report of the Entomologist, Department of Agriculture, for 1881 and 1882, pp. 139–140.

stalk just at the surface of the ground, preferably and occasionally a little below. The young larvæ, hatching, work usually downward, and may be found at almost any age in that part of the stalk from which the roots are given out. A few specimens were found which had worked upward for a few inches into the first section of the stalk above ground, but these were all very large individuals, and I conclude that the larva only bores into the stalk proper after having consumed all available pith below ground.

The pupæ were both found in cavities opposite the first suckers, surrounded by excrement compactly pressed, so as to form a sort of cell.

Wherever the larva had reached its full size, the pith of the stalk was found completely eaten out for at least 5 inches. Below ground even the hard external portions of the stalk were eaten through, and in one instance everything except the rootlets had disappeared and the stalk had fallen to the ground.

In a great majority of instances but a single larva was found in a stalk, but a few cases were found where two larvæ were at work. In no case had an ear filled on a stalk bored by this larva. The stalk was often stunted and twisted, and the lower leaves were invariably brown and withered.

In one field, which had been completely under water for six days in January, the beetles were apparently as healthy as in fields which had remained above water.

INJURIES SINCE 1895.

The records of reports of injury which follow, received by Dr. Chittenden during the past decade, substantiate the observations of Dr. Howard made in 1881, and add as well to our knowledge of the life economy of the species.

In 1895 this billbug was destructive in three localities in Kansas, complaints all being made during the first week of May. At Cedar Vale immense damage was done, the insect "taking whole fields of corn, hill by hill." Similar injury was observed at Dexter and Leon, these reports having been made by Mr. Hugo Kahl in a letter dated July 27, 1898.

The following year Prof. F. S. Earle reported, June 6, injury by this species at Wetumpka, Ala., on the Coosa River, where there was great complaint of it as a destructive enemy of corn, especially on low-lying bottom lands. The insect was well known there as a billbug, and was not found on hilly land. It worked below ground, and when the stalks were not killed outright they put out an immense number of suckers. The beetles were most destructive to early plantings, corn planted after the middle of May being usually little injured.

In 1901 Mr. J. E. Williams, Augusta, Butler County, Kans., wrote, August 28, of injury to corn. Attack commenced as soon as the corn came through the ground, and the billbugs ate and dug down to the kernel and devoured that. In larger corn they bored into the stalk and wintered over in the old stalks, usually below ground. Whole fields were destroyed, the beetles remaining to continue their work on second plantings. The insect was known locally as the "elephant bug." September 6 Mr. Williams sent larvæ and adults and their work in the root-stalks of corn. He had observed that the eggs were deposited in the stalks, and that these serve for the winter quarters of the adults; that the beetles began work when the corn was about 4 or 5 inches high by inserting their beaks in the young stalks just above ground. By taking hold of the center of the corn and pulling it it came out, as it was nearly severed as from cutworm attack. Stalks that had been preyed upon by the billbug did not yield any amount of seed. No injury was observed to crops other than corn. Injury was only in lowlands, and the principal damage was accomplished before the woody outer shell of the stalk was formed. The beetles were active chiefly after dark, when they traveled, though slowly, from one place to another. They burrowed in the ground during the day. They were described as "cleaning up everything as they go, rendering the crop entirely worthless." September 17 another sending of larvæ, pupæ, and imagos were received from the same source. Out of 100 stalks examined by our correspondent only 10 were free from the ravages of this billbug. At this date of writing the beetles were deserting the corn.

In 1903 a report was received of injury by what was with little doubt this species at Griffin, Ga., although no specimens were received, as in all preceding instances cited.

DISTRIBUTION.

This insect has been reported, according to Chittenden,[a] from Augusta, Kans. (E. L. Williams); Riley County, Kans. (P. J. Parrott); Florence, Kans.; Dadeville, Ala. (S. M. Robertson); Wetumpka, Ala. (F. S. Earle); Columbia, S. C. (L. O. Howard); Ballentine, S. C. (J. Duncan); Texas (Ulke, 1 ex.); Michigan (Knaus). It has also been reported from Texas (T. D. Urbahns), and the writer found it at several points in Oklahoma and Kansas. Owing to the fact that representatives of the species have been taken in such widely separated localities, it is very probable that it occurs over the entire territory between South Carolina and Texas and northward to Kansas and Missouri.

FOOD PLANTS.

The adults attack young corn plants and probably some of the coarser grasses. Dr. Howard, and later the writer, found both adults and larvæ feeding on young corn. Mr. Urbahns found adults at base of swamp grass (*Tripsacum dactyloides*) in considerable numbers, and probably larvæ and pupæ of the species in this same grass (fig. 8). Mr. Urbahns found several Sphenophorus larvæ

[a] Proc. Ent. Soc. Wash., vol 7, No. 1, pp. 59–61, 1905.

in burrows in this swamp grass and two pupæ. but failed to rear them. Dr. Chittenden determined these pupæ as having adult characters of *S. maidis*.

DESCRIPTION AND LIFE HISTORY.

THE EGG.

(Fig. 5.)

Eggs were found by the writer in southern Kansas during June in punctures made especially for them (fig. 7, *b*) in young corn plants. These egg punctures, which the female makes with her beak, are scarcely visible on the outer surface of the stalk, being only a slit in the sheath of the plant, through which the beak, and later the ovipositor, are thrust, the sheath closing readily when the egg is deposited and the ovipositor withdrawn. The eggs are about 3 mm. long and 1 mm. thick, creamy white in color, elongate, and somewhat kidney-shaped, with obtusely rounded ends, being slightly more rounded at one end than at the other; the surface is smooth, without punctures.

Fig. 5.—The maize billbug (*Sphenophorus maidis*): Eggs. Enlarged three times. (Original.)

In the latitude of southern Kansas eggs were laid in the corn plants during the month of June, where they hatched in from 7 to 12 days, the young, footless grub thus finding itself surrounded with the choicest food.

THE LARVA.

(Fig. 6.)

The newly hatched larvæ are white, with a light-brown head, the head changing to darker brown within a few days. The color remains white in the full-grown larvæ, with the head chestnut brown. The length of full-grown living larvæ ranges from 15 to 20 mm. and the width from 4 to 5 mm.

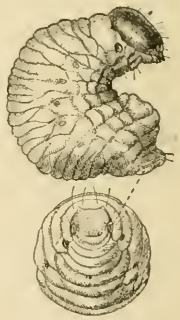

Fig. 6.—The maize billbug: Larva. Twice natural size. (Original.)

The following description of the full-grown larva was made by Mr. E. A. Schwarz under the name of *S. robustus*, from the few alcoholic specimens collected by Dr. Howard at Columbia, S. C.:[a]

Length 12 mm.; color dingy white; head chestnut brown, with four vittæ of paler color. two upon the occiput, converging toward the base, and one along each lateral margin; trophi very dark, clypeus paler; body fusiform, strongly

[a] Report of the Entomologist, Department of Agriculture, for 1881 and 1882, p. 141.

curved, swelling ventrally from the third abdominal joint posteriorly, slightly recurved and rounded at anal extremity. Head large, oblong, obtusely angulate at base, sinuately narrowed anteriorly; frontal margin with a shallow emargination between the mandibles; upper surface with a median channel, the occipital portion deeply incised, with raised edges, continuing as a shallow impressed line to the middle of the front; on either side an engraved line, commencing upon the vertex, becoming deeper after crossing the branches of the Y suture, and terminating at the frontal margin in a bristle-bearing depression; sides and vertex with several long bristles arising in depressions; antennæ rudimentary, occupying minute pits on the frontal margin at the middle of the base of mandibles; ocelli a single pair, visible only as translucent spots upon the anterior face of the thickened frontal margin, outside of and closely contiguous to the antennæ from which they are separated by the branches of the Y suture, a few pigment cells obscurely visible beneath the surface; clypeus free, transverse, trapezoidal, with faint impressions along the base and at the sides; labrum small, elliptical, bearing spines and bristles, a furrow each side of the middle, forming three ridges, so that the organ, when deflected, appears three-lobed; mandibles stout, triangular, unarmed, with an obsolete longitudinal furrow on the outer face; maxillæ stout, cardinal piece transverse, basal piece elongate, bearing a palpus of two short joints, and a small rounded lobe, furnished at tip with a brush of spiny hairs, the lobe concealed by the labium; labium consisting of a large triangular mentum, excavate beneath, and a hastate palpiger, with a deep median channel; labial palpi divergent, separated by the ligula, of two joints subequal in length; ligula represented by a prominent rounded lobe, densely ciliate on the under surface. Thoracic joints separated above by transverse folds; the first wider, covered above by a transverse, thinly chitinous plate; the two following similar to the abdominal joints; abdominal joints forming on the dorsum narrow transverse folds, separated by two wider folds, the anterior fold attaining the ventral surface, the second fold confined to the dorsum, eighth and ninth abdominal joints longer, excavate above, without dorsal folds; beneath, the first three joints contracted, the succeeding joints enlarged, the terminal joint broadly rounded, with anal opening upon a fold at its base; sides of each joint presenting numerous longitudinal folds; stigmata very large, nine pairs; the first on the anterior margin of the prothorax, low down upon the sides; the remainder upon the sides of the first eight abdominal joints, above the lateral prominences, beginning upon the first joint at the middle of the side and gradually rising to a dorsal position upon the eighth joint: thoracic and last abdominal pairs large, oval; the intermediate pairs smaller, elliptical; all with chitinous margins of dark-brown color. The noticeable features of this larva are its cephalic vittæ, and conspicuous spiracles.

Upon issuing from the eggshell the young larvæ are about 5 mm. long and 2 mm. thick. They at once begin feeding on the tissues of the young corn at the bottom of the egg puncture (fig. 7, *b*), directing their burrowing inward and downward into the taproot. When they finish eating the tender parts of the taproot they direct their feeding upward, continuing until full grown, allowing the lower portion of the burrow to catch the frass and excrement (fig. 7, *a*). This burrowing of the taproot of the young growing corn plant is disastrous to the root system (Pl. I, figs. 1, 2); the roots, first dying at the tips, soon become of little use to the plant, allowing it to die or to become more or less dwarfed (Pl. II). The corn plants shown in Plate I were collected in Kansas and forwarded, in moist paper, to Washington. D. C., and photographed by the official photographer, Mr. L. S. Williams, and show the injuries more clearly, while Plate II, photographed in the field, illustrates the effect on the standing corn. Small plants, even those of less than one-half inch in diameter, are often recipients of eggs from which the larvæ, on hatching, burrow into the heart of the plant and cut off the growing bud, thus killing the top; they then direct the burrowing downward only to

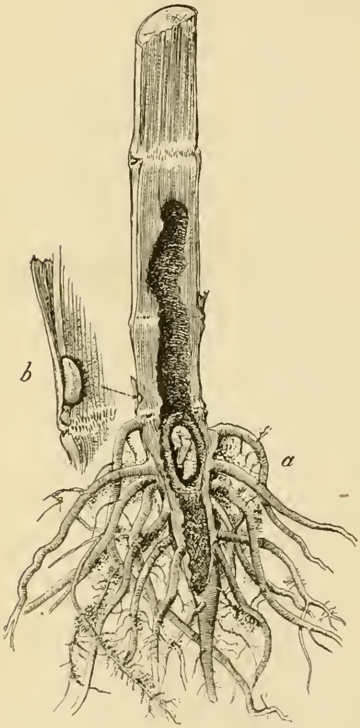

FIG. 7.—Corn plant showing result of attack by the maize billbug: *a*, Larval burrow containing pupa in natural position; *b*, egg puncture containing eggs. *a*, Reduced two-thirds; *b*, enlarged. (Original.)

FIG. 8.—Swamp grass (*Tripsacum dactyloides*), attacked by the maize billbug. Reduced two-thirds. (Original.)

devour the stub, leaving themselves without food, and, being footless grubs, they of course perish. Plants of more than one-half inch diameter which become infested with larvæ make very poor growth, being very slender, rarely reaching a height of more than 2 or 3 feet before tasseling (Pl. II), and do not produce shoots or ears. Those that do not become infested until they are half grown may produce small ears. Each larva inhabits only the one burrow, and if, owing to any mishap, it becomes dislodged from it, it is powerless to reestablish itself. The larva does not become dislodged from the burrow

FIG. 1.—CORN PLANT INJURED BY THE ADULT OF THE MAIZE BILLBUG (SPHENOPHORUS MAIDIS), AFTERWARD ATTACKED BY THE LARVA. FIG. 2.—CORN PLANT SHOWING ON STALK THE EFFECTS OF FEEDING BY ADULT MAIZE BILLBUGS, AND EFFECTS ON ROOTS OF FEEDING BY THE LARVÆ. FIG. 3.—CORN PLANT, MUCH DISTORTED, SHOWING SUCKERS; FINAL EFFECTS OF FEEDING OF ADULT MAIZE BILLBUGS.

All figures about natural size. (Original.)

CORN PLANTS SHOWING EFFECTS OF FEEDING OF MAIZE BILLBUG IN THE FIELD.

Plant at left not attacked, the two at right attacked by larvæ. Reduced. (Original.)

of its own accord. Sometimes there are three or four larvæ in the same plant, their burrows often running into each other, but this does not appear to discommode them in the least, as they can, and usually do, all mature. In badly infested fields two larvæ are quite often in the same plant, although one is the usual number and is sufficient to ruin the plant. The larvæ are easily managed in the laboratory; upon issuing from the eggshell they can be readily handled with a soft camel's-hair brush and placed inside a section of a cornstalk, where they will feed as readily as upon the growing plant. As soon as the section of plant is fairly eaten, and before decay sets in, the larvæ must be removed to fresh sections; keeping them thus supplied with fresh food they can be reared to maturity.

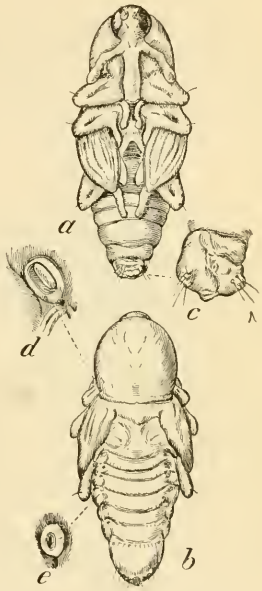

FIG. 9—The maize billbug: Pupa: *a*, ventral view; *b*, dorsal, view; *c*, anal segment; *d*, thoracic spiracle; *e*, abdominal spiracle. *a*, *b*, Twice natural size; *c*, *d*, *e*, greatly enlarged. (Original.)

The length of the larval life ranges from 40 to 50 days, as indicated by laboratory observations and checked by collections in the field. They begin maturing and pupating by the 1st of August, pupation reaching the maximum by the 20th, and with the exception of a few stragglers all are mature and changed to pupæ by the 1st of September.

THE PUPA.

(Fig. 9.)

The larvæ, on finishing their growth, descend to the lower part of the burrow, to the crown of the taproot, cutting the pith of the cornstalk into fine shreds with which they construct a cell where they inclose themselves for pupation.

The newly issued pupæ are white, becoming darker after the fourth or fifth day, and continue to darken until just before the adults issue. The adults are reddish black in color. The length of living pupæ ranges from 16 to 20 mm.

The following description of the pupa was made by Mr. E. A. Schwarz, of the Bureau of Entomology, under the name of *S. robustus*, from the single individual collected by Dr. Howard at Columbia, S. C.:[a]

Average length, 17 millimeters. Stout, rostrum reaching between first pair of tarsi. Antennæ but slightly elbowed and reaching not quite to bend of

[a] Loc. cit., p. 142.

anterior femora and tibiæ. Eyes scarcely discernible. Face with three pairs of shallow tubercles, the basal pair the largest, and each giving rise to a stiff, brown hair. Other minute piliferous tubercles, especially near the posterior dorsal border of the abdominal joints, being very stout on the preanal joint, or pygidium, where they form two series of quadridentate ridges.

To Mr. Schwarz's description the following may be added:

Lateral view: Body oblong, thickest at middle; thorax depressed anteriorly; abdomen cylindrical, tapering from seventh segment; thoracic pair of spiracles very prominent (fig. 9, *d*), first five pairs of abdominal spiracles prominent (fig. 9, *c*), the three on the rear segments not prominent. Elytra short, curving ventrally between middle and hind legs, reaching tarsi of hind leg, covering upper half of femur of hind leg; middle leg resting on elytra.

The pupæ occur mostly during the latter part of August and first part of September and are always to be found in their cells in the larval burrows near the crown of the taproot and nearly always below the surface. The pupal period is from 10 to 12 days.

THE ADULT.

(Fig. 10.)

The adults are very large, robust, and reddish black when newly issued, changing to black when older. The original description by Chittenden[a] is given here:

Body two-fifths as wide as long, of robust appearance because of the subquadrate thorax, which is nearly as wide as the elytra; general color black or piceous, moderately shining; alutaceous deposit on unelevated surfaces inconspicuous, appearing to be normally dark rufous or piceous velvety when the extraneous argillaceous covering does not persist.

Rostrum three-fifths the length of the thorax, considerably arcuate, strongly subequally compressed, apex prolonged at the posterior angle with an acute spine, producing the appearance of greater curvature of the inner surface, base feebly protuberant, moderately dilated; anterior face of apex broadly deeply concave; surface minutely punctate, more distinctly and densely at base, base moderately deeply channeled with distinct deep interocular puncture and short impressed line.

Thorax longer than wide, fully three-fourths as long as the elytra, sides usually widest just in front of middle, anterior third suddenly and very strongly arcuate and constricted at apex, posterior two-thirds or three-fourths subparallel, or gradually narrowing to the base which is feebly bisinuate. Vittæ feebly elevated, tending toward obsolescence, moderately finely but distinctly and sparsely punctate, more coarsely and densely at the ends; median vitta extending from a fine line and rapidly widening to a point just in front of the middle where it is broadly dilated, then more abruptly narrowed, extending in a narrower line to near the base; lateral vittæ sinuous with a tendency to become confluent with the median in the apical half, generally a little wider in basal half but narrower than the median, branch wide but ill-defined; interspaces and surface at sides coarsely foveate-punctate, punctures becoming confluent, especially posteriorly at sides. Scutellum deeply broadly concave.

[a] Proc. Ent. Soc. Wash., vol. 7, No. 1, p. 59, 1905.

Elytra little wider than the thorax; striæ usually deep and well defined, distinctly closely punctate; intervals with first, third and fifth elevated, with two or more series of rows of fine punctulation; first or sutural with basal third triseriately, posterior two-thirds biseriately punctulate; third widest and most elevated, with four or five rows of fine punctulations; fifth biseriately punctulate; seventh little or not at all more elevated than the remaining intervals; intervals 2, 4, 6, 8, as also 7, more coarsely and closely uniseriately punctulate. Pygidium deeply, coarsely and rather sparsely punctate, with sparse golden yellow hairs proceeding from the punctures and forming a short tuft each side, frequently abraded.

Lower surface coarsely and rather densely punctate, scarcely less strongly at the middle than at the sides, punctures largest at the middle of the metathorax. Punctures of the metepisterna (side pieces) more or less confluent. Second, third and fourth abdominal segments nearly uniformly punctured throughout, like the legs.

♂.—First abdominal segment very concave; pygidium truncate at apex.

♀.—First ventral scarcely different; pygidium narrowed and rounded at apex.

Aside from the differently shaped pygidium and the slightly shorter and less compressed rostrum there is little difference between the sexes.

Length, 10–15 mm., width, 4.5–6.0 mm.

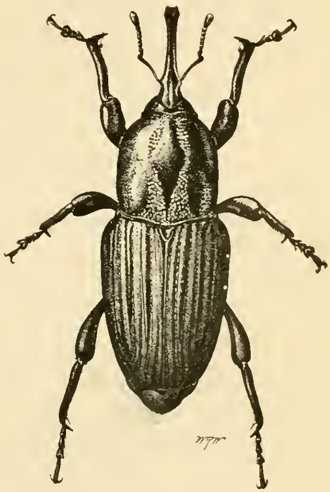

FIG. 10.—The maize billbug: Adult. Four times natural size. (Original.)

The adults begin to issue about the middle of August and continue to do so until the middle of September. Some of them leave the pupal cell, but most of them remain there for hibernation. The adults that leave the pupal cell in the late summer disappear; continued search in every situation until December failed to reveal a single individual. It is evident that they left the cornfield in which they developed, and it is very probable that they found their way to some dense, coarse grass (*T. dactyloides*), which is abundant in the locality, The adults hibernating in the pupal cells issue from them in late spring, about the time young corn is sprouting. The beetles are rarely observed on account of their quiet habits and because they are covered with mud—a condition which is more or less common among several species of this genus and is caused by a waxy exudation of the elytra, to which the soil adheres. The presence of the adults of this species in a cornfield is made evident by the withering of the top leaves of very young corn plants, the plants having been severely gouged. The adults kill the small plants outright and injure the larger ones beyond repair. After the plants grow 10 to 15 inches tall they do not kill them, but gouge out such large cavities in the stalks that they become twisted into all sorts of shapes (Pl. I, fig. 3). The attacked plants sucker profusely, affording young, tender growth for the beetles to feed upon, even for many days after the noninfested plants have become hard. The corn plants injured by *S. maidis* resemble somewhat corn plants injured by the lesser corn stalk-borer (*Diatræa saccharalis*), and are easily distinguished from plants injured by the smaller species of Sphenophorus owing to the fact that the punctures of the smaller species are not always fatal to the plants, which, however, in unfolding their leaves, show a row or series of rows of round or oblong holes in them.

The females issuing from hibernation feed on young corn for a few days before beginning to deposit their eggs. The egg punctures are made by the female in the side of the cornstalk (fig. 7, *b*) beneath the outer sheath. These egg punctures are not injurious to the plants, being only small grooves, about 5 mm. long and 3 mm. deep, in which the eggs snugly fit.

NUMBER OF GENERATIONS.

There is only one generation a year. The eggs occur throughout June, larvæ from early June until September, pupæ from the first part of August until the last part of September, and adults from the middle of August until the first part of August of the following year.

RECORDS OF DEPREDATIONS.

The depredations of this species have probably been confused with that of other species, the first and only known record of its attack on young corn being that made by Dr. Howard, at Columbia, S. C. During the season of 1910 both adults and larvæ were numerous in cornfields in lowlands in southern Kansas and northern Oklahoma, doing serious damage in some instances. They were frequently found in uplands, but not in injurious numbers.

REMEDIAL MEASURES.

The knowledge of the hibernating habits of the insect suggests an effective remedy in the pulling up and burning of the stubble, which is also the most practical means of destroying the lesser corn stalk-borer (*Diatræa saccharalis*). The beetles remain in the taproot of the corn plants until spring, allowing the farmer abundant time to destroy them. Care must be taken, however, in pulling up the infested stalks or else they will break off above the beetle, leaving the pest in the ground. The infested stalks, having a very poor root system, are easily pulled. Spraying the young corn plants with arsenical fluids at the time the beetles are making their attack is a very laborious procedure and not very effective.

O

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BUREAU OF ENTOMOLOGY—BULLETIN No. 95, Part III.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

CHINCH-BUG INVESTIGATIONS WEST OF THE MISSISSIPPI RIVER.

BY

E. O. G. KELLY,
Entomological Assistant,

AND

T. H. PARKS,
Entomological Assistant.

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CEREAL AND FORAGE INSECT INVESTIGATIONS.

F. M. WEBSTER, *in charge.*

GEO. I. REEVES, W. J. PHILLIPS, C. N. AINSLIE, E. O. G. KELLY, T. D. URBAHNS, HARRY S. SMITH, GEO. G. AINSLIE, J. A. HYSLOP, W. R. WALTON, J. T. MONELL, J. J. DAVIS, T. H. PARKS, R. A. VICKERY, V. L. WILDERMUTH, E. G. SMYTH, HERBERT T. OSBORN, PHILIP LUGINBILL, C. W. CREEL, E. J. VOSLER, R. N. WILSON, VERNON KING, *entomological assistants.*
NETTIE S. KLOPFER, ELLEN DASHIELL, *preparators.*
MIRIAM WELLS REEVES, *collaborator.*

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PAPERS ON CEREAL AND FORAGE INSECTS.

CHINCH-BUG INVESTIGATIONS WEST OF THE MISSISSIPPI RIVER.

By E. O. G. Kelly, *Entomological Assistant.*
and
T. H. Parks, *Entomological Assistant.*

INTRODUCTION.

Chinch bugs have long been a pest, and, especially so in the Middle Western States. During the last two years especially, Kansas, Oklahoma, and parts of Missouri and Illinois have suffered great losses from their ravages.

Owing largely to a lack of knowledge of the habits of the chinch bug, farmers are at a loss for remedies; the tried and successful tar lines and dust barriers, crudely used by them, to prevent the bugs from entering their corn, being often applied without success.

The "white fungus" or "fungus disease" of chinch bugs (*Sporotrichum globuliferum*), as it is commonly known among farmers, has been carefully observed and the conclusion reached that under ordinary farm conditions it can not be relied upon to afford immediate protection.

This paper has been written for the purpose of giving the farmers information regarding the habits of this insect, and the most effective methods of combating it. Field observations on this pest in Kansas, Oklahoma, and Missouri were begun during the spring of 1907 and continued till March, 1911, Mr. C. N. Ainslie and Mr. Paul Hayhurst making observations in 1907, and the senior author from the spring of 1908 to July, 1911, assisted by the junior author, who also did the photographic work, during the year ending with July, 1910.

DISTRIBUTION.

The chinch bug is widely distributed over the United States as well as in parts of Canada and in Mexico. The accompanying map (fig. 11) shows its distribution west of the Mississippi River. It is especially destructive over portions of Minnesota, Iowa, Missouri, Arkansas, Texas, Oklahoma, Kansas, Nebraska, and South Dakota, and in parts of Illinois. Prof. T. D. A. Cockerell found a few specimens of both the long-winged and the short-winged forms at Mesilla Park, N. Mex.; Messrs. E. A. Schwarz and H. S. Barber, of this bureau, found a few short-winged forms at Hot Springs, Yavapai County, Ariz.; Mr. George I. Reeves found some long-winged forms in southwestern Washington; and Mr. Albert Koebele and Dr. P. R. Uhler found a few at San Francisco and Alameda, Cal., and also in Lower California. Prof. Herbert Osborn found the short-winged form at Sault Ste. Marie, Mich., and Mr. Herbert T. Osborn found it at Wellington, Kans.

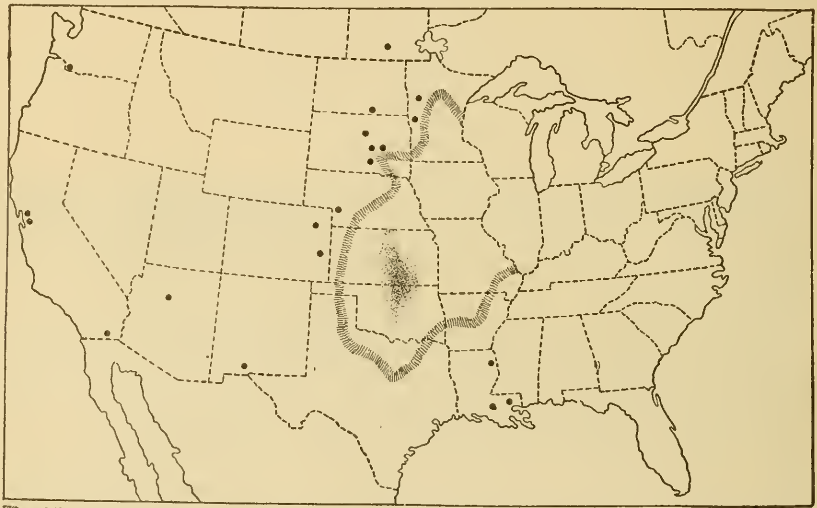

FIG. 11.—Map showing distribution of the chinch bug west of the Mississippi River, 1911. (Original.)

DESCRIPTION AND NUMBER OF GENERATIONS.

Full descriptions of this insect are found in Bulletin No. 69 and in Circular No. 113 of this bureau and will not be repeated here.

There are two principal generations annually in the Middle West; the spring generation and the fall, or hibernating, generation, and a partial third generation sometimes occurs in late fall to the southward.

MIGRATIONS.

The hibernating bugs (fig. 14) issue from their winter quarters as soon as the sun warms up the grasses in the spring, and fly out to green grasses and young wheat and barley, where they feed, mate, and deposit their eggs. The eggs (fig. 13 *a*, *b*) begin to hatch in late April and continue hatching until June, varying with the seasonal temperature and the latitude of the locality affected. The young bugs

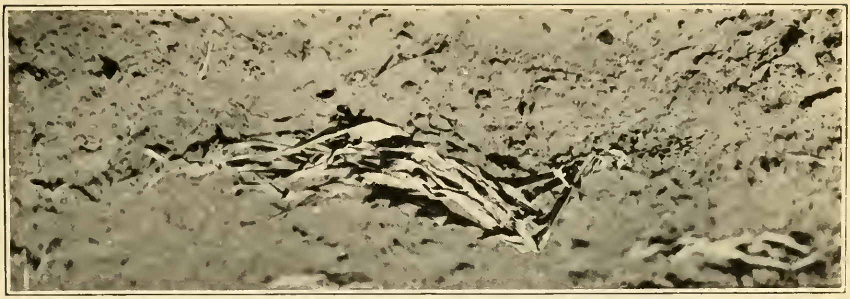

FIG. 1.—CORN PLANT KILLED BY CHINCH BUG. (ORIGINAL.)

FIG. 2.—CHINCH-BUG RAVAGES IN CORNFIELD IN SOUTHERN KANSAS, 1910. (ORIGINAL.)

FIG. 3.—CORNFIELD ADJOINING WHEAT FIELD FROM WHICH CHINCH BUGS MIGRATED IN IMMENSE NUMBERS AT HARVEST TIME. (ORIGINAL.)

RAVAGES OF THE CHINCH BUG (BLISSUS LEUCOPTERUS).

hatching from these eggs constitute the spring generation (fig. 13 *c, e, f, g*) and are the ones that do such enormous damage to wheat and young corn. Some of this generation reach maturity as they are migrating from wheat to corn, but most of them reach the corn (see fig. 12) before maturing and do much damage thereto. It is because the immature bugs reach the young corn in such immense numbers and mass upon the plants that they do such widespread damage

FIG. 12.—Corn plant about 2 feet tall, infested by chinch bugs. (Original.)

(see Pl. IV), their depredations ceasing as they reach maturity. Only on rare occasions is an entire cornfield devastated, and often the depredation is brought to an abrupt standstill within a few rods of the opposite margin of the field because the bugs have reached maturity and dispersed. During July and August the insects mate, and the eggs for the second generation are deposited about the corn plants, where the young, on hatching, find an abundance of easily accessible food. Some of this generation reach maturity (see fig. 14) before the corn becomes dry, and migrate to volunteer wheat, but most of them are forced to seek their food elsewhere. They usually find this in kafir cane fields, and among some of the grasses, where they reach maturity. From here they go to winter quarters before cold weather.

STATUS OF THE CHINCH-BUG PROBLEM IN KANSAS, MISSOURI AND OKLAHOMA.

That the seasons of 1907 to 1910 have been favorable for the development of chinch bugs in Kansas, Missouri, and Oklahoma is indicated by reports of injury to crops received during these years.

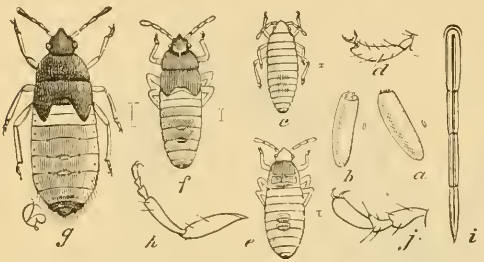

FIG. 13.—Chinch bug: *a*, *b*, Eggs; *c*, newly hatched larva, or nymph; *d*, its tarsus; *e*, larva after first molt; *f*, same after second molt; *g*, last-stage larva; the natural sizes indicated at sides; *h*, enlarged leg of perfect bug; *j*, tarsus of same, still more enlarged; *i*, proboscis or beak, enlarged. (From Riley.)

The prevalence of the pest and its depredations depend upon meteorological conditions to a great extent, as has been discovered by entomologists in the past, and this fact is clearly brought out by the observations herein recorded and made during the four seasons from 1907 to 1910, inclusive.

The bugs were very numerous in wheat fields in the early spring of 1907 and deposited numbers of eggs on the young wheat plants. Much wheat had been destroyed by the "green bug" (*Toxoptera graminum* Rond.) during the spring, and many farmers had plowed up their fields and planted them to corn; sometimes they did not use the gang plow, but planted the corn with a combination lister and planter. There were large numbers of eggs and young of chinch bugs on this more or less dead wheat that was plowed under, and apparently very few were destroyed during the operation of preparing the ground for planting the corn. As soon as the corn plants pushed through the soil they were attacked by the young chinch bugs, with the result that a large amount of young corn was ruined by them.

FIG. 14.—Chinch bug (*Blissus leucopterus*): Adult of long-winged form, much enlarged. (From Webster.)

In the fields of wheat that had not been plowed under in the spring there were also numbers of bugs, and at harvest time these found their way to other fields of young corn, where they inflicted considerable damage. The summer and fall were favorable for their development, and great numbers went into hibernation in grasses.

The spring of 1908 opened the first week of March with warm, dry weather and a deficiency of moisture which was alarming for this season of the year and which had a telling effect on young wheat. The chinch bugs flocked to the young wheat from their winter quarters, and very soon their ravages were in evidence. By the middle of April the plants were turning to a red color, and the stems were black and dry from their attacks, very few plants escaping, some plants having as many as 200 bugs massed on them. Very few eggs had been deposited up to the middle of April, but from this time on until May 1 eggs were abundant.

The eggs began to hatch about the 1st of May, and in one week's time the wheat fields were swarming with tiny red bugs, much of the wheat dying from their severe attack combined with the effects of lack of moisture. However, the situation was soon rapidly changed, for rains came, and by the 1st of June there was hardly a living bug to be found, either young or adult, but there were numbers of unhatched eggs left unharmed on the plants. The wheat partially outgrew this damage and made a fair crop, while the young corn escaped injury.

Many eggs hatched after the rains ceased, and the bugs from these eggs, together with the few that survived the drenching rains of May and June, succeeded in getting to the corn, where they bred in large numbers. By September, having left the Indian corn, which at this time was becoming dry, the young bugs were plentiful on cane and kafir. These bugs matured on the cane, kafir, and succulent grasses, and large numbers went into hibernation in the fall among the grasses.

The spring of 1909 was quite late in opening. A big snow on March 8 remained on the fields until March 20, and for several days afterwards the ground was alternately wet and frozen. During the last two days of March there was bright, warm sunshine, and the bugs began to move about. On April 3 the bunches of sedge grass, *Andropogon scoparius*, in which the insects hibernated, resembled living masses of crawling bugs, and before nightfall great swarms were flying; this continued during the next few days, and the wheat fields had now become badly infested. The chinch bugs commenced mating very soon after reaching the wheat fields, and in a few days egg laying began. Eggs were very numerous about wheat plants by April 22, some were hatching, and by May 1 young bugs were abundant. The massing in large numbers on single plants, which was so noticeable in the spring of 1908, was entirely lacking in 1909; seldom were there more than a dozen bugs on a plant, although nearly every plant was infested.

The entire month of April, together with the first ten days of May, 1909, were exceedingly dry and wheat suffered from lack of moisture. There was no noticeable injury to the young wheat from attacks of the old hibernating bugs and not much from the combined attack of both the old and young bugs, until the first week of May, when the wheat failed rapidly, owing to the great number of the insects and the lack of moisture. Here, again, heavy rains of four days (May

11–14) checked their ravages and killed great numbers of both the young and the old bugs. The rains were light from May 15 to 27, and during this interval the young chinch bugs became very abundant. On some wheat plants there were as many as 240 young bugs, while other wheat plants were free from them; infested wheat plants turned yellow and died, owing entirely to the effects of their attack. The heavy downpour of rain on the night of May 27 buried thousands of chinch bugs in the loose soil and again put a temporary check on their ravages. This rain was the last one of any importance until the night of June 22. By June 8 most of the bugs had changed to a brown color and few red ones remained among them; several eggs were observed on wheat roots. By June 14 the young chinch bugs were very abundant on the stems and leaves of wheat, and 300 to 500 bugs per tiller were counted on several plants, which were turning white and dying before the grain had matured. The ground was covered with moving insects but in no instance were the chinch bugs leaving the wheat fields. Five days later the wheat was prematurely "ripened" through insect attack and the hot sunshine. The "ripening" grain forced them to seek food elsewhere and on June 21 they began to migrate from wheat to corn. The grains in the heads of the severely attacked tillers were small and considerably shriveled, while grains in heads which had not been attacked were full size and plump. Great numbers which were migrating on June 22 were temporarily checked by a light shower, only to continue the movement as soon as the grass became dry. At night, however, a very heavy beating rain fell, burying millions of bugs of all ages and sizes in the mud. The mud-covered bugs nearly all died and those not dead by the next day were found stuck fast in the mud. The ground dried out by noon of June 24, and the bugs that were not killed by the rain continued migrating toward the cornfield. In an area of 4 square feet in a wheat field there were 2,411 dead chinch bugs, some of them buried one-half an inch in the soil. In an area of 10 square feet in the same field there were only 244 living chinch bugs, all of which were moving toward an adjacent cornfield where they collected in masses on the outer rows.

The weather was quite dry during the next few weeks and the bugs did considerable damage to young corn, some fields being almost devastated. The bugs began to transform to adults about July 5, and their ravages ceased within a week thereafter. There were hordes of adult bugs scattered throughout the cornfields, and these were mating and depositing eggs.

By the middle of August, when most of the corn had matured and dried, there were again great numbers of young bugs on the corn plants even under the outer husks below and about the bases of the ears; the greener plants were much infested. The corn now began to get too dry to afford them food and they began migrating to kafir, sorghum, and grass fields, killing all crab-grass and panic grass in the cornfields before they left them. Some bugs were observed in alfalfa fields but at no time were they feeding on the alfalfa.

During October and early November several chinch bugs were observed on young wheat and a few eggs and young larvæ of the third generation were observed. They did not damage the wheat during the late fall, and by the middle of November had left the wheat fields for winter quarters.

The kafir and cane were green until the middle of September, and great numbers of chinch bugs were feeding on these two crops at this time when the crops were harvested. They remained on these plants and were put into the shock, where they were observed on several occasions during the fall, but they all left before cold weather set in.

During early fall a few bugs were to be found in nearly every situation on the farm—some in corn husks, some in alfalfa fields under the leaves, and some among sparsely growing grasses, but most of them were in the bunches of clump-forming grasses along fences, roadsides, and railroad rights of way, in waste places, and in meadows. That the weather conditions of the summer and fall were the most favorable for the chinch bugs is indicated by the vast numbers that went into winter quarters. Some of the bunches of the red sedge grass (*Andropogon scoparius*) contained from 10,000 to 20,000 bugs, this grass affording them the most attractive and favorable hibernating quarters.

The severe cold weather of December, 1909, was disastrous to bugs that failed to reach some of the clump-forming grasses, and very few bugs in corn husks and among thin grasses survived the winter.

SOUTHERN KANSAS AND NORTHERN OKLAHOMA, 1910.

In southern Kansas and northern Oklahoma the spring of 1910 opened the last week of March with warm, dry weather. The chinch bugs began to migrate to the wheat fields; on March 24 the air was full of flying adults and by March 26 the wheat fields were badly infested. The weather turned much warmer about April 1, the chinch bugs began mating, and by April 10 were depositing eggs about the wheat roots; by April 20 the eggs were very abundant—hundreds on the exposed roots of every plant. Not many eggs hatched during April and the first 10 days of May on account of the cool weather, but they hatched profusely during the next few days, so that by May 20 the fields were overrun with myriads of very young chinch bugs.

Wheat throughout southern Kansas and northern Oklahoma had been severely winterkilled, which, together with the exceedingly dry spring, left the plants in a very weakened condition. The soil was so dry during April and May that the small amount of rainfall was of little value. The ground was badly cracked, exposing the wheat roots to the hot sun and drying winds and these, together with the bugs, killed a great many plants. Wheat was so badly killed, mostly by meteorological influences, that by May 1 thousands of acres had been abandoned and corn planted in its stead. The young bugs and eggs were little molested by the operation of corn planting and as soon as the sprouting corn pushed through the soil hundreds of bugs were ready for every plant. Some such fields were even planted the third time only to furnish food for these hungry insects. The bugs would crawl from beneath several inches of loose soil and be ready to attack the young plants as soon as they appeared.

Such wheat as was not abandoned made a poor growth on account of drought and was severely damaged by the chinch bugs, great numbers of which were on every plant, so that by June 10 they had sapped the life from them. As the wheat and grasses were killed by the drought, the bugs were forced to abandon wheat fields and hunt for food elsewhere. The corn, which had made very poor growth up to this time on account of the lack of moisture, was very small and weak when the bugs reached it, and this early attack by the young chinch bugs resulted in the devastation of thousands of acres before the bugs became mature. On reaching maturity they abruptly dispersed and their depredations were brought to an end.

Young bugs of the second generation became numerous the first week of August on the cornstalks under the sheaths and under the outer husks of the ears. Corn leaves, stalks, and husks of ears were dry by the middle of August and bugs were moving out of these into fields of kafir and sorghum, both of which suffered under their attack, many fields being laid waste by September 1. Owing to the continued drought throughout the fall the Indian corn, kafir, cane, and grasses died leaving the chinch bugs without sufficient food supply, with the result that of the vast horde of bugs hatching in August comparatively few survived to go into winter quarters. During September and October a few young chinch bugs matured on volunteer wheat, later depositing a few eggs for a partial third generation. No damage was done to wheat by these few insects, although some of them remained on or about the wheat plants till cold weather set in. There were not nearly so many chinch bugs in the bunches of grass in the fall of 1910 as in the fall of 1909.

KANSAS, 1911.

As previously indicated, the fall of 1910 was very dry and wheat failed to sprout in Kansas and Oklahoma. The winter of 1910–11 and the spring of 1911 continued dry, very little rain falling during the entire period till the last of May, 1911. This extended drought affected both crops and chinch bugs to such an extent that wheat was almost a failure and the numbers of the bugs were greatly reduced. The winter wheat which was seeded in September and October, 1910, was seeded in a very dry soil; very little of it sprouted. A few localities were favored with a shower of rain in September which sprouted the grain, and the bottom fields along the rivers and creeks contained enough moisture to sprout the grain and produce a fair crop. As a result of the drought, however, very little wheat matured on the uplands.

The chinch bugs went into hibernation in a very weakened condition because the grasses had dried up in the fall. Many of them did not reach their usual winter quarters but stopped in almost any place they could find. Many hibernated in trash in alfalfa fields where a small percentage succeeded in living through the winter. The death rate of hibernating bugs was greater than in any previous winter included in this study; in some of the bunches of Andropogon 60 per cent of the bugs were dead. When the first warm days of spring occurred the few bugs that were left were very inactive and the migration to green fields, which had been so noticeable in former years, was lacking. However, there was a migration during some very hot days in the latter part of April—over a month late. The dying of the bugs during the winter was probably due to two causes, one being the starved condition of the bugs when they went into hibernation and the other the hot days during the winter followed by the very cold days in the spring. During these hot days in the middle of winter the bunches of grass would be swarming with the bugs and the very next day the thermometer would register 8 to 10 degrees below zero. In spite of all these adverse conditions many of the bugs lived to infest the fields in the spring.

The failure of wheat caused the farmers to plant other crops in many of these fields, but some of them were left standing until May in the hope that a crop would be produced. The bugs reached the few fields that were left, damaged the plants considerably, and deposited numbers of eggs. Many wheat fields were seeded to oats after the wheat failed, thus leaving the few wheat plants growing in the fields for the young bugs to feed upon. At no time could young bugs or eggs be found on the oat plants. Notwithstanding the fact that numbers of farmers lost several plantings of corn in 1910 by planting the infested wheat field to corn, hundreds of acres of corn were planted in such fields in the spring of 1911, only to be destroyed later. There were areas of 8 to 10 square miles that did not contain an acre of wheat after the middle of May, all of the fields having been planted to other crops. In these localities where the wheat was missing the bugs were also missing, and where the wheat was plentiful the bugs were very plentiful and did considerable damage to adjacent corn.

It is very apparent that wheat has a decided effect on the presence of the chinch bugs, as indicated in the localities where the wheat was a failure this spring.

The dry weather had its effect on the fungus, *Sporotrichum globuliferum*, and it has not occurred in the fields this season (1911). Only once has it been possible to secure it in the laboratory. Continued search has been made for it in all kinds of places, especially after the rains in May and in July, beyond which latter month this record does not extend.

HIBERNATION.

At the beginning of the investigation the advisability of getting rid of the chinch bugs before they entered the young wheat in the early spring was very evident, for when once they have reached there they are not readily accessible. This led to a series of observations on their hibernating habits for the purpose of determining the places preferred by the bugs.

The current belief that most of the bugs pass the winter beneath corn husks, among cornstalks, in fence rows, under boards and rails, in heaps of rubbish, in straw stacks, along hedgerows, and in fodder shocks is not borne out by investigations in Kansas and Oklahoma following a severe winter. When the bugs are very abundant, as they were in Kansas, Missouri, and Oklahoma during the fall of 1909, a few may be found in any of these situations, especially in the early fall. The most of the bugs find their way to thick bunches of clump-forming grasses in waste places, in pastures and meadows, and along roadsides and railroad rights of way. During late fall and early winter great numbers of living bugs can be found in corn husks, fodder shocks, piles of kafir, cane, and in most any place covered with vegetation—even in alfalfa fields where they find no food. In the spring, however, very few living bugs but many dead ones can be found in such situations, indicating that most of them died there.

They find much better protection in the thicker and more dense, than in the thinner grasses and under trash in open fields. The bugs seem to prefer the thicker grasses, though they are quite often found in other situations, and after open winters, as the one of 1910–11, many living ones can be found under very thin protection. Many living chinch bugs were taken from trash collected in an alfalfa field and some were found in corn fodder and corn husks lying on the ground on February 24, 1911, at Wellington, Kans., though most of the chinch bugs are at this time in the thick bunches of sedge grass.

The situation in southern Illinois for the spring of 1911 was quite similar to that in southern Kansas; there were abundant clumps of Andropogon along roadsides, in fields, and in woodlands, and more chinch bugs were found in these clumps of grasses than in trash, under boards, or in any other place. There were not a great many bugs in any one place, however, and it would be rather difficult to make a conclusive comparison between the two widely separated localities, although the indications are that the majority of the bugs seek the thick grasses in which to hibernate.

The destruction of the hibernating chinch bugs is of much importance; it has been discussed frequently and is strongly recommended by entomologists throughout the United States. As the methods of farming, the prevailing crops, and the wild grasses vary in different localities where chinch bugs occur, the places of hibernation may also vary considerably.

Mr. C. L. Marlatt, of this bureau, in an article on the hibernation of chinch bugs,[a] has the following to say:

In nearly every account of the chinch bug which I have seen, stress has been placed on the hibernation of the adult in rubbish of any sort, such as piles of corn fodder, hay piles, straw piles, and dried leaves along hedgerows. In course of very careful investigation carried on in Kansas during a year of excessive abundance, I failed entirely to find any basis for the above supposition. Repeated careful search throughout the late fall and winter failed to discover a single living chinch bug in such situations.

Failing to find them in the situations noted, I carried the examination further and finally discovered what is probably the normal hibernating place of the chinch bug in the dense stools of certain of the wild grasses, such as the blue stem and other sorts. * * * So marked is this hibernating habit that it is reasonable to infer that it is the normal and ancient one of the species, the natural food plant of which, before the advent of settlement and growth of the cereals, must have been some of our native grasses.

Mr. H. W. Brittcher, in regard to hibernation,[b] says:

* * * they may frequently be found, more or less closely crowded, low down among the stems of clumps of wild rushes and grasses, often working their way down between the stems and the soil.

He recommends burning the sedges in which careful examination showed the bugs to be abundant. It must be remembered that in Maine it is the short-winged form that prevails and is there a grass as well as grain destroying insect.

In regard to hibernation,[c] Dr. S. A. Forbes, State entomologist of Illinois, says:

On the 7th of November a careful search was made in corn that had previously been badly infested by them, but none were to be seen upon the stalks or under the rubbish on the ground in the field; in the thickly matted grass adjacent only a single specimen was discovered by 15 minutes' search. On the 14th of this month the weather was cold and raw, and the ground was frozen about the hills of corn from an inch to an inch and a half in depth; a very few bugs were now found in the crevices of the ground, among the roots near the surface. At Champaign, on the 15th, I visited again the field of Bogardus and Johnson, making a careful search for hibernating individuals about the

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[a] Insect Life, vol. 7, pp. 232–234, 1894.

[b] 19th Ann. Rept. Maine Agr. Exp. Sta., 1903, p. 42, 1904.

[c] 12th Ann. Rept. State Ent. of Ill., pp. 37–38, 1903.

stalks, under the weeds in the field, and beneath the rubbish collected about the hedgerows. Not a single specimen was found in these situations, although every temptation was afforded to hibernating insects, and many other species occurred abundantly. To what resorts the swarms which had developed in these situations had betaken themselves to pass the winter, I am not able to say.

Prof. Herbert Osborn,[a] in giving a summary of his observations on the chinch bug in Iowa in 1894, states:

In a great majority of cases, 90 per cent or more, the infested fields were directly adjacent to hedges or thickets or belts of timber, and in 75 per cent osage-orange hedges were the most available shelter. In about 13 per cent of cases the evidence showed hibernation in grass and weeds and in some of these cases there could scarcely be a doubt that the hibernating bugs were protected by a heavy growth of grass or weeds and that they moved from these directly into adjacent fields.

Prof. F. M. Webster, of this bureau, has probably given the chinch bug more attention than any other entomologist and has contributed more to our knowledge of the pest. His observations in Ohio and those made by Prof. Herbert Osborn in Iowa are at variance with those made in Kansas by Mr. Marlatt and by the writers. Prof. Webster offers the following explanation [a] of their hibernating habits in different localities:

In Kansas, where Mr. Marlatt made his observations, there was still too much prairie, and the species was doubtless still adhering to its ancient habits of hibernation. In southern Ohio the author has found it attacking the wheat in May, in small isolated spots over the fields, while there was nothing in the least to imply an invasion from outside, but the wheat had been sown in the fall among corn, and later the cornstalks cut off and shocked, remaining in this condition until the following spring. This occurred so frequently that there seemed no room to doubt that the attacks had been caused by adults wintering over in the corn fodder and that these left their winter quarters in spring to feed and breed on the grain growing nearest at hand.

The hibernating habits of the chinch bugs have been closely observed during two seasons in Kansas and Oklahoma, and the observations made indicate that the bugs hibernate there chiefly in dense clumps of sedge grass, principally those of different species of Andropogon.

The following data with reference to the hibernating habits of the chinch bugs were made by the writers in southern Kansas, and are given here to substantiate the above statement:

From Mr. Hayhurst's notes made in the fall of 1907: On October 26, at Winfield, Kans., he found active adult chinch bugs in stools of broom beard grass (*Andropogon scoparius*) in great numbers, always close to the ground. On November 1, 1907, at Newkirk, Okla., he again found many active bugs in the stools of forked beard grass (*Andropogon furcatus*) close to the ground. They were present in nearly every stool of this grass examined along roadsides and also on the open prairie where the grass had been cut.

[a] Bul. 69, Bur. Ent., U. S. Dept. Agr., pp. 16–17, 1907.

At Wellington, Kans., the senior author, on October 3, 1908, observed adult chinch bugs flying and collecting in grass (Andropogon) down at the crown, and on October 12 he saw hundreds of bugs in some clumps of this grass along roadsides. During the early spring of 1909 hundreds of living adults were found in clumps of this same grass, where they had evidently hibernated. On November 30, 1909, in this same locality the authors observed some bunches of *Andropogon scoparius* containing 6,000 to 10,000 bugs each, and on November 29, 1909, they found a few living bugs in corn husks, but most all of the bugs were in bunches of grass. Again, on December 22 one bunch of Andropogon 2 inches in diameter was found to contain 1,508 bugs; many bunches were 8 to 12 inches in diameter, and contained as many as 15,000 to 20,000. Bugs were found only in grasses that grow in clumps; none was discovered in rubbish, old straw piles, fodder shocks, or in sorghum-cane piles. Several dead bugs were found in corn husks, but no living ones. A number of bugs collected at random from the base of some bunches of Andropogon was brought into a warm room to see how many would revive. There were 325 living bugs and 89 dead ones, or 21.5 per cent dead. None was found in bunches of reed grass (Calomagrostis), Sporobolus, blue grass (Poa), or crab grass (Digitaria).

The method for separating the living chinch bugs from the trash and dead bugs was a very simple one. The bugs and bunch of grass containing them were put on paper in an oblong box, and the box placed in front of a fire, where the living bugs would readily crawl out of the grass and trash to the corners of the box and beneath the paper. Care was taken not to heat the bugs to more than 100° F., as a higher temperature might kill them.

On December 24 another lot of chinch bugs, collected at random from clumps of Andropogon and brought into a warm room, gave 755 living and 234 dead, or 23.6 per cent dead. Again, on December 29 a third lot of bugs in clumps of Andropogon was brought into the laboratory, where the warmth of the room soon revived them, and they became active. Of this lot of bugs 20 to 25 per cent were found to be dead, probably from exposure to cold or perhaps from old age. On December 30, corn husks and the husks of fallen ears, which had not been harvested, were searched for living chinch bugs. Very few were found and none whatever about old straw piles. Very few bugs died during January, as indicated by observations during the last part of that month. Three lots of bugs were collected from bunches of Andropogon; the first contained 298 living and 72 dead bugs, or 19 per cent dead; the second contained 137 living and 35 dead bugs, or 20 per cent dead; the third, which was collected on February 12, 1910, contained a few more than 10,000 counted bugs, 20 per cent of which were dead.

The weather was somewhat drier, but agricultural conditions for the fall of 1910 were about as those of previous years, except that vegetation was practically all dry before frosts. Chinch bugs were not nearly so numerous as in the fall of 1909, clumps of Andropogon containing only 80 to 260 bugs each, whereas there were thousands the previous winter. During the early fall it was again observed that the corn husks were full of adult bugs, but by cold weather these were nearly all dead; the mild winter, however, permitted some of these bugs to live through, and some were alive on February 24, 1911.

From the foregoing data, covering four seasons, there can be little doubt that in Oklahoma, Kansas, Missouri, and probably southern Illinois these clump-forming grasses form the principal hibernating quarters of the pest. This definite knowledge of their habits puts a most practical and effectual weapon into the hands of the farmer, which he may apply months in advance, in defense of his crops.

The farmer can readily determine whether the grasses on or about his farm contain chinch bugs by pulling open the tufts of red sedge grass. (See Pl. V, fig. 3.) If the bugs are present in these clumps of grasses, it is of the utmost importance that they be burned. The habits of the hibernating generation and the migration of the spring generation offer the best opportunities for forestalling and preventing future ravages.

PREVENTIVE MEASURES RECOMMENDED.

DESTRUCTION OF CHINCH BUGS WHILE IN HIBERNATION.

The burning of grasses and rubbish about the farm to destroy chinch bugs has been often recommended and is doubtless the most effective measure to be taken against future ravages of the pest.

In the Southwest the chinch bugs are known to congregate in bunches of grass in late October and remain there till the warm days of early spring. It is only a matter of burning off these grasses at the proper time to effectually rid such places of the pest, and the grasses are generally sufficiently dry to burn readily by the 1st of November. The chinch bugs crawl deep down among the grass stems, a few of them even getting beneath the dust and débris, thus seeking protection from the freezes that are to come. It is very important that the grass be dry and yet burn slowly, so that the heat will thoroughly penetrate the dense grass and reach the bugs. It is not necessary for the fire to come into direct contact with the bugs in order to kill them, as they died very quickly in the laboratory when exposed to the heat of a flame from 12 to 20 inches distant, the fatal temperature being in these experiments about 111° F. Fall burning of the grasses among which the bugs are congregated has a

FIG. 1.—PILE OF SORGHUM CANES IN WHICH NO HIBERNATING CHINCH BUGS COULD BE FOUND. (ORIGINAL.)

FIG. 2.—WASTE LAND ALONG STREAM IN FOREGROUND, SEDGE-GRASS MEADOW IN BACKGROUND; CHINCH BUGS FOUND HIBERNATING IN BOTH. (ORIGINAL.)

FIG. 3.—CLUMPS OF RED SEDGE GRASS (*ANDROPOGON SCOPARIUS*) IN WHICH OVER 6,000 CHINCH BUGS WERE FOUND HIBERNATING DURING WINTER OF 1909-10. (ORIGINAL.)

HIBERNATION OF THE CHINCH BUG.

twofold value; first, it will kill large numbers of bugs directly; and, second, the bugs not killed by the fire will be left exposed to the winter freezes, which of themselves will in ordinary seasons kill many of them. On several occasions during fall and spring bugs were removed from the stubs of burned grass and the percentage of dead and live bugs obtained. On an average about 75 per cent were killed in the fall and about 63 per cent in the spring. In the spring about 20 per cent of the bugs, which hibernated in the clumps of grasses, were dead from exposure and other causes. From natural causes and burning in spring, there were about 83 per cent of the bugs dead. These percentages were obtained by actually counting the insects and are not from estimates. The fire can not reach all the bugs, even with the most careful burning, because of protection afforded by green or wet stems in early fall and late spring; therefore it is essential that the grass be burned during late fall or early winter. While this remedy is recommended above all others, its effectiveness is entirely dependent upon the farmers and their cooperation, and it is an easy matter for neighborhoods to combine in an effort to fight the pest in this manner.

DUST BARRIERS.

If the bugs are not killed out during hibernation, the main dependence of the corn grower must be in the destruction of the bugs as they migrate from the ripening small grain to enter the cornfields. As soon as the ripening grain compels the bugs to desert it and they start for the corn, a narrow strip of ground between the corn and wheat should be deeply plowed and thoroughly pulverized, making a dust bed. Then a short block or a triangular box should be made in form of a sled with the bottom fitted with a seat for a driver. This should be dragged back and forth in this dust bed until a deep groove or furrow has been made. If this furrow has been well prepared, and the weather continues dry, it will prove an impassable barrier to the progress of the bugs. In order that this kind of barrier may be successful, the block must be kept in constant use, from early until late and sometimes well into the night. Often, during the migration, the bugs travel all night. Slight showers render dust furrows useless and if a shower is pending, and under such weather conditions, it is best to employ the coal-tar barrier. Owing to the fact that dry weather often prevails on the plains during this season the furrow method under these conditions is especially recommended.

COAL-TAR BARRIERS.

The coal-tar barrier can be operated successfully in the Middle-Western States to prevent the bugs from migrating to young corn. The success of this measure depends on the farmer and his careful attention to the tar line. Preparations for the barrier should be begun in all cases where the bugs are found abundant in ripening grain. Frequently the soil is quite compact along the margins of wheat fields and if it is, a smooth path can be readily fixed at the edge of the field next to the corn. If the soil is not compact it is well to throw two furrows together, making a ridge, and with a heavy block make the top of it very smooth and compact. Along this smooth path, post holes 12 to 18 inches deep should be dug about every 20 or 30 feet. Get a supply of coal tar, or if it is more convenient, pine tar or crude oil, ready to use as soon as the bugs begin to travel. An old coffee pot with the spout pinched so as to allow a small stream to flow is convenient for putting the line of tar on the patch. By holding the vessel near the ground a narrow line no wider than a pencil can be made, and this is all that is necessary. The tar line should strike the post holes near the middle extending directly around the edge of the hole on the side next to the corn, leaving the edge of the hole next to the wheat free. When the chinch bugs reach the tar line they will not cross it but will turn aside and run or crowd each other into one of the post holes. As soon as the holes are partially filled with bugs a small amount of kerosene poured in them will kill them. Care must be taken in putting the line around the post hole so that the assembling mass of bugs does not crowd over it. When first applied the material will soak into the ground, but a hardened crust will readily form which will hold it until it slowly dries out. The line must be closely watched and renewed as often as the bugs begin to break over it. Wherever the soil is sandy and very loose a slight windstorm will cover the tar, making passageways for the bugs, and under such conditions the line must be renewed quite often. A man or boy can care for from 80 to 100 rods of the barrier, but he must stay with it from early till late. Ordinarily the bugs will have finished their migration from wheat in 10 days. This method is apparently costly and troublesome, but the actual expenditure of labor and money is insignificant as compared with the loss of the corn crop which may thus be prevented.

REMEDIAL MEASURES.

DESTROYING BUGS WHICH ENTER CORNFIELDS.

After the bugs enter the cornfields they will at first collect in masses on the plants of the first two or three rows and should be killed before they proceed farther. This can be done in two ways, by applying a gasoline torch and by spraying them with specially prepared solutions.

The flaming torch is not altogether satisfactory on account of the liability of damaging the plants. Great care must therefore be taken with the flame in order to use it safely and effectively. The flame must be in motion all of the time while on the plant, and generally one blast will cause all the bugs to fall to the ground, where they can be burned.

There are several spraying materials which can be used effectively against the bugs after they have congregated on the young corn, but, unfortunately, most of these are injurious to the plants. Kerosene emulsion of 5 per cent strength will generally kill the bugs and will not always injure the corn. The stock solution is made by boiling 1 pound of good lye soap in 1 gallon of water, adding this to 2 gallons of kerosene and stirring the mixture with a paddle for five to ten minutes. A better way to stir the mixture is to put the nozzle of the spray in the vessel and pump the liquid back into the vessel for five minutes. Dilute the mixture to a 4 or 5 per cent solution by adding soft water. Some of the proprietary spraying materials and cattle dips have been used to kill the bugs where they have become alarmingly abundant. One serious objection to these materials is that they are very injurious to the plants. However, it is sometimes better to sacrifice the first few rows and save the field than to let the bugs have their way.

UNSATISFACTORY REMEDIAL MEASURES.

GREEN-CORN BARRIERS.

Cutting the first half dozen or dozen rows of green corn and making a continuous pile along the last row cut is a method of creating a barrier very often employed. The green-corn barrier is made about the time the chinch bugs begin to enter the corn. The bugs are checked an hour or two by the corn pile, but readily pass on to the fresh, living plants.

The piles of corn plants afford shelter for the bugs, and often a quart of cast skins can be found in a heap under these piles. These cast skins have often been misleading to farmers, inducing them to believe that the bugs died from eating the sour juices of the cut corn or having died from disease. *A barrier of this kind is not to be recommended.*

PLOWING UNDER INFESTED CROPS.

As the chinch bugs in the Southwest do not hibernate in cornfields, plowing under of stalks and stubble in such localities will be of no advantage. It has been repeatedly shown that plowing under a crop of wheat, rye, or barley badly infested with young bugs is not effective unless the plowing is deep and very thoroughly done and the field is immediately afterwards harrowed and rolled.

In experiments conducted by Dr. Forbes in 1888 [a] bugs buried with wheat at a depth of 6 inches were alive after five days and some buried 5 inches came to the surface. The earth was packed over these to imitate rolling.

E. M. Shelton,[b] from observations in Kansas, writes:

Chinch bugs plowed under with young wheat to a depth of 8 inches May 9–10—the ground afterwards harrowed and repeatedly rolled—nevertheless emerged in enormous numbers (some having apparently hatched in the earth), escaped from the plots and attacked adjacent crops.

Because of the wheat being winter-killed in central and southern Kansas and northern Oklahoma during the winter of 1909 and 1910 many of the wheat fields containing young and old bugs and eggs were listed during April, at the time when the eggs were hatching. In many cases corn was listed directly into the wheat ground, tearing up the young wheat, but not entirely destroying all of it between the rows of corn. The eggs and young bugs were buried from 1 to 6 inches. The undestroyed wheat was soon covered with young bugs, which afterwards attacked the corn as soon as it appeared above the ground.

Even in fields where no wheat was visible after listing the corn was entirely destroyed. There is every reason, the authors believe, for presuming that the eggs hatched beneath the ground, and the young, after feeding there, had found their way to the surface and to the corn. Corn listed in fallow ground was free from bugs. Planting of corn in wheat fields badly infested with chinch bugs is not advisable, and is generally attended by the complete destruction of the corn. When a badly infested crop is plowed under it should be followed by a crop not affected by chinch bugs, such as cowpeas, soy beans, alfalfa, or clover. Plowing the bugs under as a means of destruction is not recommended unless in connection with a trap crop, the work being thoroughly done and followed by harrowing and rolling or otherwise packing the surface of the ground.

PARASITIC FUNGI.

EARLY OBSERVATIONS.

The susceptibility of the chinch bug to a contagious fungous disease was first observed by Dr. Henry Shimer in Illinois in 1865. Since that time two fungi have been found, which are credited with being fatal to this insect. These have been determined as *Entomophthora aphidis* Hoffman, and *Sporotrichum globuliferum* Speg. Of these two fungi, Sporotrichum (known by farmers as "fungous disease" or "white fungus") appears the most abundant in localities badly

[a] 16th Rept., State Ent. Ill., p. 45.

[b] Bul. No. 4, Kans. Agr. Exp. Sta.

infested with chinch bugs, and it is on this fungus that most observations have been made.

The genus Sporotrichum includes a large number of fungi, the most of which are purely saprophytic (i. e., living on dead animal or vegetable tissues). According to the best information obtainable, some of these are known to attack living tissues, causing their death, but afterwards developing rapidly on the body of the dead host. *Sporotrichum globuliferum* belongs to the latter class, and is known to occur on insects belonging to the orders Coleoptera, Lepidoptera, Hemiptera, and also on myriapods (centipedes and millipedes). It is credited with effectively attacking the elm leaf-beetle, the pupæ and adults of which are found covered with the fungus, especially in late summer of a moist season.[a]

Attempts have been made in most of the Central-western States to grow this fungus under artificial conditions, and then introduce it into fields badly infested with chinch bugs, where the fungus is not known to be present. With the possible exception of the Kansas experiments, made by Dr. Snow in the early nineties, these attempts met with little success. In most cases some unfortunate circumstance always arose to make the success of the experiment uncertain. (This fungus requires rather cool, moist weather for most rapid development, and is present in greatest profusion when the bugs are exceedingly plentiful and massed together.) In many of the early attempts at artificial introduction, Entomophthora was present as well as Sporotrichum, thus giving rise to some confusion concerning just which fungus was credited with actually killing the bugs.

The most important of these experiments are fully set forth in the reports of the State entomologist of Illinois and in Bulletins 15 and 69 and Circular 113 of this bureau, and therefore require no extended discussion here.

OBSERVATIONS BY THE WRITERS.

FIELD STUDIES IN KANSAS AND OKLAHOMA.

It is fully realized by the writers that the determination of the cause of a disease is most difficult, and that it requires extended laboratory research along many different lines. To state that this fungous disease is the cause of the mortality among the chinch bugs, without this extended laboratory investigation, would be entirely unscientific. The observations given here are published for what they are worth.

Observations on the habits and occurrence of the fungus were made in Kansas and Oklahoma during the spring of 1908 and 1909, and the spring and summer of 1910. Some additional data were obtained with respect to its behavior in the field among chinch bugs of all ages

[a] Conn. Agr. Exp. Sta., Bul. No. 155, 1907.

and under varying weather conditions. Most of the observations were made in Sumner County, Kans., where the fungus had probably been present among the bugs in the fields for a number of years. Considerable fungus was present during 1908 and 1909.

It again appeared among the chinch bugs in southern Kansas during April, 1910, and was first observed in the fields April 18 on the dead bodies of some adults lying on the ground at the base of young wheat plants. From this date the fungus gradually increased, dead adults covered with fungus being found almost every day. These were always on the soil, or slightly buried beneath the surface, about the roots of wheat.

During the first week of May the weather was cool and rainy, the mean temperature of the week being 59° F. and precipitation 0.75 inch for four days. The bugs, during this period, were sluggish and sought shelter under blades of wheat or any trash that would keep them off the ground. Succeeding this week of wet weather, followed two hot days, with a mean temperature each of 68.5° F. and 79.5° F. At the end of this period the following note was made:

A number of dead bugs were found lying on the ground, their bodies whitened with the fungus. One plant had 7 dead, fungus-covered bugs at its base. No young bugs found covered with the fungus.

From notes of May 18:

A great many old bugs are dead and covered with the Sporotrichum, but failed to find any young bugs covered with this fungus. The dead bugs are on the surface of the soil.

About this time the young bugs which had hatched from the eggs deposited in the wheat were massed together about the bases of the wheat plants. Where the wheat had winter-killed, and had been torn up and corn listed into the ground, the bugs which hatched on the wheat had gone to the nearest corn plants. Some stalks of these plants were red from the myriads of young bugs assembled upon them; in no case could any fungus be found on these young bugs, but there were usually a few overwintering adults to be seen about the base of these plants, and upon turning over a clod some of their dead bodies covered with Sporotrichum were usually to be found. Plenty of the fungus could be found at this time in wheat fields where the adult hibernating bugs were still present. Sporotrichum gradually became more abundant during the succeeding days of May and early part of June, the amount observed seeming to fluctuate with the weather, being most abundant while it was damp and cool and checked by a few days of dry weather. It developed most rapidly in wheat fields during the first 10 days of June, while the bugs, both young and old, were migrating from the wheat to the corn, the fungus being at this time abundant on dead adults in contact with the soil and in some cases on the bodies of young dead bugs.

At this time attention was transferred from the wheat to the cornfields where very little fungus was noted, most of the old bugs being dead, and the young ones seemingly free from any fungus. Some of it could be found on the bodies of the adults about the base of the corn, just as observed about the corn which had been listed in the wheat infested with the bugs; none, however, could now be found above the surface of the soil, all fungus being either below or on the surface of the ground.

The bugs were now seriously damaging the corn, as will be seen by the following note made on June 15:

Bugs still migrating from wheat to corn. They are out for 40 and 50 rows on corn adjacent to wheat. No Sporotrichum is developing.

The farmers of Sumner County were informed of the presence of the fungus in this locality, through the press, and by interviews with them at the laboratory at Wellington. On June 24, two reports came from the farmers that the fungus was killing off the bugs. Visits were made to their farms, and the "dead bugs" proved to be only piles of cast pupal skins, which they had found beneath piles of green corn, and bundles of wheat and oats. This same mistake on the part of the farmers was made during the experiments of Dr. Snow in 1891. In reports of farmers to him we quote: "In some fields the bugs have been reported dead in bunches," but he continues "of the fields visited, no large bunches of white-fungus bugs have been found, * * * each bug had died by himself." [a] This confusion of the fungus-killed bugs with their cast-off pupal skins is one frequently made by farmers, and such reports in regard to the efficiency of the fungus are very apt to be erroneous.

On June 23 the bugs began to leave the badly infested corn, as the young had now developed wings. By July 1 they were so widely scattered over the corn as to give the appearance of having left the fields. In some instances this apparent disappearance of the bugs was credited to the fungus by those who had not been constantly watching them, several farmers reporting that the fungus had killed their bugs because there were so very few to be found.

Heavy rain fell on July 8 and 10, but little Sporotrichum could be found among the bugs in the corn. On July 19 a few dead adults located on corn leaves from 1 to 2 feet above ground were observed covered with Sporotrichum. This was the only case during the summer where the fungus was observed not in contact with the ground. At this time an examination of the wheat stubble was made and the following note made:

In pulling up wheat stubble large numbers of dead fungus-covered bugs were found in some places, the soil about the wheat roots being speckled with the fungus.

[a] 1st Report on Contagious Diseases of the Chinch Bug, F. H. Snow, 1897.

Particles of the fungus were found on dead adult bugs or a part of their bodies—some masses of white fungus covering only a broken abdomen, or a thorax with wing attached, by which the insect was identified. It appears that the fungus had developed rapidly on fragments of bugs and entire bodies of the bugs, especially when buried beneath the soil. The indications here were that much white fungus had made its entire growth on the dead bodies of the hibernating adults which had migrated to the wheat fields.

During the last week of July the weather was hot and dry and myriads of young bugs of the second generation, now feeding, sought shade under blades of corn, or beneath the clods at the base of the plant, but during this time no fungus developed. This condition prevailed until the middle of August, when wet weather again set in, and while this did not seem to increase the amount of Sporotrichum present, plenty of the fungus could be found in the soil around wheat stubble. However, this fungus seemed unable to infect the young bugs in the corn above ground, even where the cornfield joined the wheat stubble.

Sumner County, Kans., seemed to be about the center of the Kansas-Oklahoma chinch-bug infestation. With a view of finding out whether or not the fungus Sporotrichum was present in other places over the infested area, as well as to determine the extent of the infestation, a trip was made during June of 1910 through central and southern Kansas and central and northern Oklahoma, which represents pretty well the area infested during 1910 in this part of the Southwest. Twenty localities were visited, viz: Herrington, McPherson, Hutchinson, Pratt,* Dodge City,* Great Bend,* Sedgwick, Wichita, Winfield, Arkansas City, South Haven, Caldwell, and Caney, Kans.; Medford, Enid, Kingfisher, Elreno,* Chickasha,* Oklahoma City,* and Tulsa,* Okla. *Sporotrichum globuliferum* was found in every locality except those marked with an asterisk. The fungus covered bodies of the dead bugs were usually found lying upon the surface of the ground in wheat fields and in every case these were old migrant bugs, precisely as found in Sumner County, Kans. The seven localities where no Sporotrichum was found were all on the extreme outer edge of the infested area where there were very few bugs present. In every one of these seven localities the soil was very sandy, apparently not retaining moisture necessary for the development of the fungus.

Artificial introduction.—The fungus *Sporotrichum globuliferum* was already so abundant among the bugs in Sumner County during the summer of 1910 that no attempt was made upon the part of the authors to introduce it artificially. It seemed useless, since the amount already present so far exceeded any amount which could be introduced. However, a number of farmers anxious to try this secured some Sporotrichum from outside sources and introduced it into their fields. These attempts were made independently and, as far as could be learned, no satisfactory results followed.

In the neighboring counties of Harper and Cowley, Kans., and Kay County, Okla., farmers united in spreading the fungus over their fields, after having grown plenty of it in boxes on their farms. This experiment was tried very thoroughly and on a very large scale in Cowley County, Kans., where the farmers secured the fungus from boxes of chinch bugs at two central stations, and after having grown more of the fungus in boxes on their own farms spread the whole over their fields where the bugs were thickest. The distributing points were Arkansas City and Winfield, Kans., and about 700 farmers secured fungus from the two boxes at these points. This was done in early June, and was followed by rainy weather just after the fungus was placed in the fields. The precipitation record at Wellington showed an aggregate rainfall of 0.82 inch on June 6, 7, 8, 10, and 11. When Cowley County was visited on June 21 it had been dry for a week preceding. The central distributing points were visited, and it was learned that a large quantity of *Sporotrichum globuliferum* had been distributed from these boxes. No satisfactory results were reported to the central station. Many of the farmers were interviewed, and in almost every instance the lack of success was attributed to the dry weather, which prevailed between June 12 and 21. In some localities every farmer had used some of the fungus. Upon visiting the exact spots where the fungus had been placed in the fields many bugs were found covered with white fungus; however, the fungus was as easily located in places remote from any artificial importation. The fungus was always put out in places where the chinch bugs were massed together. In consequence of this massing more fungus would normally occur in these places than elsewhere, regardless of the source of infection. The damage caused by the chinch bugs was fully as great where the fungus was introduced as it was in places remote from these, and also fully as great in this locality as it was in Sumner County, where no fungus had been introduced.

The parties who carried on this experiment were so united in their work, and extended it over such a wide area, that it constitutes one of the most satisfactory field experiments ever carried out with this fungus. From the results obtained we arrive a step nearer the actual position this method should occupy. There can be hardly a doubt that Sporotrichum was present before the experiment was tried, and that, too, in sufficient quantity to inoculate the healthy bugs. Since this failed to hold the bugs in check, no artificial introduction could accomplish what nature failed in doing.

Sporotrichum has appeared during the past three years in this part of the Southwest, and has not been effective as a natural enemy, occurring chiefly among the old spent and therefore practically harmless bugs of the hibernating brood, they having already performed their mission of depositing their eggs. Since the fungus is so dependent on meteorological conditions, it can not be depended upon to exterminate the chinch bugs in this region. Farmers can accomplish a great deal more by employing methods more under their control.

OFFICE STUDIES IN WASHINGTON, D. C.

The following experiments were conducted at Washington, D. C., by the junior author who did the work on a table in an office room with no facilities for more elaborate experimentation. He entered into the investigation with a view of determining if the growth of this fungus is confined to the dead bodies of the chinch bugs and other insects, as the preceding field observations had, in most cases, borne out this supposition. These experiments led to a further study of the behavior of this fungus among living chinch bugs, and the results are here presented, in the hope that a better and more clear understanding may be had of what was observed to occur in the fields.

In these experiments the author is greatly indebted to Prof. F. M. Webster, of this bureau, under whose direction the work was done. Also to Dr. Flora W. Patterson, mycologist, Bureau of Plant Industry, for her valuable suggestions and kindness in determining the fungus.

Sporotrichum globuliferum was secured for these experiments by placing under a bell jar, on blotting paper kept constantly moist, dead bugs taken at Wellington, Kans., from beneath leaf sheaths of cornstalks, where they had died the previous autumn. The fungus was also secured by placing on moist blotting paper dead bugs collected in clumps of *Andropogon scoparius*, where the adults were hibernating but among which no fungus was observed. From 2 to 4 of all the dead bugs so treated became covered with the white fungus (fig. 15). The fungus was obtained also from live bugs collected from these same stools of *Andropogon*, confining the bugs in small cages of wheat kept well moistened. Some of these bugs died in the cages and on their bodies, lying upon the soil, the fungus appeared and was first observed eight days after the live bugs were placed in the cages.

During the spring of 1909, in the laboratory at Wellington, Kans., the senior author confined, on potted, growing wheat plants, numbers of living chinch bugs which were collected from tufts of *Andropogon scoparius*. The fungus appeared on several of the bugs which had died and were in the soil. He also obtained the fungus on adult dead chinch bugs collected from the tops of wheat blades and put on potted wheat plants. In these experiments the soil had been previously sprayed with a weak solution of corrosive sublimate for the purpose of killing any fungus spores that might have been present in the soil in these cages, thus eliminating that source of infection. This indicates that the spores of the fungus were present on the bodies of the living bugs and were only awaiting favorable conditions for germination and abundant growth. In all such cage experiments the fungus appeared only on the bodies of the chinch bugs that had died in the cages and were lying on the soil.

In the experiments at Washington, D. C., it was desired to obtain a better knowledge of this fungus and its relation to dead bugs, in order to ascertain to what extent, if any, it will grow saprophytically upon their dead bodies. Also to observe the rate of mortality among live chinch bugs, placed in cages and artificially inoculated, as compared with those under similar cage conditions not so inoculated. In the artificial inoculation, the fungus was applied by thoroughly dusting the bugs with the spores of the fungus by means of a small brush, or in other cases by shaking them about in a vial containing the fungus-covered chinch bugs.

FIG. 15.—The chinch bug: Adults covered with "white fungus" (*Sporotrichum globuliferum*). Enlarged. (Original.)

EXPERIMENTS WITH DEAD CHINCH BUGS.—To determine whether or not *Sporotrichum globuliferum* would make its entire growth upon the dead bodies of chinch bugs, a large number of live bugs, collected from tufts of *Andropogon scoparius*, and which died while confined in a vial, were inoculated artificially and their bodies placed on moist blotting paper. The results of these artificial inoculations compared with their checks are here given.

Inoculation experiments with dead bugs.

Artificially inoculated.			Checks.		
Number bugs used.	Number developing fungus.	Per cent which developed fungus.	Number bugs used.	Number developing fungus.	Per cent which developed fungus.
25	5	20	100	2	2
25	1	4	200	2	1
25	5	20	25	0	....
25	4	16	25	2	8
40	5	12	25	0	....
			40	0	....
140	20	14.28	415	6	1.45

From this table it is seen that while the check cages gave but 1.45 per cent developing the fungus, this percentage was raised to 14.28 when the bugs were artificially inoculated.

Some live and apparently healthy bugs were then killed mechanically by piercing them with a sharp needle, their bodies then being inoculated with the fungus and placed on moist blotting paper.

Inoculation experiments with bugs killed mechanically.

Artificially inoculated.		
Number bugs used.	Number developing fungus.	Per cent which developed fungus.
25	4	16
35	3	8.57
25	3	12
85	10	11.76
Check.		
50	0	0

Others were killed with fumes of chloroform, allowed to dry overnight, then washed in distilled water, and treated as in the preceding experiment.

Inoculation experiments with bugs killed with fumes of chloroform.

Artificially inoculated.		
Number bugs used.	Number developing fungus.	Per cent which developed fungus.
20	6	30
25	5	20
20	6	30
65	17	26.15
Check.		
200	0	0

From these experiments with dead bugs it was found that a small percentage of them could be made to produce *Sporotrichum globuliferum* after inoculation, with every indication that the fungus made its entire growth on their dead bodies.

EXPERIMENTS WITH LIVE CHINCH BUGS.—The cages used in these experiments consisted of a series of small flowerpots containing growing wheat, over each of which was placed a glass cylinder. Into these cages the living chinch bugs were placed and cheesecloth stretched over the top to prevent their escape. All of the cages were kept on a table in the office, which was heated day and night, and were kept well moistened to promote the rapid development of the fungus. The live chinch bugs which had been dusted with the spores of the fungus were then placed in these cages and the results compared with check cages into which were placed live chinch bugs not previously inoculated. Most of the bugs were provided with plenty of food. Some, however, were placed in a cage containing no food to see if the rate of mortality and appearance of the fungus were to any extent dependent upon the food supply. These experiments are here given, with a record of each cage and its check.

Experiments with living chinch bugs.

CAGES CONTAINING PLENTY OF FOOD.

Cage No.	Number bugs used.	Treatment given.	Number of days experiment continued.	Number of bugs which died.	Number upon which visible fungus appeared.
a {63	25	Inoculated	14	11	7
a {62	40	Check	14	0	0
b {63	15	After 14 days transferred from 62*a* to 63*a*	24	15	11
b {62	18	Taken from 62*a* and inoculated	24	17	7
80	9	Taken from 63*a* and placed in cage free from fungus.	24	0	0
82	25	Inoculated	22	18	4
83	33	Check	22	4	0
90	25	....do	31	20	7
89	25	....do	31	4	0
93	25	....do	35	20	1
92	30	....do	39	4	0
108	25	....do	30	17	11
108*a*	25	....do	30	5	0

CAGES CONTAINING NO FOOD.

Cage No.	Number bugs used.	Treatment given.	Number of days experiment continued.	Number of bugs which died.	Number upon which visible fungus appeared.
120	29	Inoculated	18	27	21
122	25	Check	18	5	0

The fungus always appeared about the third day after the death of the chinch bug, and in no case did it appear sooner than six days after inoculation, the bugs gradually dying and some remaining alive 35 days. Living bugs removed from cage 63, where the bugs were dying and fungus developing, did not die when removed to another cage away from all infection, even though the moisture conditions were about the same. However, all of those remaining in cage 63 died and afterwards became covered with the fungus. This indicates that the rate of mortality can be checked if the bugs are removed from the presence of the fungus.

As between the inoculation and check cages there was a marked difference observed in the rate of mortality, for which no cause other than Sporotrichum seemed to be responsible, as the death rate was always greatest in the inoculated cages. The greatest mortality and most rapid development of the fungus appeared in cages where the bugs had little or no food. In the stock cages only a very small supply of the fungus could be secured until the food was removed, when it soon appeared abundantly upon their dead bodies lying on the soil.

CONCLUSIONS.—From these experiments it is apparent that *Sporotrichum globuliferum* will to a certain extent develop entirely upon the dead bodies of adult chinch bugs. However, the fungus was easily secured in the cages containing living bugs artificially inoculated, particularly when the bugs in these cages were given insufficient food supply.

The indications were also that this fungus is communicable to living chinch bugs, but is evidently not very effective in causing their death unless the bugs possess weakened vitality. This being the case, it would be most effective in nature against old spent adults which have laid their eggs and are comparatively harmless, and it is upon these bugs that the fungus always appeared in greatest abundance, as borne out by field observations during the past three years.

For this reason, as well as its dependence upon favorable weather conditions, its practical efficiency is very questionable; and since it is unable under favorable conditions of moisture and temperature to rapidly exterminate healthy bugs confined in a cage in the laboratory, little dependence can be put upon it to be used against the insects in the field when favorable moisture conditions are so apt to be lacking.

SUMMARY.

Injuries due to the chinch bug west of the Mississippi River are chiefly confined to the States east of the Rocky Mountains where wheat and corn are extensively grown, the most serious outbreaks during 1909 and 1910 occurring in southern Kansas and northern Oklahoma.

There are two generations each year, one during the spring, which attacks the wheat and corn, and one during the summer, which develops on the corn and hibernates. These last pass the winter as adults, and in the States west of the Mississippi River prefer for hibernation the dense clumps of red sedge grass in which they collect in the fall. Very few survive the winter in fallen ears or stalks of corn during severe cold winters, but may survive a mild winter. They fly from the sedge grass to fields of wheat during the first warm days of spring, where the eggs are deposited, and the young hatching therefrom feed with the adults upon the wheat until it has ripened, when they all march in a body to the nearest cornfield. The young become mature on the corn and lay eggs from which hatch the bugs that winter over as above stated. Weather conditions have much to do with the numbers that reach maturity, many young being killed during a period of wet weather attended by hard dashing rains. Dry weather is most favorable to their development in abundance. The injury to wheat and corn is often severe, sometimes resulting in almost complete destruction of the latter crop after serious injury to the former.

During the severe winter of 1909 and 1910 about 20 per cent of the bugs died normally in the clumps of red sedge grass, where they hibernate.

Experiments in Kansas made during the winter of 1909–10 showed that as high as 75 per cent of the hibernating chinch bugs could be killed by burning this grass. The best time to burn is in the fall, when the grass is as dry as possible. It is not necessary that the flame come in actual contact with the bugs.

The effectiveness of the burning is almost entirely dependent upon the cooperation of the farmers in infested localities. Neglect to destroy chinch bugs collected in these grasses will often result in serious injury, if not indeed a complete destruction of wheat, corn, cane, and kafir.

Next to burning, the dust and coal-tar barriers are the most effective remedies, and should be used while the bugs are migrating from wheat to corn. These barriers must be properly made, and demand constant attention to be of any value.

Many bugs can be killed while massed on the first rows of corn by applying a torch or spraying with kerosene emulsion or proprietary spraying materials.

Plowing under infested crops is not recommended unless the work is done very thoroughly and followed by a crop not susceptible to chinch-bug attack.

Barriers made of piles of green corn are of no value, and are not recommended.

The "white fungus," can not be depended upon to exterminate the chinch bugs. This fungus is very dependent upon moist weather conditions for its rapid development and diffusion. It can usually be secured by collecting live or dead chinch bugs from the sedge grass, and placing them under proper conditions of temperature and moisture. This fungus has many host insects, and is generally present where chinch bugs are found in destructive numbers.

Laboratory experiments show that this fungus is present in greatest abundance among old spent adults, or those bugs that are in a weakened condition. Also that it will grow upon dead bugs. This will partially account for the fact that the time of its greatest abundance in the fields occurs after the hibernating bugs have laid their eggs and are dying normally. These bugs have performed their mission of laying eggs, and are comparatively harmless.

Many bugs lived for weeks, and even months, in confinement in the presence of the fungus under conditions favorable for its development.

Attempts at artificial introductions of the fungus in the fields have so frequently resulted in complete failures that this method is not recommended. Vastly more may be accomplished by applying the same amount of time and labor to the application of practical, successful remedies.

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BUREAU OF ENTOMOLOGY—BULLETIN No. 95, Part IV.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SO-CALLED "CURLEW BUG."

BY

F. M. WEBSTER,

In Charge of Cereal and Forage Insect Investigations.

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Nettie S. Klopfer, Ellen Dashiell, *preparators.*
Miriam Welles Reeves, *collaborator.*

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE SO-CALLED "CURLEW BUG."

(*Sphenophorus callosus* Oliv.)

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

INTRODUCTION.

The so-called "curlew bug" (*Sphenophorus callosus* Oliv.) (fig. 16) is allied to the maize billbug, *Sphenophorus maidis* Chittn., the subject of Part II of this bulletin. It is commonly known in the Carolinas as the curlew bug, sometimes as the "klew" or "clewbug," and the "kloobug," all probably contractions of "curlew bug." The curlew is a shore bird, having a long, curved bill, while the insect, *Sphenophorus callosus*, which is provided with a long, curved snout, is found plentifully under rubbish along the shores of sounds and rivers, especially those of North Carolina. Intelligent fishermen, who are familiar with it, claim that it is often found clinging to their fish nets spread in Albemarle Sound.

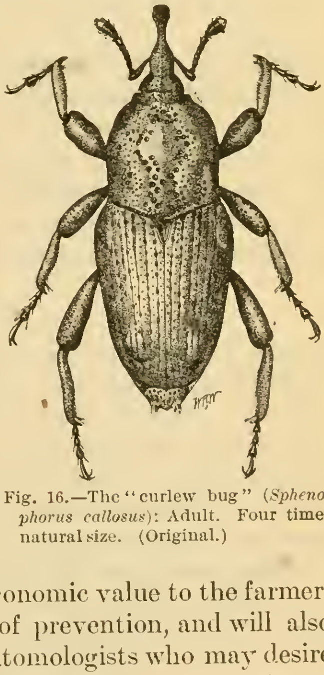

Fig. 16.—The "curlew bug" (*Sphenophorus callosus*): Adult. Four times natural size. (Original.)

The information herein given, in so far as it is original, has been accumulating for a number of years, some of the facts having been taken from the general correspondence of the bureau and others from the results of more or less fragmentary and more recent studies by several assistants engaged in the investigations of cereal and forage insects. While not complete in all of the scientific details, so much of this information is of economic value to the farmer, pointing out to him a practical method of prevention, and will also prove of assistance to station and State entomologists who may desire to study the pest in their own States, that it seems an injustice to withhold publication longer with the object of securing details of perhaps minor importance. The species was studied to some extent in Illinois several years ago by Dr. S. A. Forbes, State entomologist of Illinois, and his assistants, the results obtained by him being published later by Dr. Forbes under the name *Sphenophorus cariosus* Oliv. Information from that source is also embodied herein.

The author does not himself assume credit or responsibility, except where indicated in the text. Where so many individual investigators have contributed results of observations and studies, it becomes the duty of some one to act as spokesman and put the matter in shape for publication, and this duty the author has endeavored to fulfill.

In his paper relating to this and other species of the genus Dr. F. H. Chittenden,[1] of the Bureau of Entomology, came to the conclusion that *S. sculptilis* Horn is a synonym of *S. callosus* and that *S. sculptilis* Uhler is a synonym of *S. cariosus* Oliv.; also that in many cases specimens received by him showed that references to either of these three species related properly to *S. callosus*. It is upon these conclusions that many of the facts herein given are based.

HISTORY OF THE SPECIES.

The insect was first described by Olivier in 1807, from "Carolina," as *Calandra callosa*.[2] This locality, now somewhat vague, will, as shown in figure 17, apply almost equally well to both this species and *S. maidis*.

While it does not seem possible that this particular species of insect could have existed all of these years in that section of the country—one of the earliest settled, and therefore one of the first to be brought under cultivation—without doing injury to corn and rice, yet as a matter of fact over half a century did elapse before proof of its ravages, accompanied by specimens of the beetles, were in the possession of the Department of Agriculture.

BUREAU NOTES.

June 1, 1880, specimens of the beetle were received from Mr. E. T. Stackhouse, of Marion, S. C., who accused them of damaging young growing corn in his neighborhood.

May 27, 1884, a report was received from Prof. J. A. Holmes, of Chapel Hill, N. C., that this species was injurious to corn near Bayboro, N. C., where it is known as "kaloo bug"; also that the belief was prevalent there that the "insect winters in the rice stubble."

This species, specimens of which were kindly loaned Dr. Chittenden for identification by Messrs. Forbes and Hart, is recorded in the published notes of the State entomologist of Illinois as injuring corn at

[1] Proc. Ent. Soc. Wash., vol. 7, No. 4, pp. 166-182, 1906.

[2] Hist. Nat. des Ins., vol. 5, p. 92, pl. 27, fig. 416, 1807.

Pittsfield, S. C., June 4, 1888. The beetles when received were ovipositing in the box in which they were sent. The species was also found attacking young corn May 1, 1891, the beetle gnawing a large cavity in the stalk just below the ground. "When placed in a breeding cage the beetle made its way into the seed kernel of the stalk."

Brief mention has already been made of its occurrence in Illinois by Dr. Forbes in different papers.[1] It is obvious, as determined by Chittenden, that this entire account of *Sphenophorus cariosus* refers in reality to *callosus*. The illustration given in the publication first cited is of the latter species, as is also the description, and it should be further stated that the occurrence of *S. cariosus* in Illinois is doubtful.

June 10, 1889, Prof. A. J. Cook also reported injury to corn in North Carolina, though the source of his information is not clear.

July 20, 1893, Mr. S. L. Willard, Washington, N. C., wrote that this billbug, called "curlew bug" in that vicinity, was doing considerable damage to the corn crop. Rice also was injured, and it was stated that the insects had been noticed at least 8 years (or since 1886) in that neighborhood. The beetles were also operating in chufa (*Cyperus esculentus*), and some farmers had abandoned rice growing on account of the ravages of this pest.

July 8, 1895, we received word from Mr. B. A. Hallett, Mount Olive, N. C., that this species had completely destroyed the upland rice crop of that section and had greatly injured corn.

During July and August, 1895, Mr. A. N. Caudell reported injury to chufa or yellow nut-grass (*Cyperus esculentus*) at Stillwater, Okla., and August 24 sent pupæ.

May 11, 1896, we received report from Mr. R. J. Redding, Experiment Station, Ga., that this species was attacking fields of young corn in Jefferson County, Ga., by thousands.

May 22, 1897, Mr. Charles B. Guinn reported injury to fields of green corn at Georgia City, Mo.

August, 1898, Dr. Chittenden found, in low bottom-land on the banks of the canal at Glen Echo, Md., the pupa of this species at the roots of witch grass or tumbleweed (*Panicum capillare*). Transformation to imago took place on the 22d.

May 30, 1899, Mr. Edward Markham, jr., Kehukee, Pasquotank County, N. C., wrote that this species had made its appearance in that region, had spread rapidly, and that it was doing so much damage to corn that some crops were being abandoned. It was considered the worst pest of that vicinity—worse than all others combined. It was known locally as the "clue bug," a contraction of curlew bug. Beetles were received from this source as late as July 8.

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[1] 16th Rept. St. Ent. Ill., f. 1887 and 1888, pp. 64, 68, 71, 1890. 22d Rept. St. Ent. Ill., f. 1903, pp. 19–21. Bul. 79, Univ. Ill. Agr. Exp. Sta., p. 453, 1902.

August 3, of the same year, Mr. James K. Metcalfe, Silver City, N. Mex., reported beetles as well as larvæ in stalks of corn growing near the Gila River in that vicinity. It was reported that the beetles deposited their eggs in the stalks near the ground; that the grubs ate all the lower part of the stalk and soon destroyed the plant. The beetles destroyed entire fields of corn, working in the usual manner.

August 6, 1900, Mr. G. L. Swindell, Swindell, Hyde County, N. C., reported that this beetle and its larva were injurious to rice—the larva by feeding on the roots and the beetles by attacking the stalks near the ground. The damage done by the beetle to corn in Hyde, Pamlico, Beaufort, and Tyrrell counties could hardly be estimated. In some years it amounted to almost total destruction and was noticeably worse near old rice patches. August 20 this bureau received crowns and roots of the infested rice, as well as larvæ and beetles. In nearly every case there was a cavity in the crown just above the roots, containing the larva and its castings.

During 1901 this species was reported by Mr. Franklin Sherman, jr., Raleigh, N. C., as the cause of general complaint in the eastern part of North Carolina of "billbugs," "klewbugs," "curlew bugs," etc. The species was identified from Elizabeth City and Goldsboro, N. C. Injury was not noticed in the western part of the State. April 23 a report was received from Mr. Robert T. Smith, Grant, Fla., of this species attacking corn, being most troublesome in early March, and infesting the young stalks just below the center, in such a manner that the central leaf often comes out entirely.

Prof. Franklin Sherman, jr.,[1] has given an account of this species with accompanying reports of its injuries to corn in 1902 and 1904 in low, swampy lands in the eastern sections of North Carolina. Injury was also reported by Mr. Sherman in portions of Bladen, Cumberland, Duplin, Moore, and Brunswick counties.

During June and July, 1904, Mr. Thomas J. Clark, Cliff, Grant County, N. Mex., reported billbug damage, and July 27 sent larvæ and imago of this species with the statement that the beetles began operations on young corn as soon as it came up; that they deposited their eggs in the roots; that the larvæ continued feeding in the stalk, and that after the corn began to tassel it would fall over and blight. The stalks, however, seldom developed to that extent before they were killed. He stated that cutworms were nothing to compare with them in their attacks on corn; also that the species was believed to be native to old Mexico and that it had been seen in that vicinity seven or eight years earlier.

June 26, 1906, information was received from Mr. F. B. Hopkins, in charge of the testing gardens at the Arlington Farms, Va., of injury

[1] "Insect Enemies of Corn," Bul. N. C. Dept. Agr., 1905, pp. 19–22.

by the beetle of this species to chufa. The larva was at this time operating in the crown of the plant at the base of the leaves. It was observed that the insect was capable of doing considerable damage even at this early date, as crowns were then found completely honeycombed. On June 28 Mr. I. J. Condit, detailed by Dr. F. H. Chittenden, in charge of Truck Crop and Stored Product Insect Investigations for the purpose of obtaining material, visited the infested locality and obtained numerous specimens of hibernated beetles and larvæ. It was then estimated that the damage would amount to about 20 per cent of the crop. June 30 a larva was found nearly grown. Eggs were also obtained at that time and until the end of the first week of August. Search was made for the natural food of the insects, and this was found in Frank's sedge (*Carex frankii*).

May 22, 1907, Mr. R. I. Smith sent this species from Atlanta, Ga., with the statement that these billbugs were reported as quite abundant and doing great damage to corn at Statesboro, Ga. They had been present at the date of that writing for about three weeks.

DISTRIBUTION.

As will be observed by consulting the accompanying map (fig. 17) this species covers a wider range than *Sphenophorus maidis*. It seems to center in point of abundance in eastern North Carolina, extend-

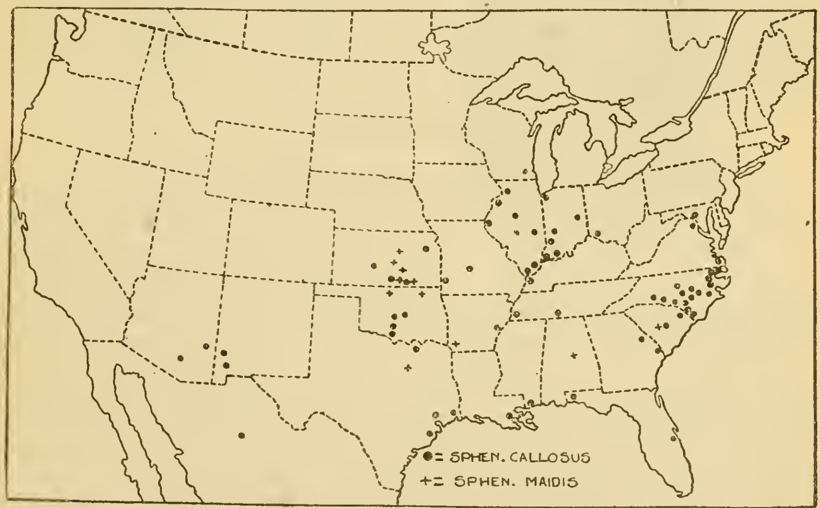


FIG. 17.—Map showing distribution of the "curlew bug" (*Sphenophorus callosus*) and the maize billbug (*Sphenophorus maidis*). (Original.)

ing southward to southern Florida, northward to Maryland, thence northwest to northwestern Illinois, southwest to extreme southeastern Arizona and northern Mexico, and eastward to the Gulf coast.

It is essentially a lowland form, as its food plants clearly indicate, and will therefore especially interest the farmer whose fields are of bottom, swamp, or other low-lying lands.

The following are the localities from which the species has been received:

Arizona: Tucson (Wickham), near Duncan (Cockerell). *Arkansas:* Helena (L. E. Howard). *Florida:* McLellan (W. H. Gill), Grant (Robt. T. Smith). *Georgia:* Jefferson County (R. J. Redding), Statesboro (R. I. Smith). *Illinois:* From Pekin to Cairo, Savanna, Urbana, Metropolis (Forbes), Warsaw (Dr. Shafer), Rock Island (Det. Chittenden). *Indiana:* Lake, Vigo, Posey, Perry, Putnam, and Blackford counties (W. S. Blatchley). *Kansas:* Great Bend, Arkansas City (T. H. Parks), Wellington (Kelly and Parks), Douglas County (Det. Chittenden). *Kentucky:* Opposite Cairo, Ill. (Forbes). *Louisiana:* New Orleans (H. Soltau). *Maryland:* Glen Echo (Det. Chittenden). *Mississippi:* Gulf View (Det. Chittenden). *Missouri:* Georgia (Chas. B. Guinn), Atoka (Det. Chittenden). *New Mexico:* Cliff (T. J. Clark), Silver City (Jas. K. Metcalfe). *North Carolina:* Edenton (J. W. Mason), Elizabeth City (J. P. Overman), Hertford (W. T. Shannonhouse, Mrs. S. D. Jordan), Pineview (W. Barnett), Pyreway (Maj. Gore), Bayboro, Chapel Hill (J. A. Holmes), Washington (S. L. Willard), Mount Olive (B. A. Hallett), Kehukee (Edw. Markham), West Raleigh, Proctorville, Braswell (R. I. Smith), and Hyde, Pamlico, Beaufort, and Tyrrell counties; Swindell (G. L. Swindell), Bladen, Cumberland, Duplin, Moore, and Brunswick counties (Franklin Sherman). *Ohio:* Cincinnati and vicinity (Chas. Dury). *Oklahoma:* Stillwater (A. N. Caudell, C. E. Sanborn), Duncan, Anadarko, Pocasset, Hastings, Cement, Rush Springs, and Chickasha (A. L. Lovett), Duncan, Chickasha (T. D. Urbahns), Marlow (J. F. Davidson), Oklahoma City (T. H. Parks). *South Carolina:* Marion (E. T. Stackhouse), Pittsfield (Forbes and Hart), Rimini (C. R. F. Baker). *Tennessee:* Appleton (P. Cox, Geo. G. Ainslie), Memphis (H. Soltau). *Texas:* Whitesboro (E. O. G. Kelly), Wallisville (W. L. McAtee), Alligator Head (J. D. Mitchell). *Virginia:* Norfolk (Popenoe), Arlington (F. B. Hopkins). *Mexico:* (Prof. Herrera).

FOOD PLANTS.

Dr. Forbes gives *Cyperus strigosus* as the natural food plant, in the roots of which it develops in Illinois. Mr. T. D. Urbahns found it developing in *Tripsacum dactyloides* at Plano, Tex., in July, 1909. At Appleton, Tenn., July 14, 1911, Mr. Geo. G. Ainslie found the infested fields in part grown up with weeds and a swamp Carex (*C. vulpinoidea*), but he was unable to find the beetle actually developing therein. (See Pl. IX, figs. 1, 2.) Mr. A. N. Caudell reported the larvæ injuring the roots of yellow nut grass (*Cyperus esculentus*) at Stillwater, Okla., in 1895. Dr. Chittenden reared the adult from a pupa found in the roots of *Panicum capillare* growing in low bottom lands along the canal near Glen Echo, Md., in August, 1897. Mr. I. J. Condit found it breeding in Frank's sedge (*Carex frankii*) growing on the department farm at Arlington, Va. In Florida the insect develops from egg to adult in *Cyperus rotundatus*, while farther north, in the Carolinas, the common food plant is the "chufa" (*Cyperus esculentus*). To such a degree is this true in the latter locality that the insect is supposed by farmers to have been introduced with that plant. Quite in accord with the foregoing, Mr. J. G. Sanders reared adults March 30, and again April 25, 1908, from *Cyperus exaltatus*, introduced from Egypt and growing on the department farm at Arlington, Va.

The cultivated food plants are corn, rice, and peanuts, in importance according to the order given.

DESCRIPTION AND LIFE HISTORY.

THE EGG.

(Fig. 18.)

The egg appears to have been first observed by Mr. A. N. Caudell, who noted the female ovipositing at Stillwater, Okla., July 18, 1895. The egg was described as white, 1.5 mm. long and half as wide, oblong-oval in shape. Mr. E. O. G. Kelly, who studied the species carefully at Wellington, Kans., found eggs deposited June 17, 1911, to be "white," 1.5 mm. long, one-third as wide, and elliptical in form.

Dr. Chittenden described the egg as found at Arlington, Va., as considerably larger, measuring 2.2 to 2.3 mm. in length and only 0.8 to 0.9 mm. in diameter. The outline is subreniform-elliptical, one side having a tendency to straightness along the greater portion of its length. The color is dull, slightly yellowish white. The surface is nearly smooth, with faint reticulation showing in very limited areas. The variation in size of the egg has also been observed by Mr. R. I. Smith, in North Carolina.

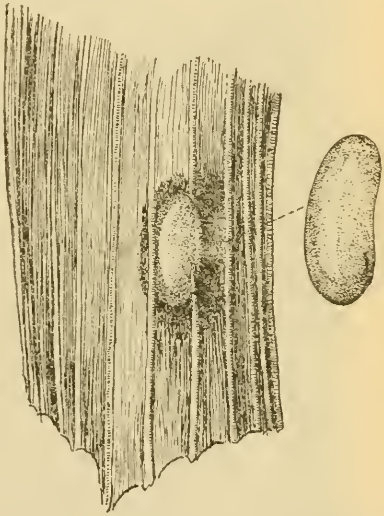


FIG. 18.—The "curlew bug": Egg as placed in stem of young corn plant. Greatly enlarged. (Original.)

Mr. Kelly, in his studies, found eggs from June 16 to September 11, a period of nearly 3 months. The egg period varied from 4 to 6 days in June, in July 5, and from 6 to 8 days in September. In one case 58 eggs were secured from one female, and there was a possibility that she might exceed this number.

Mr. Vernon King and the author found ovipositing adults and half-grown larvæ on Harveys Neck, about 15 miles southeast of Hertford, N. C., on June 20, 1911. This would indicate that oviposition was in progress about June 1. Mr. Jas. A. Hyslop, of this bureau, and Mr. R. I. Smith of the North Carolina Agricultural

Experiment Station, found pupæ in the same locality November 4. If we allow 8 days as the egg period and 37 to 41 days as the larval period, as determined by Mr. Kelly in Kansas, the eggs, judging from the records just mentioned, are deposited in North Carolina from about June 1 to September 20, or during a period of approximately 4 months. Mr. I. J. Condit found a nearly full-grown larva at Arlington, Va., June 30, 1906, which confirms in a general way the preceding observations.

THE LARVA.

(Fig. 19.)

Quite naturally the larva of this species closely resembles that of *Sphenophorus maidis*. The principal differences are brought out in the illustration of *S. callosus*. The head (fig. 19,*b*), is more slender, especially toward the vertex, the area between the Y sutures is nearly smooth and quite different in outline from that of *S. maidis* (fig. 19, *c*) drawn on the same scale. In this latter species the space is shallowly sculptured, with the sutures more sinuate. The larvæ of both species vary greatly in size, and it is doubtful if in this respect they differ materially from each other.

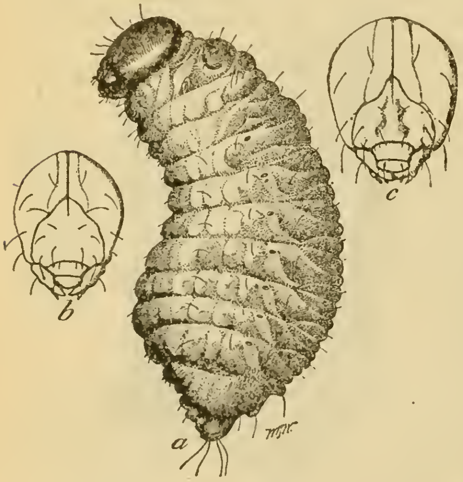


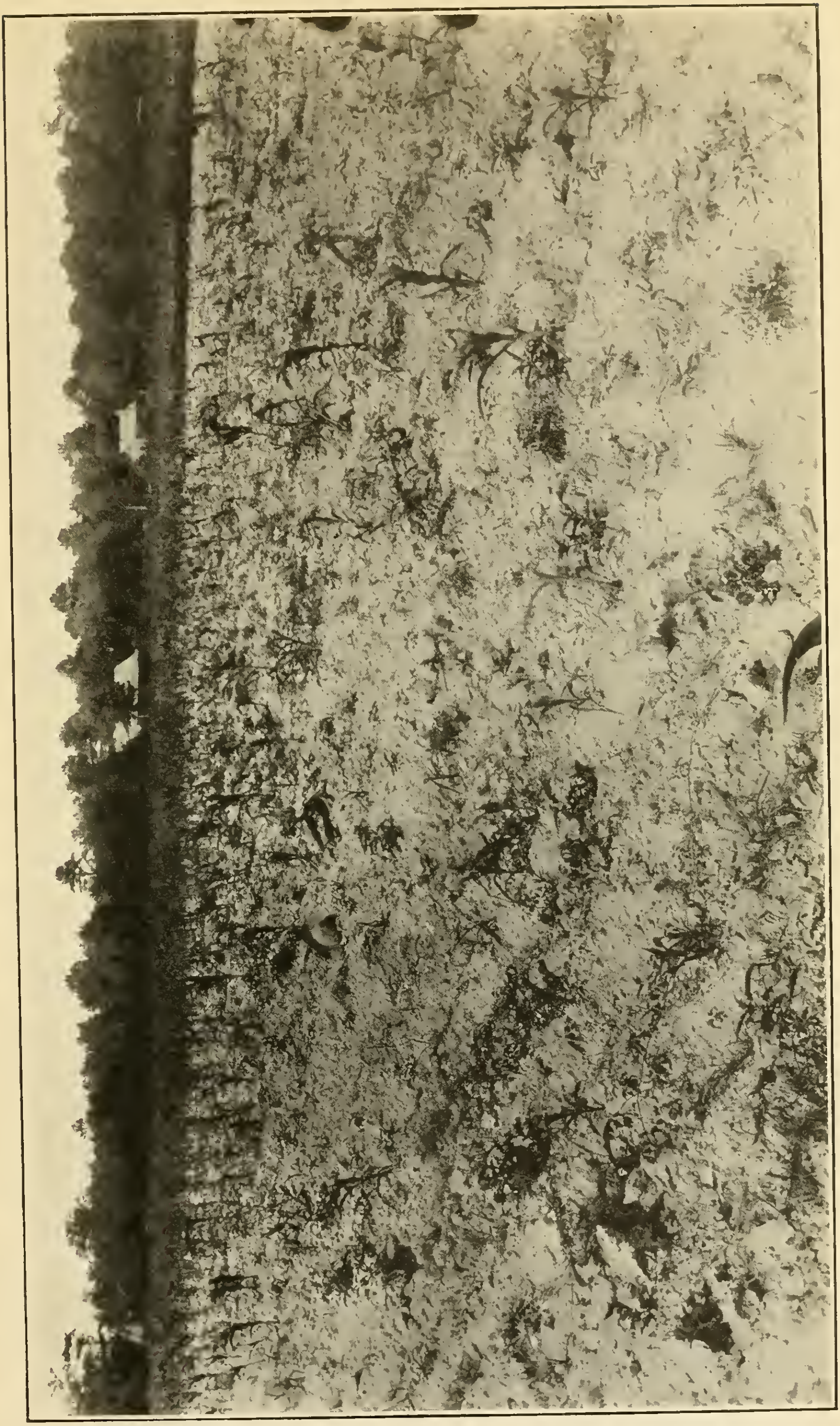
FIG. 19.—*a*, Larva of the "curlew bug" (*Sphenophorus callosus*); *b*, head of same; *c*, head of larva of the maize billbug (*Sphenophorus maidis*). Enlarged. (Original.)

Mr. Caudell found the larvæ among the matted roots, where they form cells and where they are frequently seen completely embedded in the chufa. These they hollow out, leaving only the hull. They are sometimes so numerous that frequently as many as a dozen can be taken in a single bunch of roots.

Mr. I. J. Condit, on October 8, found the larvæ in chufa at Arlington Farms, Va., usually from half an inch to an inch below the surface of the ground. They seemed quite capable of subsisting upon the dead, perfectly brown, and nearly rotten substance of the leaves, stems, and crowns of the plant, but they also perforated the roots.

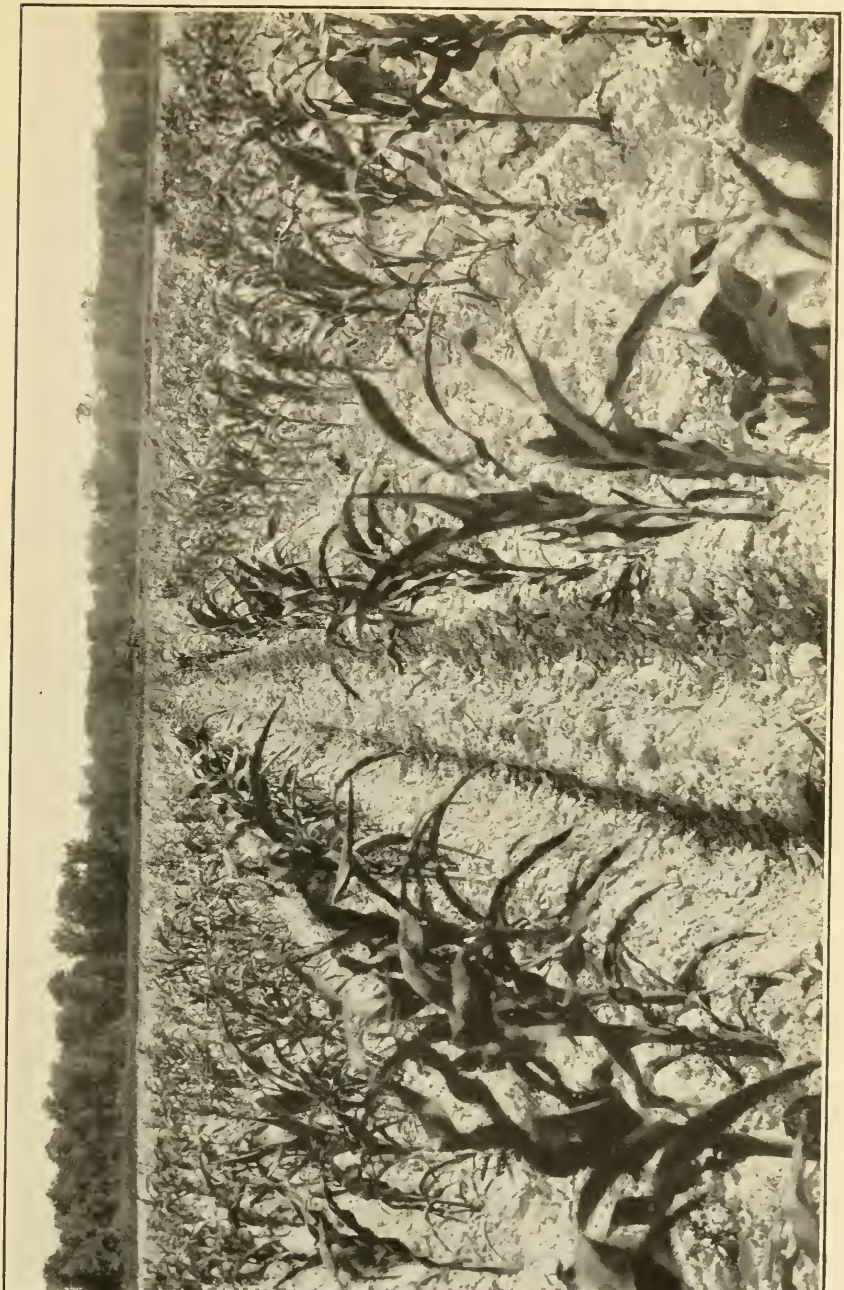
Mr. F. B. Hopkins observed, on June 26, also at the Arlington Farms, Va., that the larvæ were operating in the crown of this same plant, *Carex frankii*.

Mr. G. L. Swindell, in a communication dated August 6, 1900, states that at Swindell, N. C., the larvæ injured the roots of rice by



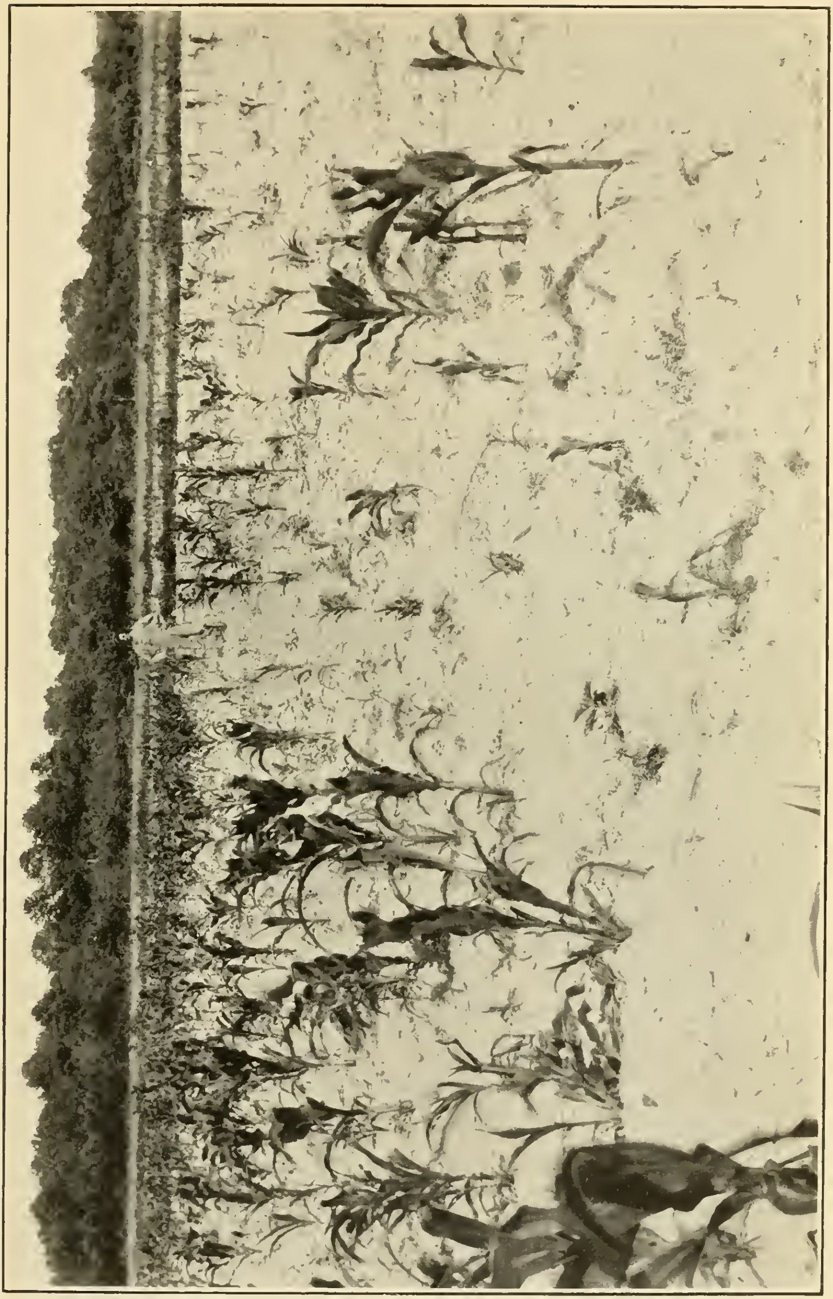
THE "CURLEW BUG."

The portion of the Shannonhouse cornfield, Hertford, N. C., on which corn was grown in 1910; totally destroyed by the "curlew bug" *Sphenophorus callosus*, in 1911. (Original.)



THE "CURLEW BUG."

The portion of the Shannonhouse cornfield that was devoted to cotton in 1910; planted to corn in 1911 and uninjured by the "curlew bug." (Original.)



THE "CURLEW BUG."

The dividing line in the Shannonhouse cornfield in 1911 between the portion (to the left of the man standing in the center) devoted to cotton in 1910 and the portion (to the right) where corn was grown in 1910. Note how exactly this corresponds, in point of damage by the "curlew bug," with the nature of the previous crop. (Original.)

feeding thereon. Later, roots sent to the bureau by Mr. Swindell contained larvæ in both the crowns and roots. In nearly every case there was a cavity containing a larva in the crown of the plant just above the roots.

Mr. S. L. Willard, Washington, N. C., under date of July 20, 1893, complained also of injury to rice, stating that the depredations had been observed in his neighborhood since 1886.

Under date of July, 1895, Mr. B. A. Hallet, of Mount Olive, N. C., complained that the insect had completely destroyed the upland rice crop of that section.

In August, 1910, Mr. J. W. Mason, of Edenton, N. C., through Representative J. H. Small, stated that the insect had attacked both corn and peanuts in his neighborhood, killing corn and seriously injuring peanuts.

Mr. R. I. Smith, of the North Carolina Agricultural Experiment Station, states that where rice is grown this grain appears to be its favorite food, as the insect is ten times more abundant in rice fields than in cornfields. The eggs are placed in the corn plant above the roots, as shown in figure 21, *b*. The larvæ work downward, eventually pupating at the lower end of the root, as shown in figure 21, *c*.

In nearly all of our records of injuries by this species, attention is called to the fact that its attacks are upon low or swampy land. The very nature of its food plants would indicate that the natural habitat of this species is in low or swampy lands. In a great many cases such lands are either subject to overflow or the plants are more or less submerged in water for considerable periods of time. While the insect is not aquatic, it most certainly is capable of living and developing on submerged plants without suffering material inconvenience therefrom. In the cornfields they are often found working several inches below the surface of soil thoroughly saturated with water. Farther on, it will be noted that the adult can also live submerged in water without apparent inconvenience.

INJURIES TO CORN BY LARVÆ.

While, as will be shown, corn is injured both by adults and larvæ, attacks by the latter are by far the most fatal to the plant. Good illustrations of a serious attack from a larva of this species are shown in Plates VI, VII, and VIII, from photographs of a field belonging to the Messrs. Shannonhouse, on Harveys Neck, N. C., along the shore of Albemarle Sound. While it is probably true that the insect is much more abundant in rice fields, it must be borne in mind that the area of rice culture is very small compared with that of corn. While local injuries to rice may be very severe, nevertheless the greatest losses from attacks of this insect most certainly fall upon corn growers, especially those whose fields are on low or bottom lands. As illustrating this point, as well as the severity of attack, Mr. Swindell, who has been previously quoted, stated that in some years the loss amounted to almost total destruction. Mr. R. I. Smith, under date of May 22, 1907, stated that the species was doing great damage to corn at Statesboro, Ga. Under date of May 30, 1899, Mr. Edward Markham, Kehukee, N. C., complained that the insect was doing so much damage to corn in his neighborhood that in some instances the crop was being abandoned. In his estimation it was the worst insect pest observed in his community. Under date of August 3, of the same year, Mr. James K. Metcalf, Silver City, N. Mex., complained that the insects were destroying entire fields of corn, working in this same manner. At Arkansas City, Kans., June 22, 1910, Mr. T. H. Parks, of this bureau, found the species exceedingly abundant in fields of young corn growing along the Arkansas River. Mr. T. J. Clark, sr., of Cliff, N. Mex., under date of June 25, 1904, states that the larvæ are more destructive than cutworms. In his opinion the species is a native of old Mexico and had not been observed in his locality until about eight years previous. Mr. T. D. Urbahns, of this bureau, found that corn about Duncan, Okla., during June 18 and 19, 1909, had suffered very severely. In one case about 20 acres of lowland in the heart of a large field had been entirely destroyed. It had been replanted, but the second planting was also badly damaged. In another field an area, also of about 20 acres, in the heart of a still larger field had been completely destroyed. This land was wet and had been flooded during the previous summer. In a field near Comanche, Okla., consisting of about 100 acres of bottom land, Mr. Urbahns found that the crop had been very severely damaged, some of it having been twice replanted. This land had also been flooded the previous year. A field of about 60 acres in this same neighborhood, examined June 19, had been entirely destroyed. At Great Bend, Kans., July 7, 1910, Mr. Parks found that a field of 6 acres of corn had been damaged about 20 per cent by these insects. Under date of May 17, 1909, Mr. J. F. Davidson, of Marlow, Okla., complained that the insect had completely destroyed 100 acres of young corn on his farm. Some of this ground had been replanted a third time, with discouraging prospects of his being able to secure a crop of corn. He further states:

> My land is all bottom and valley and adjacent to Little Beaver Creek, a stream 50 feet wide. The heavy floods of last spring caused this creek to overflow its banks and the water spread out over all the bottom land, inundating thousands of acres and destroying the growing crops; 40 acres of my land was thus under water seven different times. I assume the result is the billbug and its depredations this spring on all bottom lands, which are the best corn lands in this section of Oklahoma. Thousands of acres have already been completely destroyed by this pest, and farmers are now busy replanting, with slight hopes of securing a stand that will justify cultivation.

The larva on first hatching is, of course, very small, although, as the eggs increase in size after being deposited in the plants, the size of the larva will considerably exceed that of the newly deposited egg.

It burrows its way downward through the center of the lower stem into the main root or taproot and, unless this is entirely eaten away, probably finishes its development there. Although we have not observed it, it seems quite likely that under certain conditions it may transform to the pupa in the earth outside of the plant.

Studies carried out by Mr. Kelly at Wellington, Kans., have shown that the larval stage may occupy from 37 to 41 days—the latter period in most of his experiences.

THE PUPA.

(Fig. 20.)

Pupation in the crowns of chufa takes place normally in cocoons formed of dried castings, but in cases where the crowns have been much eaten away, the larva before transforming evidently falls out and pupates in the earth nearby, generally within an inch or less of the crown. In the earth a cell is made by the larva, which turns round and round, thus forming quite a distinct earthen cocoon. In one instance noted by Mr. Caudell, a pupal case or cocoon was found on chufa about 2 inches above the ground, indicating that the larva had floated to the surface of the water, the plants being submerged at the time.

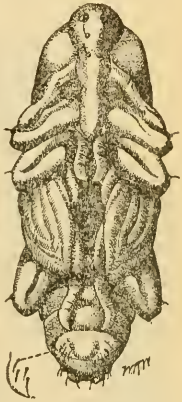


FIG. 20.—The "curlew bug:" Pupa. Greatly enlarged. (Original.)

In corn plants pupation takes place in the larval chambers as shown in figure 21, *c*.

A larva noted by Chittenden transformed to pupa August 22, and the beetles issued September 1, the period of the pupal stage having been about 9½ days. As the weather during this time was considerably over 80° F., and quite humid, 9 days is probably the minimum pupal period for this species.

Of a number reared by Mr. Kelly at Wellington, Kans., during August, 1910, one pupated in 9 days, while three others pupated in 13 days.

THE ADULT.

(Fig. 16.)

This species was first described by Olivier in 1807.[1] In his paper entitled "New species of Sphenophorus with notes on described forms,"[2] Dr. Chittenden has fully discussed this species as follows:

This species was united by LeConte[3] and Horn with *cariosus* Ol., but wrongly so, as I shall attempt to prove. Olivier's description reads in substance as follows:

Body black with dark cinereous coating. Antennae brownish black, shining, cinereous at apex. Rostrum black, dark cinereous at base. Thorax uneven, "and

[1] Calandra callosa Olivier, Hist. Nat. des Ins., vol. 5, p. 92, pl. 28, fig. 416, 1807.
[2] Proc. Ent. Soc. Wash., vol. 7, No. 4, pp. 176–177, Mar. 9, 1906.
[3] Rhynch. N. A., p. 425.

one sees on the superior portion an elevation in the form of a cross, feebly marked." Elytra uneven, feebly variolate, marked toward the apex with a callous point, nearly spinose, blackish, shining.

Olivier's illustration is imperfect in that it is very crude, showing neither punctuation nor sculpture and the general impression is that of a shining species, which was certainly not intended. The thorax is a little short, otherwise the form coincides with the species which is figured herewith.

The cinereous base of the rostrum is an important character, as it signifies that a considerable portion of the base is coated while in *cariosus* it is not. The cross-like elevation of the thoracic disc is aptly described as feebly indicated, in fact it requires a little imagination to discern it in many individuals; moreover, it is not shown in Olivier's figure.

Among coleopterists in general the adults of this species are supposed to be covered by a coating, consequent upon the beetles coming in contact with the soil. This supposition is most certainly erroneous, as adults secured by Dr. Chittenden from cocoons and by others of the bureau from the chambers in the roots of corn before they had come in contact with anything excepting the débris with which the chambers are more or less filled, are found to possess this coating.

Specimens secured by Dr. Chittenden are of a rich brown color with velvety surface. It is only when the beetles become somewhat abraded and this coating worn off of the elevations and the shoulders and near the tip of the elytra that the callouses are formed, a character upon which the specific named is based. Strictly speaking, the perfect insect has not been described, and it does not become "*callosus*" until the insect has moved about and rubbed these points bare.

The adults evidently hibernate to some extent in corn in the chamber in which they have developed, but seemingly lower down than in the case of *Sphenophorus maidis*. (See fig. 21, *c*.) They were found very sparingly, by Mr. James A. Hyslop of this bureau and by Mr. R. I. Smith, of the North Carolina Agricultural Experiment Station, occupying this position in the cornfields of Harveys Neck, previously mentioned, on November 1, 1911. The numbers found, however, were far too limited to indicate that this can be true of even the majority, the others probably wintering over either in or near the surface of the ground. This was in the same field where Mr. Walton had fruitlessly searched for them on September 5 and 6.

When we come to take into consideration the fact that the natural coating with which the adults are covered is almost exactly the color of the soil, with which it is, indeed, more or less begrimed, and that the insects on being disturbed will draw up their legs and remain as quiet as if dead, it will be seen that it is exceedingly difficult to detect their presence in or on the surface of the ground, even by an expert who knows exactly for what he is searching. Therefore that careful search should not happen to reveal their presence is not especially to the discredit of those who are engaged in trying to find them.

As will be observed, this method of hibernation is of the greatest importance from an economic standpoint, because hibernation in the lower stalk or roots would bring the inhabitants within reach by pulling up and burning these stalks during the winter or early spring. For data on the larger corn stalk-borer see Circular No. 116 of the Bureau of Entomology, entitled "The Larger Corn Stalk-Borer."

The beetles probably come forth from their hibernation quarters quite early in spring, as soon as the ground has become permanently warm from the spring temperature. Mr. Kelly found them under cornstalks of the previous year at Whitesboro, Tex., April 13, 1910. They evidently feed for a considerable time by puncturing the lower part of the stems of the plants. These punctures are quite different from the egg punctures, and the effect is often not so fatal as that occasioned by the downward burrowing of the larva. These punctures are usually made about or a little below the surface of the ground, the beetle evidently searching for a point where the stem is tender and succulent.

FIG. 21.—The "curlew bug:" *a*, Corn plant attacked by adult insect; *b*, egg as placed in stem of young corn plant, enlarged at left; *c*, pupa and adult in root of corn in chamber eaten out by the larva, slightly reduced. (Original.)

If the punctures are made lower down on the plant, just above the root, the result is a throwing up of a number of tillers or suckers from the roots, the main stem itself having a stalky appearance, with the result that no ears are produced. In this respect the effect produced resembles to a degree that of an attack of the Hessian fly on a young wheat plant in the fall. This unusual development of tillers or suckers has sometimes been vulgarly termed "frenching," although it must not be understood that all of the difficulties known as "frenching" in corn have been due to the attack of these beetles.

If the puncture made by the beetle for the purpose of securing food has been made higher up the stem, food has been obtained from the unfolded leaves above the crown of the plant. When these leaves finally push forth, the puncture made by the beak of the beetle appears in the shape of transverse rows across the leaves, as illustrated in figure 21, at *a*. Frequently there will be a distorted growth on the stem, having much the appearance of galls or excrescences, as shown also in this figure.

While the damage done by the beetles in feeding is in many cases doubtless severe—if the corn plants are very young at the time of attack they are probably destroyed in this way—generally speaking the greatest damage is probably caused by the larvæ, especially in the East.

Attention has already been called to the fact that the larvæ can apparently live without difficulty for a considerable length of time in the stems of plants that are completely covered by water. This is surprisingly true in the case of the adult insect.

August 4, 1906, Dr. Chittenden collected adults of this species at Arlington, Va., and placed them in a jar of water with a few stalks of grass and chufa. The beetles attached themselves to these stalks under water and remained there. Two of the beetles were removed November 21 of the same year, and although they had been submerged during the entire period they were still "very much alive." Another instance has come to our notice which would indicate that not only can these beetles survive in fresh water, but also in salt water.

Mr. James Overton, a farmer and fisherman residing on the north shore of Albemarle Sound, informed the author that this species was frequently found by him clinging to his fish nets set in the water of the Sound, and that he found them abundantly under the débris along the shore. As Mr. Overton is perfectly familiar with the work of the insect in the cornfields, and was one of the first in his neighborhood to recognize it, there does not appear to be any reasonable doubt of the correctness of his statement. Indeed, farmers living on Harveys Neck are of the opinion that the pest first came to them from the South, having drifted across the Sound from the opposite shore. Mr. Overton, who resided on the southern shores of the Sound before taking up his residence on Harveys Neck, states that the insect was destructively abundant along the southern shore before it was observed in his present neighborhood. Whether this theory of the diffusion of the pest is correct or not, there does not appear to be any good reason why the insect might not drift about in the waters of the

Sound and be carried ashore by the tides. In at least two cases, each involving a different species of Sphenophorus, adults have been found along the sea beach in situations where they must have been submerged at each flow of the tide.

The length of life in the beetle stage is not definitely known, but Dr. Chittenden has observed overwintered adults as late as August 8, thus overlapping the appearance of the new generation of adults.

INJURY BY THE BEETLES.

It is rather difficult to separate out, in the correspondence of the bureau, injuries that have been caused by the adults, or beetles, of this species from those inflicted by the larvæ. That the larvæ are eminently capable of totally destroying young corn is very evident, but the following extract points more or less conclusively to the beetles themselves as being the authors of the injuries inflicted.

Mr. C. R. S. Baker, Rimini, S. C., June 26, 1909, in a communication to the Bureau of Statistics, stated that the beetles were killing young corn by puncturing the stalk to the heart, killing the plant precisely as with the "budworm." This particular field had been highly fertilized with guano and stable manure. Maj. Gore, of Pireway, N. C., May 12, 1910, stated that 30 acres of corn planted on new land had been literally eaten up by the beetles; presumably the new land was either very low or reclaimed swamp. Under date of May 21, 1910, Mr. W. Barnett, of Pireway, N. C., stated that a farmer in his neighborhood had lost half of his crop of corn from attacks of this beetle. Writing from Helena, Ark., June 2, 1911, Mr. L. E. Howard stated that these beetles were killing the corn, mostly young corn, but some as large as waist-high. Writing from McLellan, Fla., May 2, 1909, Mr. W. H. Gill stated that the pest had just made its appearance in Santa Rosa County and attacked young corn about a month old by boring in the stalk underground and killing the center. On June 1, 1910, a complaint was received from Mr. P. Cox, Appleton, Tenn., inclosing specimens of the beetle which he stated were destroying his corn crop and asked for an investigation of the trouble. July 14, Mr. G. G. Ainslie visited the locality and found that Mr. Cox's field consisted of about 40 acres lying in a creek bottom. Farther down the stream were two other fields of corn all of which had been damaged. It seems to be the plan in that particular locality to allow the land to go uncultivated every alternate year. During the season in which the land is idle there springs up a heavy growth of weeds and swamp grass. This particular field was plowed the latter part of March and replowed the last day of April, corn being planted soon after. The first planting came up quickly, but was utterly destroyed. The second planting, the date of which was not obtained, was also practically destroyed, and a little before the middle of June a third planting was made. On the lower depressions of the field (see Pl. IX, fig. 1), termed "swales" in that neighborhood, the corn from this planting was either small or missing, the size of the stalks being very irregular. In most cases the main stalk was aborted and suckers had been thrown up, sometimes a distance of several inches from the original plant. The main stalk was either missing altogether or had become so dwarfed and distorted as to be practically worthless. (See Pl. IX, fig. 2.) It lies prostrate on the ground, curled and twisted, being sometimes almost buried in the loose earth, and the beetles were still found attacking the plants.

RECENT INVESTIGATIONS OF THE BUREAU OF ENTOMOLOGY.

Reference has already been made in the proper places to the investigations carried out in Kansas, Oklahoma, and Texas by Messrs. Kelly, Urbahns, and Parks, of the Bureau of Entomology, and in North Carolina by Mr. James A. Hyslop, also an assistant in the bureau. On May 23, 1911, we received a communication from Mrs. S. D. Jordan, Hertford, N. C., accompanied by specimens of these beetles, stating that the insects take possession of and destroy whole fields of corn as soon as it comes up. Many farmers had been obliged that season to plow and plant their corn for the second time. The insects attack the plants by inserting their bill into the stalk near the ground, causing the plants to wilt in a few hours. The trouble had been noticed for several years and appeared to be rapidly on the increase. Apparently, unless some steps were taken for their protection, the farmers in that neighborhood would not be able to raise sufficient corn for their own use. Two days later a communication was received from Mr. William T. Shannonhouse, from the same post office, accompanied by specimens of the bettles. Mr. Shannonhouse complained that these insects attacked the corn from the time it was 3 or 4 inches high until it became 10 inches or a foot in height. Then they were found just below the surface of the ground puncturing the stalk, causing the death of the plant. Mr. Shannonhouse called attention to the fact that where corn had followed cotton crops no damage was apparent, but where the preceding crop had been corn the damage was in many cases very severe, often resulting in a total loss of the crop. In cases where the land had been planted to corn in alternate years, and during the intervening years to some other crop, no difficulty was experienced. The author, together with Mr. Vernon King, visited these fields in company with Mr. Shannonhouse on June 20 and made a careful examination of them. It was found that where cotton had been the previous crop, attack by Sphenophorus was hardly noticeable. Larvæ were abundant, ranging from newly hatched to half-grown, while eggs were being deposited on both small, tender plants, and on larger, more mature

FIG. 1.—VIEW OF CORNFIELD NEAR APPLETON, TENN., SHOWING DAMAGE BY THE "CURLEW BUG." (ORIGINAL.)

FIG. 2.—CORN PLANTS, SHOWING NORMAL PLANT AND THOSE DAMAGED BY THE "CURLEW BUG." (ORIGINAL.)

THE "CURLEW BUG."

ones. From one to several eggs were laid on each plant, either just beneath the surface of the soil, slightly above the roots, or from 2 to 3 inches above this point in the stem. Beetles usually rest on stems head downward, often partially hidden by soil around the plant, and frequently with the beak inserted into the tissues of the stem. At the bottom of slits made by the beak, and easily seen with the naked eye, there is often a white, elliptical egg, sometimes with one end transparent. Both males and females were common. On June 22, about 3 miles away across the Perquimans River, on the farm of Mr. R. L. Spivey, Mr. King observed the same work in a small patch of corn planted on spring-plowed land which bore corn the year before. Near Mr. Spivey's farm injury was also done to 3 or 4 acres of corn on the farm of Mr. J. T. Jackson, whose land also bore corn the year before. At this time only a few large plants of the first crop were standing. The land had been replanted, but only sickly plants were produced, as these had been attacked by Sphenophorus and by *Diatræa* sp., the latter of which is locally known as the "budworm." An adjoining patch of corn, planted on soil which bore corn last year, but cut early and the land fall-plowed, was seemingly growing.

On July 25 Mr. W. R. Walton visited the same locality and, in the same fields previously examined by Mr. King and the author, found larvæ, apparently nearly full grown, in the taproots and crowns of the plants. Although no longer feeding, they had not yet transformed to pupæ, nor were they yet in cells formed for pupation. Some of the less seriously injured stalks of corn were from 6 to 8 feet high, with one well-developed ear. No grasses or sedges in which the insect could develop could be found in the neighborhood, although Mr. Walton was told by Mr. Overton that masses of both of these plants, with heavy root-stalks, sometimes drift across Albemarle Sound from the South. Farmers in that neighborhood say the pest began its depredations along the north shore, and express the opinion that the pest came from the South. Later, September 5 and 6, Mr. Walton again visited the same locality to learn the condition of the pest, but although he examined and pulled up about 100 stalks of corn where the pest had been abundant earlier in the season, he could find no trace of it in any stage.

REMEDIAL AND PREVENTIVE MEASURES.

With these insects in full possession of a field, there does not appear to be any thoroughly practical and effective measure for preventing or overcoming their ravages. While throwing up the soil or hilling up the young plants with the cultivator might prevent the beetles themselves from puncturing the stems low enough down to cause the plants to sucker or become distorted, this is by no means assured.

We only know that the higher up the insect punctures the stem the more likely is the attack to result only in the transverse rows of holes across the leaves, as shown in figure 21 at *a*. In any case this ridging or hilling up would only form a possible slight protection against the injurious effects of the feeding of the beetles. Once the larvæ have started to burrow their way downward in the stem there is no way whereby they can be reached by any measure likely to seriously affect them. The beetles can not be trapped by inducing them to hibernate under piles of rubbish prepared for them especially for this purpose, because there is excellent proof that they pass the winter in fields entirely bare of vegetation. Late planting of the crop, as exemplified by repeated replantings, does not offer any encouragement in the way of preventing future injuries. As shown by the observations of Messrs. Walton and Hyslop, very few of the insects hibernate in the roots or old stalks, so that the pulling up and burning of these, as in destroying the larger corn stalk-borer, would not be of much value against this insect. They probably do not hibernate to any extent in their uncultivated food plants.

Fortunately, however, the farmer has within his reach two most practical and efficient measures of prevention. One of these is to entirely exterminate from his fields any of the natural food plants of this species. Indeed, he should by no means attempt to raise a crop of corn while any of this natural vegetation, upon which the insect can subsist, is still in existence. The other measure is to follow corn or rice with some crop upon which this insect can not feed and never to plant corn immediately after corn or rice. On the farms of the Messrs. Shannonhouse most convincing illustrations were afforded of almost complete protection by rotation of crops. While in no case was it possible to find a badly infested field of corn following cotton, there were plenty of illustrations of the disastrous effect of attempting to raise corn during successive years on the same ground.

One field offered such an excellent illustration of this phase of the problem that Mr. William T. Shannonhouse had it photographed, and these photographs are used for illustration in Plates VI to VIII. In 1910 the eastern portion of this field had been devoted to cotton, the western portion to corn. In the year 1911 the entire field was planted with corn; as a result that portion on which corn had been raised the previous year (see Pl. VI) was almost totally destroyed by this insect, while the other portion, where cotton had been grown (see Pl. VII), was almost entirely exempt from attack. In order to show the abruptness with which this injury terminated and the exactness with which this corresponded to the dividing line between the two previous crops, the farmer who had himself cultivated the field in 1910, and was therefore perfectly familiar with it, was induced to stand exactly upon the dividing line between the corn and the cotton. Plate VIII shows the area where this dividing line between the two crops of the previous year was located and the radical difference in attack by Sphenophorus between the two portions of the field. This field illustrates conclusively both the fact that the beetles winter in the fields where they develop and also that crop rotation is effective in preventing serious injury.

NATURAL ENEMIES.

Mr. W. L. McAtee, of the Biological Survey, has recorded the finding of *Sphenophorus callosus* in the stomach of the nighthawk (*Chordeiles acutipennis texensis*) at Wallaceville, Tex., August 4, 1907. This is the only exact record obtainable of the eating of this species by birds. In addition Dr. Chittenden has placed the following notes at the disposal of the author:

> Among the larvæ of this species in our rearing cages in late August and early September some years ago were some which had died, apparently of fungus attack, although there is a possibility that the fungus attacked the insect while dying or after death.
>
> In another instance, during the last week of August, larvæ of this same species were dying and specimens were referred to Dr. Haven Metcalf, a pathologist in the Bureau of Plant Industry, who stated that they were apparently free from fungi, and that while there was a possibility of the presence of a bacterial disease such presence could not be established at that stage. Examination, however, revealed the fact that the bodies of the larvæ were fairly reeking with nematodes, and it is not impossible that these are the cause of the insect's fatality.

On September 5 and 6 Mr. Walton found, in cornfields in North Carolina where the corn had been destroyed (see Pl. VIII), many exit holes of the predaceous maggots of a robber fly, *Erax lateralis*, between the rows of corn, and it is possible that these may have devoured some of the larvæ of Sphenophorus. Lamphyrid larvæ were noted, both by the author and by Messrs. King and Walton, about the infested hills of corn. Although these are known to be predaceous, none of us was able to catch them in the act of devouring the larvæ of the curlew bug.

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE FALSE WIREWORMS OF THE PACIFIC NORTHWEST.

BY

JAMES A. HYSLOP,

Agent and Expert, Cereal and Forage Insect Investigations.

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By JAMES A. HYSLOP,
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INTRODUCTION.

Up to within the past five years, except for a few scattering notices, the species of Eleodes have been considered of only incidental, if of any, economic importance. The Tenebrionidæ, to which this genus belongs, are sometimes saprophagous, feeding on dead vegetable matter in the soil, and occasionally on dead animal tissue as well as on stored grain and other food products.

Superficially the larvæ resemble the true wireworms (elaterid larvæ), and on account of this resemblance and the similarity of their

FIG. 22.—The false wireworm, *Eleodes letcheri vandykei:* Adults in characteristic attitudes. Somewhat enlarged. (Original.)

depredations in the grain fields the two are often confused. On closer examination, however, Eleodes larvæ can be easily recognized; the antennæ are rather long and very conspicuously clavate, the body is not flattened, and the forelegs are long and stout. These larvæ can move with great rapidity as compared with true wireworms

The confusion of Eleodes with the true wireworms is unfortunate, as the preventive and remedial measures for the two pests are quite distinct, what is efficient treatment in one case being quite useless in the other.

HISTORICAL.

Among the earliest references to the economic importance of these beetles in this country is a note by Prof. Lawrence Bruner,[1] in which the species *Eleodes tricostata* Say is recorded as attacking cabbage

[1] Bul. 26 (old series), Div. Ent., U. S. Dept. Agr., pp. 11-12, 1892.

plants at Lincoln, Nebr., doing even more damage than the cutworms. It was also said to have attacked other garden crops, but these are not definitely recorded.

In 1895 Prof. C. V. Piper published an article in the Northwest Horticulturalist in which he refers to Eleodes larvæ attacking garden crops.

In 1898 Mr. Theo. Pergande[1] notes having received from McPherson, Kans., two larvæ of a tenebrionid with the statement that they do serious damage to wheat in Salina County, Kans., by attacking the grain when it becomes softened, destroying the germ. From one of these larvæ an adult was reared which proved to be *Eleodes suturalis* Say. In the autumn of 1911 Mr. E. O. G. Kelly, of this office, found the wheat in southern Kansas attacked by an Eleodes larva which may prove to belong to this latter species.

In 1908 Mr. Myron Swenk,[2] assistant State entomologist of Nebraska, reported *Eleodes opaca* Say as doing very serious damage to wheat in Nebraska, in some instances 60 per cent of the seed having been destroyed.

The larvæ were first found by the author in enormous numbers in May, 1909, in a wheat field south of Pullman, Wash. The field was entirely ruined and had to be reseeded, though these depredations were not entirely due to the Eleodes, as a true wireworm, the larvæ of *Corymbites inflatus* Say, was also very numerous.

On May 12 several adult *Eleodes pimelioides* Mann. were found at a depth of about 4 inches below the surface in the field above mentioned, and more were found under boards and rubbish about the fields. Many larvæ were placed in flowerpot rearing cages with wheat as food, and on July 3 a pupa was found in one of these cages. On July 20 an adult *Eleodes pimelioides* emerged. Later examination of several collections very clearly indicates that this species is far the more predominant in the Palouse country.

Other species known to occur in this region are *Eleodes obscura* Say var. *sulcipennis* Mann., *Eleodes hispilabris* Say var. *lævis* Blaisd., *Eleodes extricata* Say, *Eleodes manni* Blaisd., *Eleodes humeralis* Lec., *Eleodes schwarzii* Blaisd., and *Eleodes nigrina* Lec.

In the spring of 1909, on examining an oat field at Govan, Wash., that had been almost completely destroyed, many tenebrionid larvæ, *Eleodes letcheri* Blaisd. var. *vandykei* Blaisd., were found crawling over the surface of the field. They had evidently been forced to leave the ground by a heavy rain which fell the day before. On digging in this field many more larvæ were found about ready to pupate.

In the spring of 1910 the adults were found in enormous numbers on the roadsides in the Big Bend region and in the middle of the

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[1] Bureau of Entomology Notes, No. 8186.

[2] Journ. Econ. Ent., vol. 2, p. 332, 1909.

summer they were found under the grain shocks in large numbers. In this region the species in enormous preponderance is *Eleodes letcheri vandykei*. *Eleodes pimelioides*, *Eleodes nigrina*, *Eleodes hispilabris* var. *lævis*, and *Eleodes obscura* var. *sulcipennis* also occur; the first one rarely, the last three quite commonly.

The results of three seasons' work in the Pacific Northwest demonstrate quite conclusively that the false wireworms are among the most destructive insects to recently planted wheat and corn in this region. They rank second only to the true wireworms (elaterid larvæ).

False wireworms are native and not introduced forms; the climatic conditions of the country are, therefore, ideal for their existence. The converting of enormous areas of the scantily verdured sagebrush prairie into wheat ranches has afforded them a new and increased food supply and the destruction of the sage hen, badger, and horned toad has removed their normal foes.

DISTRIBUTION.

The genus Eleodes, to which the beetles treated in this paper belong, is very closely confined to the Upper and Lower Sonoran Zones. These beetles do not fly and are therefore more restricted in their distribution than insects which have a more active means of dissemination. The mass of the species occur in the Southwest, while several occur in the arid and semiarid regions of California, Oregon, Washington, and Idaho. A few species extend into the Carolinian Zone in Kansas, Nebraska, and Iowa, *Eleodes tricostata* having been collected as far east as Independence, Iowa.

Eleodes pimelioides, however, seems to be an exception to this general rule, and is very nearly confined to the northwestern portion of the Transition Zone, only occasionally being found in the Sonoran where this zone merges into the Transition. Specimens have been collected in the very humid coastal region of Washington, as well as in semiarid regions of this State, of Idaho, and of Oregon; in the Rocky Mountains at Helena, Mont., as well as at very nearly sea level on Vancouver Island. The species is predominant in the semiarid Transition of Washington and Idaho, the region commonly known as the Palouse country. The southernmost records of this species are Lake County, Cal.; Elko, Nev.; Wasatch, Utah; and Garland, Colo. It extends east to the middle of Colorado and north to Vancouver, British Columbia.

Eleodes letcheri vandykei has been collected at The Dalles, Oreg., by Messrs. Hubbard and Schwarz. Dr. E. C. Van Dyke has taken this species in Modoc County, Cal., and we have found it to be the predominant species in the Big Bend region of Washington. All of these localities are well within the Upper Sonoran Zone.

Eleodes opaca is apparently confined to the Plains region east of the Rocky Mountains, specimens having been collected in central and eastern Colorado, western Kansas and Oklahoma, northern Texas, all of Nebraska, and southern and eastern South Dakota.

Eleodes suturalis occurs over about the same region as *E. opaca*, with its variety *texana* Lec. extending southward into New Mexico and southern Texas.

THE WORK IN THE BIG BEND REGION OF WASHINGTON.

On May 28, 1909, an oat field at Govan, Wash., was examined. This field had been almost completely destroyed by true wireworms; besides these, many larvæ of *Eleodes letcheri vandykei* were found on the surface of the ground, evidently forced out by the unusually late heavy rains of the preceding day. These latter were by far too few in numbers to have destroyed the oats. Bluebirds (*Sialia mexicana occidentalis*) were noticed feeding in the fields in large numbers on the exposed Eleodes larvæ. Many of the larvæ were also found in the ground at a depth of from 3 to 5 inches, in small spherical cells, wherein they lay in a curled position. These were considerably softer and paler colored than those found in an active condition.

The work in 1910 started early in April when the false wireworms were to be found scatteringly throughout the grain fields, the grain having just sprouted.

Adults were first observed in 1911 on April 17, the day being quite hot, but the weather up to this time having been very cool. The beetles were to be seen at about 3 o'clock in the afternoon in great numbers along all the roadsides, where they were either awkwardly hurrying over the ground or nibbling at the foliage of the very young *Polygonum littorale*, which is very abundant in this region.

Adults of the larger species, *Eleodes obscura sulcipennis*, were usually to be found in or about the burrows of the ground squirrel (*Citellus townsendi*) and the badger.

When disturbed, the species of Eleodes have the ludicrous habit of standing still and elevating the abdomen so that the long axis of the body approaches the perpendicular instead of the nearly horizontal position it normally maintains while walking or at rest. The two beetles to the right in figure 22 are in this attitude. Thus they will remain motionless for several minutes and finally, if they are not further disturbed, they walk off. If one places the finger near the insect, an oily liquid is excreted from the anal aperture, which flows down over the elytra and abdomen. This liquid is pale yellow in color and makes a dark-brown stain; it has a very characteristic, strong, astringent, and offensive odor, and is evidently protective in function. Mr. Carl F. Gissler[1] describes this secretion and the glands from which it is secreted.

Many pairs were in coitu on the 17th of April, and on the 21st a female that was confined in a pill box laid four eggs. Between the 21st and 23d, when the female died, she laid 10 more eggs, which, however, failed to incubate. Females dissected in the laboratory were found to contain from 92 to 199 eggs. The eggs were found to lie on the ventral side of the abdomen and to extend upward and over part of the viscera, filling all the interstices about the alimentary canal. The eggs were so crowded in the abdomen that they were quite distorted. Anteriorly the eggs were smaller and were fastened to the anterior abdominal sclerite by fine filaments.

The mating season lasted about two weeks, but the adults were in evidence throughout May and June. Well-grown larvæ were also to be found at this time. Many of the adults in the rearing cages, as well as two individuals observed in the field, were seen to burrow into the ground. This is accomplished by digging with the front tibiæ, which are expanded and armed with spines for the purpose, the tarsi being folded back out of the way. The loose dirt is conveyed backward by the middle legs and piled up behind the beetle by the hind legs. When about one-fourth of an inch of dirt has accumulated the beetle backs out of the hole, pushing the earth out with the abdomen, the hind legs assisting in this process by keeping the earth piled behind the abdomen. On examining these burrows two or three eggs were found in each. The burrows are filled with earth after the beetles come out and are from 4 to 8 inches deep.

Rearing cages were established by sinking barrels to the surface level, filling them with earth, and fitting vertically onto the top a galvanized-iron cylinder 10 inches in height and the diameter of the inside of the barrel top, the open upper end being covered with wire mosquito bar, with an introduction hole made in the wire screen and corked.

On April 20 about 30 pairs of mated *Eleodes letcheri vandykei* were placed in this cage, which had previously been seeded with wheat and planted to *Polygonum littorale*.

By June 25 the beetles were all dead in the cage, probably due to abnormal conditions as well as age, though no living beetles could be found in the fields at that time. Small larvæ 4 to 5 mm. (about three-sixteenths inch) in length were then to be found in the cage.

On examining the cage on November 14 the larvæ were found to be about 14 mm. (nine-sixteenths inch) in length and at about a depth of 12 to 24 inches below the surface. The soil in the rearing cage was as dry as powder to a depth of nearly 2 feet, but the desiccation did not seem to affect the larvæ.

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[1] Psyche, vol. 2, no. 58, 1879, p. 209.

July 4, 1911, the cage was again examined and the larvæ were found to be about 1¼ inches long. From early in July to the middle of August it became necessary to be away from Govan, where this experiment was in progress. On returning, August 16, the root cage was examined and two adults found about 6 inches below the surface. They were hard and had evidently emerged some days before this date. When the boards which had been placed over the barrel to protect it during the winter were removed in the spring, a number of adults was found that had hibernated under this shelter. On the above date and at a depth of about 20 inches a very young false wireworm (3.5 mm. long) was found; it was pure white and had evidently but very recently hatched. This larva was undoubtedly the young of one of these accidentally introduced beetles.

The soil at this time was dry to a depth of 4 inches. On June 25 a pupa was found in the field, placed in a pill box with dirt, and on the 30th an adult *Eleodes letcheri vandykei* emerged. In the fields, where a farmer was plowing his summer-fallow—and it may be remarked that this is exceptionally late for working the summer-fallow in this country—pupæ were found turned out by the plow. A little flock of Brewer's blackbirds (*Euphagus cyanocephalus*) were walking in the furrow a few yards behind the plow and picking up the upturned insects.

From the middle of July until the grain is harvested adults are to be found in large numbers under the grain shocks and bundles as they stand in the field, and also under grain sacks. Most of the beetles are quite soft early in the season, but later become hard.

DESCRIPTIONS.

Eleodes letcheri vandykei Blaisd.

The egg (fig. 23).—The egg is bluntly oval in longitudinal section and circular in cross section; it measures 1.1 mm. in length and 0.62 mm. in diameter; it is of a pure glistening white color and absolutely without sculpturing. Ovarian eggs measured 1.17 mm. in length and 0.74 mm. in diameter.

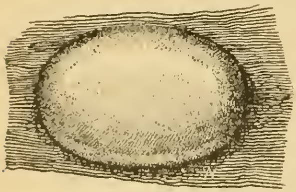

FIG. 23.—False wireworm, *Eleodes letcheri vandykei:* Egg. Greatly enlarged. (Original.)

The larva (fig. 24).—Elongate, subcylindrical, convex dorsally, flattened ventrally. Yellowish, ventral surface paler, anterior and posterior margins of first thoracic and posterior margins of succeeding segments brown; head slightly brown, edge of mandibles black, base of mandibles brown; claws, spines on legs, and caudal segment dark brown; antennæ pale yellow. Anterior and posterior margins of first and posterior margins of succeeding segments with striate marginal bands; band on anterior margin of first segment broader and more coarsely striate. Caudal segment scutelliform, flattened dorsally and convex ventrally, bearing 18 stout spines on its margin—4 on each lateral margin and 10 on terminal margin; a slight space equal to that occupied by one spine separates the lateral from the terminal spines. Several long hairs and a basal row of short hairs on caudal segment. Head subquadrate, very convex, distance from base to labrum equal to one-half width of head, sides converging anteriorly, posterior angles rounded; two stout hairs on lateral dorsal surface; two oblong black eye-spots on lateral anterior part, a large one at base of antennæ, and a smaller one posterior and dorsad of this. Suture arising at base of each mandible flexed laterally and converging posteriorly to unite with the median suture at a distance from base of head equal to one-fourth distance from base to labrum; mouthparts usually directed ventrally. Labrum large, basal joint trapeziform, terminal joint rounded, bearing several hairs on margin, both joints margined anteriorly. Mandibles large, visible from above. Labium not covering mandibles, ligula broader than palpifer; labial palpi cylindrical, two-jointed, second joint papilliform; mentum larger than palpifer, submentum larger than mentum, all quadrangular and narrower at base than at anterior margin. Maxillæ larger than labium, stipes directed laterally, palpifer elongate and directed antero-medially; maxillary palpi at about middle of palpifer, three-jointed, first and second joints about equal in length, first stouter, third papilliform. Thoracic legs stout; first pair longer than width of thorax, second and third pairs one-third shorter; first pair very heavy, terminal hook as long as fourth joint, second joint bearing 2 stout short spines on inner distal margin, third joint bearing 3 marginal spines and fourth joint bearing 4 such spines.

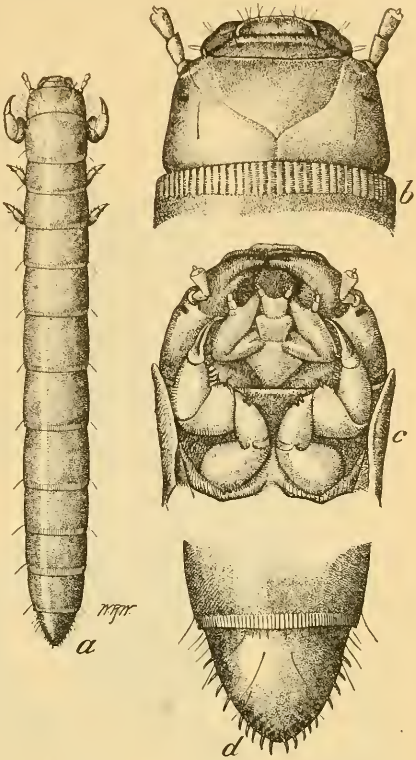

FIG. 24.—False wireworm, *Eleodes letcheri vandykei*. *a*, Larva, dorsal aspect; *b*, head, dorsal aspect; *c*, head, ventral aspect; *d*, caudal segment, dorsal aspect. *a*, Much enlarged; *b*, *c*, *d*, more enlarged. (Original.)

The pupa (fig. 25).—Length 11 mm., width 5.3 mm., arcuate dorsally, flattened to slightly concave ventrally. Entirely white when first pupated but eyes soon become black followed by tips of mandibles; just prior to emerging the elytra and dorsum of thorax become black. Head pressed to the prosternum. Pronotum very broad and protruding anterior to the head, making the latter invisible from above. Mesonotum very narrow and scutelliform, with indistinct transverse sulcus slightly anterior to middle. Metanotum sagittiform, about as broad at anterior margin as mesonotum. At the base of each elytron and of each secondary wing pad is a rounded swelling. Seven abdominal plates visible dorsally. Between dorsal and pleural abdominal

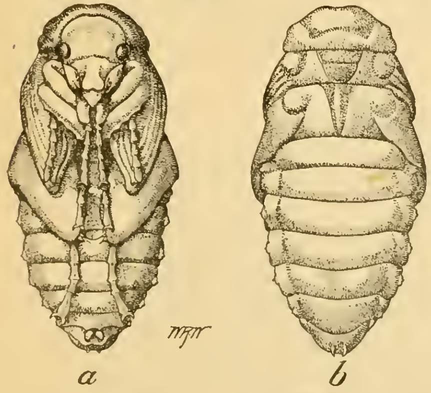

FIG. 25.—False wireworm, *Eleodes letcheri vandykei*: *a*, Pupa, ventral aspect; *b*, same, dorsal aspect. Much enlarged. (Original.)

plates is a distinct depression forming a submarginal groove. The caudal segment bears a pair of posteriorly directed spines near posterior margin dorsally and a pair of median anal lobes ventrally. Head, legs, and antennæ free. Antennæ passing behind first and second pairs of legs and over wing pads. Elytra folded ventrally over the posterior legs. Eyes conspicuous. Pleural margin of abdominal segments bearing mammiform tubercles. Body without hairs or bristles.

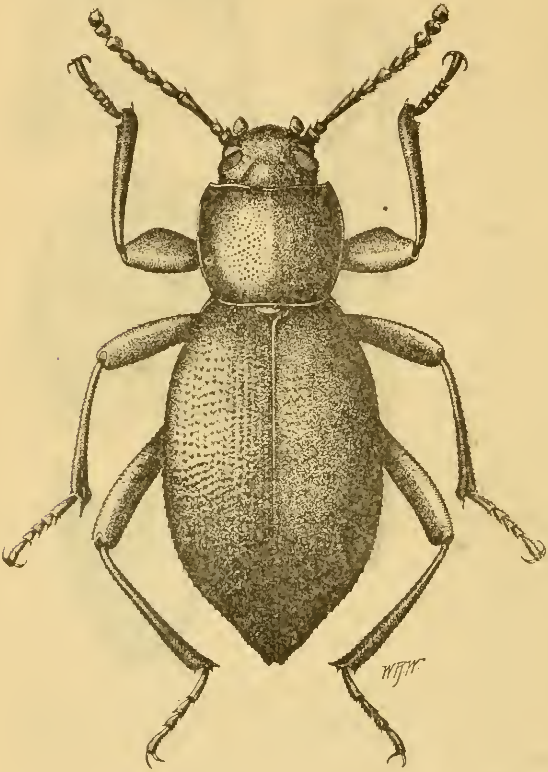

FIG. 26.—False wireworm, *Eleodes letcheri vandykei*: Adult, dorsal aspect. Much enlarged. (Original.)

The adult[1] (fig. 26).—More or less shining, elytra not pubescent. Antennæ with the third joint scarcely as long as the next two combined, fourth joint a little longer than the fifth, the latter slightly longer than the sixth, the latter and the seventh equal.

Pronotum usually widest at the middle, frequently widest just in front of the middle.

Elytra irregularly and quite densely muricately punctate, very minutely so on the dorsum, coarser on the sides and apex; from each puncture arises a rather short, stiff, curved, inconspicuous and semirecumbent seta. These are not evident on the inflexed sides.

Otherwise as in *letcheri*, but a little more robust.

Measurements.—Males: Length, 14.5–16 mm.; width, 5–6.5 mm. Females: Length, 15-16 mm.; width, 7.5 mm.

Genital characters as in *letcheri*.

Eleodes pimelioides Mann.

The egg.—Oval in longitudinal section and circular in cross-section; 1.34 mm. in length and 0.85 mm. in diameter; pure glistening white; without sculpturing of any kind.

The larva.—Elongate, cylindrical, convex dorsally, flattened ventrally. Yellowish, first thoracic and eighth abdominal segments brownish, ventral surface paler, anterior and posterior margins of first thoracic and posterior margins and anterior submarginal areas of succeeding segments brown, a distinct pale median vitta; head brownish posteriorly, edge of the mandibles black, base of the mandibles brownish; claws, spines on legs, and caudal segment brown; antennæ brownish. Anterior margin of first thoracic segment excavated, posterior margins on all segments except caudal

[1] The description of the adult given herewith is taken from "A Monographic Revision of the Coleoptera, belonging to the Tenebrionide Tribe Eleodiini, inhabiting the United States, Lower California, and Adjacent Islands," by Frank E. Blaisdell, Sr. Bul. 63, U. S. Nat. Mus., p. 136, 1909.

depressed, faintly striate. Caudal segment scutelliform, slightly convex dorsally, margined laterally, tip curved slightly upward, bearing 18 acute spines on margin—4 groups of 2 spines each on each lateral margin and 2 spines at tip. A number of hairs on dorsal surface and many on ventral surface. Head subquadrate, very convex, sides converging anteriorly, posterior angles rounded, 2 hairs on lateral dorsal and several hairs on ventral surface; 2 black eye spots on lateral anterior part of head, a large oblong one at the base of antennæ, and a smaller square one posterior and dorsal of this. Suture arising at the base of each mandible flexed laterally and converging posteriorly to unite with median suture near base of the head. Basal joint of labrum trapeziform, terminal joint rounded, trilobed, hairs on margin. Mandibles large, visible from above. Ligula broader than palpifer, labial palpi cylindrical, 2-jointed, second joint papilliform, mentum larger than palpifer, submentum larger than men-

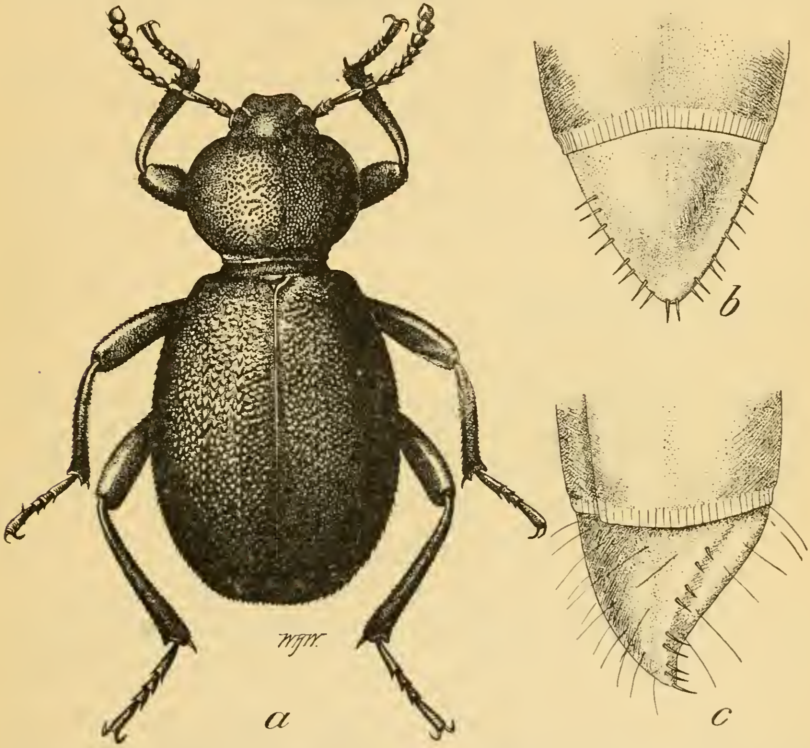

FIG. 27.—False wireworm, *Eleodes pimelioides: a,* Adult, dorsal aspect; *b,* caudal segment of larva, dorsal aspect; *c,* caudal segment of larva, lateral aspect. *a,* Much enlarged; *b, c,* more enlarged. (Original.)

tum. Legs 4-jointed. Second joint of anterior legs with 2 short stout spines on inner anterior margin; third joint of anterior legs with 3 longer spines on inner margin, and fourth joint with 3 still longer, stout spines; 2 spines on inner side and 1 spine on outer side of base of claw.

The pupa.—The pupa of this species is very similar to that of *Eleodes letcheri vandykei,* from which it can be distinguished, however, by a pair of rather stout spines at the apex of the secondary wing pads.

The adult (Fig. 27).[1]—The following description is from page 384 Dr. Blaisdell's monograph previously mentioned in this paper:

Moderately robust, ovate, feebly shining to opaque, about twice as long as wide; prothorax more or less strongly constricted at base, densely rugoso-punctate; elytra

[1] Originally described in Bul. Soc. Nat. Moscou, vol. 16, p. 274, 1843.

sculptured with small tubercles, which may be rounded or reclinate and more or less piliferous. Head densely punctate, antennæ somewhat slender, ninth joint triangulo-orbicular to transversely oval, tenth more or less transversely oval.

Pronotum subcordate to transversely suboval, widest near the middle, a fourth to scarcely a half wider than long; sides evenly and quite strongly arcuate to basal seventh, or subangulate at middle, rounded in front and quite rapidly converging posteriorly and sinuate at basal fourth, thence in each instance quite straight and parallel to the basal angles; base equal to the length or in some males shorter than the length; apical angles obtuse, frequently not in the least rounded, at other times more or less so.

Elytra quite broadly oval to subquadrate, widest at or behind the middle, a fourth to a third longer than wide; disc more or less deplanate on the dorsum, strongly, arcuately, and vertically declivous posteriorly; surface densely tuberculate, tubercles apparently arranged in rows on the dorsum or irregular throughout; each bears a very short, black seta near the apex; when arranged in rows there are very small muricate punctures scattered sparsely and irregularly between, always less distinct along the suture centrally; the tubercles are more or less rounded and shining, the interstices between more or less opaque. Otherwise as in *cordata*.

Male.—First two joints of the protarsi with tuft of yellowish pubescence near tip beneath; that of the second joint is rather small; tuft on the first joint of the mesotarsi quite small. Tufts somewhat long and truncate at tips. Otherwise as in *cordata*.

Female.—First joint of the anterior tarsi distinctly thickened at tip beneath. Otherwise as in *cordata*.

Measurements.—Males: Length, 12–14.5 mm.; width, 6–7 mm. Females: Length, 13–15.2 mm.; width, 6.5–8 mm.

Genital characters, male.—As in *cordata*.

Female.—Genital segment triangular, surface quite plain and slightly setose.

Valvula.—Dorsal plate oblong, feeble or scarcely narrowed apically, slightly explanate externally; apical margin nearly transverse to feebly oblique, inwardly not defined from the surface of the apex, angle obtuse and more or less feebly rounded.

Ventrolateral surfaces.—Submarginal groove distinct and well defined beneath the expanded external border of the dorsal plate. Otherwise as in *cordata*.

FOOD SUBSTANCES.

False wireworms are known to feed on the seed of wheat, oats, and corn, on the tubers of potato, on the fleshy roots of sugar beet, and on several garden crops, as well as on a variety of dead organic matter.

If several larvæ are placed in a small rearing cage with insufficient food they invariably prey upon one another until there is but a single survivor. Mr Swenk[1] observed that in cages where larvæ died of a disease their more fortunate survivors ate the dead individuals.

The adult beetles have been observed feeding on the seed of wheat and corn, on the leaves of corn, on *Polygonum littorale* and other weed leaves, and on decaying vegetable matter. An adult beetle was kept alive for several months in our laboratory. It was fed on wheat and occasionally drank from a piece of wet cotton.

[1] Journ. Econ. Ent., vol. 2, p. 336, 1909.

SEASONAL HISTORY.

The following life history was worked out for *Eleodes letcheri vandykei* at Govan, in the Big Bend region of Washington, and unless otherwise indicated the data refer to this species.

The adults emerge from hibernation in the early spring, about the middle of April, and after feeding for a short time on the leaves of various weeds, principally *Polygonum littorale,* mate and start oviposition. The eggs are deposited a few at a time in the ground, the adult female burrowing down through the soft dust to the moist soil below, usually to a depth of from 2 to 4 inches. The average number of eggs laid by one female is probably about 150. Five specimens of female *Eleodes letcheri vandykei* that were collected on April 30, 1911, were dissected and found to contain 199, 138, 161, 157, and 92 eggs, respectively. Most of these eggs were full-sized and probably mature, though one female contained 45 eggs and another 91 eggs which were about one-third full size. A female *Eleodes pimelioides,* collected May 1, 1911, at Pullman, Wash., was found to contain 167 eggs and 2 females of *Eleodes nigrina* collected late in April contained 96 and 58 eggs, respectively.

The eggs hatch in about 18 days, the recently emerged larvæ being cream-white, but rapidly assuming the normal amber-yellow color.

The larvæ feed throughout the ensuing summer, usually on decaying vegetable matter, hibernate, and resume feeding as soon as the soil becomes warm enough the following spring, but this time disastrously to the spring-sown grain. In June the larvæ transform to pupæ, and early in July the newly emerged adults commence to appear. They are quite soft on first emerging and take two or three days to become thoroughly hardened. These adults feed during the remainder of the summer, congregating in large numbers under the grain sacks, shocks, and any convenient shelter. They eat a small amount of grain and other vegetable matter and go into hibernation without mating. In the spring they resume activity and mate, thus completing the life cycle. They hibernate under boards, in squirrel holes, and in the ground. Prof. W. T. Shaw, of the Washington State College, in digging out burrows of a ground squirrel (*Citellus columbianus*), found specimens at a depth of 6 feet below the surface in the burrows. I have dug out the hibernating beetles at a depth of about 6 inches in the soil in wheat fields and also in barrel root-cages.

Larvæ of *Eleodes suturalis* were received by Mr. Theo. Pergande [1] on October 26, 1898, from McPherson, Kans. These pupated before May 19 and adults emerged May 30. From this note it would seem that *Eleodes suturalis* varies from *Eleodes letcheri vandykei* in its life

[1] Bureau of Entomology Notes, No. 8186.

history, hibernating as mature larvæ or pupæ and transforming to adults much earlier in the season than the latter.

The adults of the species herein treated seem normally to live but one season, but Dr. F. E. Blaisdell records keeping adults of *Eleodes dentipes* in confinement for over four years.

NATURAL ENEMIES AND PARASITES.

The hard chitinous integument, together with the offensive secretions, of these beetles render them almost immune to attack by birds. Several western vesper sparrows (*Poœcetes gramineus confinis*), two horned larks (*Otocoris alpestris* var.), a killdeer plover (*Oxyechus vociferus*), a "billy" owl (*Speotyto cunicularia hypogæa*), and a Brewer's blackbird (*Euphagus cyanocephalus*) were shot while feeding in the grain fields and the stomach contents examined; these failed to show any evidence that the birds had fed on adult Eleodes.

Of the domesticated birds, chickens and ducks eat adult Eleodes in large numbers. Twenty-five beetles were fed to one hen and were eaten very greedily. Young turkeys would not eat these insects. They would seize the beetle and immediately drop it and shake the head violently as though they disliked the taste, and after two or three similar experiences would learn to recognize these insects and would not touch them.

A large number of these beetles were fed to confined pheasants, and though the conditions were very abnormal, the results may be suggestive. Reeves pheasant (*Phasianus reevesi*) and the silver pheasant (*Gennæus nychthemerus*) ate the beetles freely, while the golden pheasant (*Chrysolophus pictus*) and the Lady Amherst pheasant (*Chrysolophus amherstæ*) refused even to notice the beetles. However, these birds seemed quite annoyed by our presence, and might have eaten the beetles had they not been frightened. No Chinese pheasants (*Phasianus torquatus*) were available, so we can not say whether or not these birds would be of any value as enemies of Eleodes.

From several sources we were informed that the sage hen (*Centrocercus urophasianus*) feeds largely on these beetles, the crop at times being gorged with the black chitinous fragments. In the records of the Bureau of Biological Survey of this department the following birds are listed as feeding more or less extensively on adult Eleodes:

California shrike (*Lanius ludovicianus gambeli*), road-runner (*Geococcyx californianus*), Lewis's woodpecker (*Asyndesmus lewisi*), western crow (*Corvus brachyrhynchos hesperis*), bronzed grackle (*Quiscalus quiscula æneus*), red-headed woodpecker (*Melanerpes erythrocephalus*), curve-billed thrasher (*Toxostoma curvirostre*), hairy woodpecker (*Dryobates villosus* var.), western mocking bird (*Mimus polyglottos leucopterus*), western robin (*Planesticus migratorius propinquus*), the field plover (*Bartramia longicauda*), the mallard (*Anas platyrhynchos*), and the baldpate (*Mareca americana*).

Dr. Blaisdell[1] refers to the ground owl (*Speotyto cunicularia hypogæa*) as one of their enemies, and further states that the butcher bird impales them on thorns.

It is very generally known among the farmers of the wheat regions of the Pacific Northwest that the Brewer's blackbirds (*Euphagus cyanocephalus*) follow the plow and eat the "white worms" (*Eleodes* pupæ) when the summer-fallow is being worked. The birds are to be seen walking in the furrows and flying away with their beaks filled with the soft white pupæ.

The western bluebirds (*Sialia mexicana occidentalis*) were seen at Govan, Wash., in large flocks feeding on the larvæ which had been driven to the surface by an unusually heavy rain.

The stomachs of several horned toads (*Phrynosoma douglasii douglasii*) were examined and found to contain fragments of Eleodes larvæ, but several of these toads kept in captivity refused to eat the adult beetles, though they would feed voraciously on other beetles. These little horned toads, or, as they are locally known, sand toads, are without doubt one of the most valuable animals in the western dry-farming regions. In the Southwest a larger species (*Phrynosoma cornutum*), with long stout spines on the head, supplants the former species. These toads move very rapidly and eat enormous numbers of insects. The garden toad (*Bufo* sp.) is recorded in the files of the Bureau of Biological Survey as feeding on Eleodes. Dr. Blaisdell[2] gives the skunk as a natural enemy of these beetles.

In the files of the Bureau of Entomology there is a note (No. 8186) by Mr. Theo. Pergande, wherein he records having received two larvæ from McPherson, Kans. These pupated, and later one of these pupæ was killed by an ant (*Tetramorium cæspitum*).

Another of Mr. Pergande's notes[3] records receiving an adult of *Eleodes suturalis* from Mr. C. E. Ward, of Belvidere, Nebr. This beetle was placed in a cigar box, and on examining the box on the following morning a large number of larvæ were noticed crawling about. These larvæ later spun cocoons around the edge of the box and were believed to be microgasterid parasites that had issued from the beetle. The adult parasites were later determined as *Perilitus* n. sp., and these are preserved in the National Museum collections.

The author found an adult beetle with the abdomen nearly filled by a nematode worm, but lost the specimen, making further determination impossible. Mr. Myron Swenk[4] records a disease, probably caused by bacteria or a fungus, that attacks the larvæ. The

[1] Bul. 63, U. S. Nat. Mus., p. 29, 1909.
[2] Loc. cit., p. 29.
[3] Proc. Ent. Soc. Wash., vol. 2, pp. 211, 219, 1892.
[4] Jour. Econ. Ent., vol. 2, p. 335, 1909.

first symptom of this disease is a small red spot on one of the body segments, usually on the first thoracic or the terminal abdominal segment. This spot enlarges, finally encircling the body, and within a very short time the insect succumbs. This disease was so prevalent as to interfere with much of Mr. Swenk's experimental work.

REMEDIAL AND PREVENTIVE MEASURES.

If a field is well stocked with false wireworms at the time wheat is sown, remedial measures are of little avail, as was demonstrated by our experiments carried out in the Big Bend country of Washington. The insects are well adapted to the present agricultural practices of the spring-wheat growers in the Pacific Northwest. Here the plowing of summer-fallow land is commenced as early as possible in the spring, which in the average season is in April. Those who can spare teams and men often commence while the seeding of the crop in other fields is in progress. The most progressive farmers then disk their fallow land in June so that this will be well finished when haying commences.

By slightly modifying this procedure an enormous number of these beetles would be destroyed. Instead of plowing early in the spring and disking in summer, reverse the process. Disk as early as the land can be worked and the apparatus is available, which will usually be in April. This will conserve the moisture fully as well as plowing. Then plow as late as possible; if the land has been well disked and the men and horses can be spared, it is well to defer this plowing to late July and early August. At this time the beetles are in the pupal, or, as they are commonly called, "white-worm," stage. They can not move through the ground as can the active larvæ, but can merely squirm when irritated. The plowing, which should be deep to be effective, turns out great numbers of these pupæ, and they are either eaten by birds or killed by the burning sun. Many more are destroyed by being crushed or suffocated in the broken pupal cells. Aside from killing many Eleodes pupæ, this practice of late plowing the summer-fallow would greatly aid in weed eradication. The early disking would not bury the weed seed to retard germination; all the seed would develop; then the late plowing would destroy the entire crop of weeds. If the weeds start very early, a second disking may be necessary, as weeds very rapidly deprive the soil of its moisture.

Concerted effort and very thorough work are absolutely essential to render this treatment appreciably effectual. The cooperation of all the farmers over a considerable area is advised, as the adult beetles walk rapidly and will readily reinfest a well-treated ranch, coming in from an adjoining, poorly worked field or pasture.

This treatment is by no means advocated for those farmers who find it impossible to disk their summer-fallow, as leaving the land untouched until July would cause all the accumulated winter's moisture to evaporate, and the plowing would simply be stirring the dust and be of no value whatever.

In the spring of 1910 a series of experiments was carried out at Wilbur, Wash., to determine the value of certain substances alleged to be useful as poisons or repellents against elaterid larvæ. Eleodes larvæ were also quite numerous in the fields where these experiments were carried out; hence mention of the results, though relating principally to another insect, may not be out of place here.

Seed in bulk was treated with the following substances: Lead arsenate, at the rate of two-thirds of a pound per bushel of seed, dissolved in water; strychnine sulphate, at the rate of two-thirds of an ounce per bushel of seed, dissolved in water; coal tar applied until seed was all coated, then sanded until dry. The substances were stirred into the grain thoroughly with a wooden paddle and then allowed to dry several days.

The experiments were sown in strips with a wheat seeder 11 feet wide and one-half of a mile long. Untreated check strips were planted between each treated plat.

Just after sprouting the percentage of damage done by insects was estimated by counting the damaged and undamaged seed in several areas of 1 square yard each in each plat. The results were entirely negative as all the plats, including the checks, were about equally attacked.

These treatments, even had they been found efficient, would have been impracticable from an economic standpoint. The poisons were too expensive and the application too expensive and laborious, and, in addition, the coal-tar treatment, even after drying several days, so clogged the seed cups on the seeder as to cause very uneven distribution of seed.

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE LEGUME POD MOTH. THE LEGUME POD MAGGOT.

BY

JAMES A. HYSLOP,

Agent and Expert, Cereal and Forage Insect Investigations.

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Nettie S. Klopfer, Ellen Dashiell, *preparators.*
Miriam Welles Reeves, *collaborator.*

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE LEGUME POD MOTH.

(*Etiella zinckenella schisticolor* Zell.)

By James A. Hyslop,
Agent and Expert, Cereal and Forage Insect Investigations.

HISTORICAL.

The first mention of the legume pod moth (*Etiella zinckenella schisticolor* Zell.) as of economic importance in the United States is found in the unpublished notes of Mr. Theodore Pergande [1] in the files of the Bureau of Entomology, and refers to a number of lima-bean pods sent in by Mr. Albert Koebele from Eldorado County, Cal., on July 21, 1885. The larvæ were reported as doing considerable damage to the bean crop in that region. They left the pods and, if not full grown, entered other pods to continue feeding or, if full grown, constructed slight cocoons in the bottom of the rearing jar and pupated. Adults emerged September 2 and September 15.

A similar reference,[2] from the same source, refers to a number of pods of *Crotolaria incana* collected by Mr. E. A. Schwarz at Cocoanut Grove, Fla., on May 9, 1887, and sent to the Bureau of Entomology. The larvæ were eating the seed, and from these on May 16 an adult emerged. From a second lot of seed pods from the same source received on June 1, three more moths emerged on the 24th.

On May 2, 1896, a number of pods of *Astragalus* sp. were received by the bureau from Mr. C. L. Marlatt,[3] the material having been collected at Neucestown, Tex., infested with larvæ of *Etiella zinckenella*. On May 13 a braconid parasite issued, and on June 5 an adult moth emerged.

A single specimen was received from Mr. E. E. Bogue,[4] of Stillwater, Okla., on August 17, 1896, which he had previously reared from the seed pod of *Crotolaria sagittalis*.

Dr. F. H. Chittenden,[5] of this bureau, has published a paper on this insect in which the records made by Mr. H. O. Marsh are incor-

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[1] Bureau of Entomology Notes, No. 3819.
[2] Bureau of Entomology Notes, No. 4129.
[3] Bureau of Entomology Notes, No. 7044.
[4] Bureau of Entomology Notes, No. 7173.
[5] Bul. 82, Pt. III, Bur. Ent., U. S. Dept. Agr., p. 25, 1909.

porated. Mr. Marsh found the larvæ attacking lima beans at Santa Ana, Garden Grove, Anaheim, and Watts, in California. At Garden Grove they had destroyed 40 per cent of the crop.

SYNONYMY AND DISTRIBUTION.

The species *Etiella zinckenella* was described by Treitschke [1] in 1832, and the variety *E. zinckenella schisticolor* was described as *E. schisticolor* in 1881 by P. C. Zeller [2] from two specimens, a male and a female, collected from "very different parts of North America." The male was from California and was collected October 8, but of the female he has nothing to say. He also refers to specimens of *E. zinckenella* examined by him from Sierra Leone, West Africa; Madagascar; Honda, Colombia, South America; and "Carolina" in this country. Later Rev. G. D. Hulst [3] redescribed this species under the name *Etiella villosa*, and gave Colorado and Califorina as the habitat. Dr. H. G. Dyar in his catalogue gives Arizona as an addition to the habitat.

The typical *E. zinckenella* is represented in the National Museum collection by specimens from Hampton, N. H.; Weekapong, R. I.; Key West and Archer, Fla.; Oxbow, Saskatchewan; Texas; Stillwater, Okla.; and Denver, Colo. The variety *E. zinckenella schisticolor* is represented by specimens from Stockton, Utah; Springfield, Idaho; Eldorado, Clairmont, Alameda, and San Diego, Cal.; Nogales, Ariz.; and Pullman, Wash. It will be noted that all the specimens of the variety were collected west of or in the Rocky Mountains.

Etiella zinckenella schisticolor differs very slightly from the typical form. It has a suffusion of gray scales on the primaries as its chief distinctive character. A number of specimens from Florida, one specimen from Rhode Island, and one from New Hampshire very closely resemble the European specimens of *E. zinckenella.*

A possible explanation of the above facts may be that the variety *schisticolor* is a native of the Pacific slope of this continent, while the forms found in the eastern United States are the typical *E. zinckenella* recently introduced into this country from the Old World or South America.

FOOD PLANTS.

Larvæ of *Etiella zinckenella* have been recorded as feeding on the seed of several species of leguminous plants. In California (Eldorado County) Mr. A. Koebele [4] found them doing considerable damage to lima beans and they were recently found by Mr. H. O. Marsh,[5] of this bureau, working on the same crop in that State. Mr. E. E.

[1] Die Schmetterlinge von Europa, von Friedrich Treitschke, 9 Band, p. 201, 1832.
[2] Horæ Societatis Entomologicæ Rossicæ, vol. 16, p. 177, 1881.
[3] Ent. Amer., vol. 3, p. 133, 1887.
[4] Bureau of Entomology Notes, No. 48 K.
[5] Bul. 82, Pt. III, Bur. Ent., U. S. Dept. Agr., p. 25, 1909.

Bogue[1] found the larvæ in the seed pods of the common rattlebox (*Crotolaria sagittalis*) at Stillwater, Okla., and Mr. E. A. Schwarz[2] found them in the pods of a tropical species of this genus (*Crotolaria incana*) at Cocoanut Grove, Fla. Mr. C. L. Marlatt[3] records finding the larvæ in the seed pods of milk vetch (*Astragalus* sp.). They are also recorded by Herrich-Schäffer[4] as feeding in the seed pods of *Spartium junceum* near Vienna, Austria.

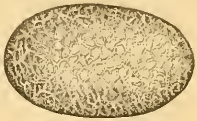


Fig. 28.—The legume pod moth (*Etiella zinckenella schisticolor*): Egg. Greatly enlarged. (Original.)

During 1910 and 1911 the author reared the species from the pods of common lupines (*Lupinus* spp.) and Canada field peas at Pullman, Wash.

DESCRIPTION.

THE EGG.

(Fig. 28.)

Egg glistening white, bluntly elliptical in outline and circular in cross section, measuring 0.58 mm. in length and 0.31 mm. in diameter. Chorion very delicate, colorless, and with fine irregular corrugations on the surface.

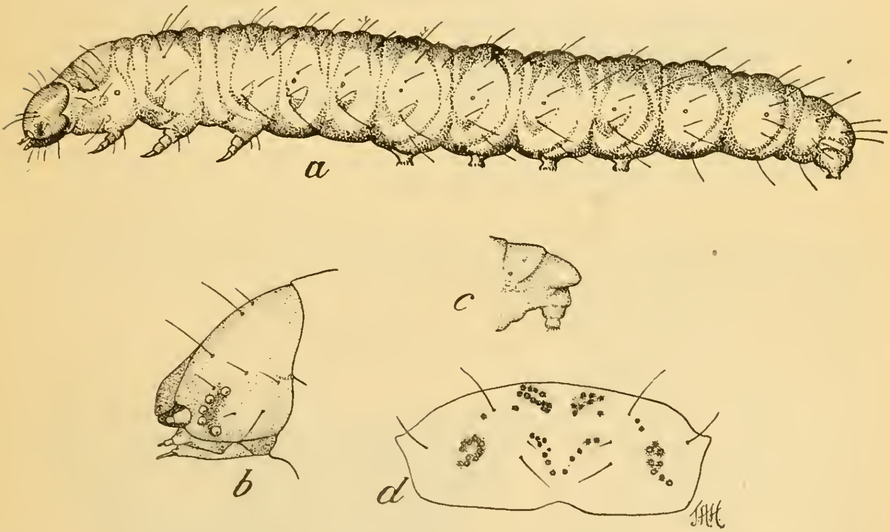


Fig. 29.—The legume pod moth. Larva: *a*, Side view; *b*, lateral aspect of head; *c*, caudal segments; *d*, pronotal shield. *a*, Enlarged; *b*, *c*, *d*, greatly enlarged. (Original.)

THE LARVA.

(Fig. 29.)

Full-grown larva from 12 to 17 mm. in length and from 2.5 to 3.5 mm. in diameter. Head yellow, black patch over ocellar area; mandibles and tip of labrum black; five ocelli arranged in an anteriorly directed semicircle at base of antennæ. Dor-

[1] Bureau of Entomology Notes, No. 7173.
[2] Bureau of Entomology Notes, No. 4129.
[3] Bureau of Entomology Notes, No. 7044.
[4] Syst. Bearb. der Schmett. von Europa, vol. 4, p. 72, 1849.

sum ruddy pink, except the pronotum (immature larvæ are evenly pale green or cream colored, with head and pronotal shield black or brown), the pleural and ventral surfaces pale green or cream white. Head pale yellow. Tips of thoracic legs and head brownish yellow. Five pairs of prolegs situated on segments 3, 4, 5, 6, and 9; the last pair can be retracted, so as to be almost invisible. Pronotum yellowish, with brown or black markings as follows: Two medial pairs of dot patches, the posterior pair nearly touching the posterior margin and somewhat oblong in outline, the anterior pair approaching the anterior margin and linear in outline, being for the most part made up of a single row of dots; both pairs converging anteriorly, the anterior rows forming a V. Posterior margin bearing four bristles. Two pairs of bristles flanking the anterior median patches of dots, the posterior bristle in each pair short.

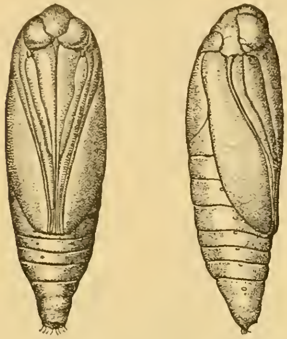


FIG. 30.—The legume pod moth: Pupa. Greatly enlarged. (Original.)

THE PUPA.

(Fig. 30.)

Pupa from 6 to 10 mm. in length, amber-yellow, with the tip of the abdomen, the edges of the abdominal segments, and margins of the wings outlined in brown. Fourth, fifth, and sixth abdominal segments each bearing a pair of short spines on the ventral surface. Abdominal segments 2 to 9 bearing well-defined brown spiracles. Terminal abdominal segment provided with a transverse row of 6 hooked bristles and a pair of lip-shaped tubercles on its dorsal surface.

THE ADULT.

(Fig. 31.)

"The adult expands 24–27 mm. Labial palpi russet-gray above, gray below. Maxillary palpi yellowish, brown on end. Head, collar and fore-thorax orange fuscous. Thorax behind fuscous gray. Abdomen fuscous; fore wings mouse color, consisting of bluish gray, overlaid partly with fuscous. A broad white stripe extending from base along costa to apex. Extreme edge of costa of ground color broadening outwardly just beyond middle and fading away toward apex. A dull yellowish basal stripe reaching from white costal stripe to inner margin, edged inwardly with a row of maroon-brown scales, the scales being longer than usual. Hind wings fuscous, deepening outwardly, with dark marginal line. Beneath even glistening, very light fuscous." (Hulst, Trans. Amer. Ent. Soc., vol. 17, p. 170, 1890.)

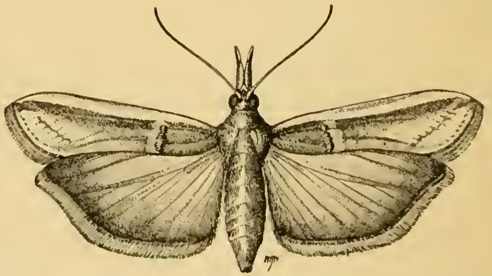


FIG. 31.—The legume pod moth: Adult. Enlarged about 2½ diameters. (Original.)

SEASONAL HISTORY.

On July 26, 1911, an eggshell was found on the outer surface of the calyx of a well-filled though still green lupine seed pod. The larva, which had evidently emerged only a few minutes before it was discovered, measured 1.2 mm. in length and was found just inside the pod at the terminus of a burrow which led from just in front of the egg through the calyx and pod wall. The hole through which the larva emerged from the eggshell was terminal, round, and very neatly cut. A few days later two eggs were found on the calcyces of field peas; these were brought into the insectary but failed to hatch.

During late July and early August, 1911, larvæ in all stages of development, from very small specimens, evidently just hatched, to those which were mature and spinning cocoons, were found in both the pods of field peas and lupines. The larvæ on first emerging are pale green or cream colored, the pronotal plate and head being entirely black or brown; with the first molt the pronotal plate assumes the characteristic pattern described elsewhere in this paper, but the body does not assume the rosy tint as described until nearly mature.

The larvæ feed for about three weeks, only partly consuming the peas, as is seen in figure 32, destroying them as seed, besides greatly reducing their weight as stock feed. The pod always contains a mass of frass held together by a loosely constructed web. The larva will leave one pod and enter another if the food supply is exhausted, or if for any other reason the pod becomes uninhabitable. When mature, if the peas are still unharvested in the field, it emerges from the pods and enters the ground to pupate, or if the pods have been harvested it spins a tough silken cocoon in the nearest available sheltered place.

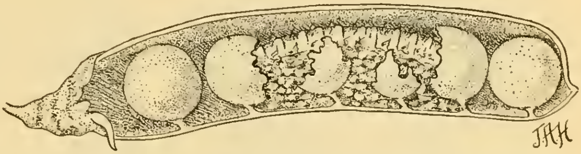


FIG. 32.—The legume pod moth: Larva feeding in a pod of field pea. Enlarged. (Original.)

Larvæ that become mature during the warm weather of early August, out of doors, or later under laboratory conditions, pupate immediately and emerge as adults in about six weeks. Adults have been obtained in our laboratory on August 5 and as late as August 28. Whether these lay eggs which pass the winter successfully, or whether they hibernate as adults, is still undetermined. Larvæ that reach maturity in late September, when the nights are cold, spin their cocoons and hibernate therein as larvæ, pupating in the spring and emerging at the time the earliest lupines are setting seed.

On the lupines there are very probably two generations a year. The moths of the first generation, coming from hibernating larvæ, lay all their eggs on the lupines, as the field peas are just commencing to grow. The offspring of this generation mature late in July and, finding the field peas ripening, very naturally turn their attention to these large areas of suitable food as well as to their natural food, the later lupines.

Mr. C. L. Marlatt [1] reared adults on June 5, 1896, from larvæ that were collected May 2 of that year at Nuecestown, Tex. Mr. Albert Koebele [2] reared adults on September 2 and 15, 1885, from larvæ collected June 21 at Rattlesnake Bridge, Eldorado County, Cal. Mr. Koebele also noticed the entrance holes of young larvæ and the exit holes of older larvæ in the pod husks. He says, "The larvæ * * * spun a web on the bottom of the jar in which they pupated."

Mr. Theodore Pergande [3] received a number of larvæ from Mr. E. A. Schwarz collected at Cocoanut Grove, Fla., on May 9, 1887, and on May 26 reared an adult from this material. More material from the same source was received on June 1, and on the 24th three more adults emerged.

Mr. H. O. Marsh obtained adults from January 9 to February 25, 1909, from larvæ collected October 22, 1908, at Anaheim, Cal.[4]

These observations indicate that two generations a year is characteristic of this species, the adults of the first appearing in early June and those of the second in September. The adults obtained in January and February were reared under laboratory conditions, which very probably accelerated their development. In the more southern parts of its range this species may have more than two generations.

FIELD WORK.

July 21, 1909, while examining the seed pods of the common lupine (*Lupinus* sp.) many were found to contain lepidopterous larvæ. In such pods the seeds were always more or less destroyed. The pods also contained a mass of frass which was held together by a loosely constructed web. A few days later, on examining the collected material, several of the pods were found with newly eaten holes in the sides and two larvæ were found with half their bodies within fresh pods.

On August 7 one of the larvæ, very plump, was found still in the pod, it having in the meantime become suffused with a rosy color. This larva had constructed a loose silken cocoon, through which its body could be easily seen. Ten days later the larva pupated and emerged as an adult (*Etiella zinckenella schisticolor*) September 28.

In the rearing cages with solid bases most of the larvæ left the seed pods and spun their cocoons among the litter and dirt in the bottom of the cages. In cages with bottoms of earth the larvæ always burrowed 2 or 3 inches below the surface to pupate.

On August 1, 1910, Mr. M. W. Evans, of the Bureau of Plant Industry, told the author of a larva that he was finding in the field-pea

[1] Bureau of Entomology Notes, No. 7044.
[2] Bureau of Entomology Notes, No. 48 K.
[3] Bureau of Entomology Notes, No. 4129.
[4] Bul. 82, Pt. III, Bur. Ent., U. S. Dept. Agr., p. 25, 1909.

pods in his experimental plats at Pullman, Wash. On examining some of these larvæ it was found that they resembled those of *Etiella zinckenella schisticolor* that had been found in lupine-seed pods the previous year, differing only in being larger, measuring about 17 mm. in length, while those from lupine measured only 13 mm., due, without doubt, to the difference in food plant.

The following day a number of the larvæ were collected from the field-pea pods and placed on earth in a flowerpot, into which they immediately burrowed.

From a larva placed in a pill box an adult emerged on August 27 and on the same day two moths emerged from the earth in the flowerpot.

EXPERIMENTAL WORK CARRIED ON DURING THE SEASON OF 1910.

In the spring of 1910 the Bureau of Plant Industry planted over 100 varieties of field peas at Pullman, Wash. These were planted

FIG. 33.—The work of the legume pod moth (upper row) compared with that of the pea weevils (Bruchidæ) (lower row). Enlarged. (Original.)

in plats 1 rod square, in order to study development and adaptability of the various varieties under semiarid conditions. Mr. M. W. Evans has very kindly permitted the use of his field notes, and of the crop when harvested from these plats, which has greatly facilitated this investigation. These notes indicated the time of planting, the time the first flowers of each variety came into bloom, the time of maximum blooming, and the time of last blossoms. The seed harvested from each plat was kept in individual packages.

By actual count the writer determined the percentage of damage to each variety of field peas by these moths. The "worms" do not usually consume the entire seed, but so far destroy it as to render germination impossible. Seed thus damaged is easily distinguished from that attacked by Bruchus. The latter makes a very smooth round exit hole, while the former gnaws into the seed very irregularly. (See fig. 33.)

Figure 34 is a plan of the experimental plats and shows very clearly that the attacks of the pod moth were not restricted to any one part of the field, but were more or less promiscuously distributed. The plantings were made on a gentle slope, the upper side being to the south, thus giving a northerly exposure. The vacant rectangle in the center of the plan indicates a wheat-straw stack. All sides of the field were bounded by grain fields, and the roadside was practically

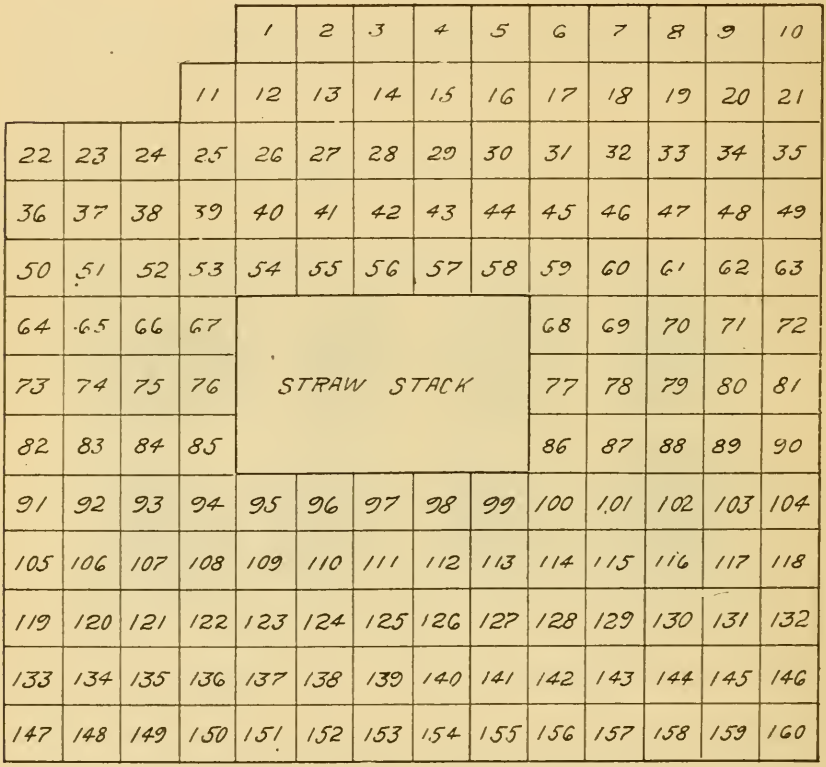


FIG. 34.—Planting plan of plats used in investigations of the legume pod moth during the season of 1910. (Original.)

without weeds of any kind. The plats were separated from each other by strips of oats 1 yard in width.

Field peas vary greatly in texture of the seed, time of blooming, time of maturing seed, and adaptability to semiarid conditions. The variability, however, is confined to the varieties to a large extent, the individuals of a variety being quite uniform in response to given conditions. This fact at once opened the question of a worm-resistant variety. The results arrived at by this investigation are very suggestive. The actual records made in the investigation are to be found in Table I, but to make the results more readily available the variations in percentage of damage under several variables are graphically illustrated by diagrams.

TABLE I.—*Record of experimental work on the legume pod moth for the season of 1910.*

Plat No.	B. P. I. No.	Began blooming.	Full bloom.	Blooming ended.	Total number of seed.	Number of seed damaged.	Per cent damaged.
51	21289	June 14	June 17	July 6	21,802	0	0.0
97	24177	June 16	June 21	...do...	14,098	11	.0
102	21288	June 17	June 23	July 9	19,920	0	.0
26	11097	...do....	June 21	July 12	7,506	0	.0
20	11112	...do....	June 23	...do....	24,722	15	.0
43	22639	June 19	June 24	...do....	9,010	0	.0
46	24895	...do....	June 25	...do....	13,828	10	.0
31	24179	...do....	June 26	...do....	19,508	8	.0
59	22077	June 14	June 21	July 14	14,517	0	.0
2	23331	June 21	June 26	July 16	6,662	2	.0
100	22007	June 16	....	July 17	15,484	4	.0
1/10 acre	20466	June 28	July 1	...do....	22,117	4	.0
8	22036	June 23	...do....	July 24	15,539	14	.0
16	21709	June 26	...do....	...do....	24,581	11	.0
101	21605	June 10	June 16	July 3	26,431	36	.1
4	23290A	June 26	July 1	July 7	11,781	21	.1
63	22638	June 10	June 17	July 12	30,276	36	.1
149	23525	June 19	June 26	...do....	10,500	20	.1
5	22640	June 26	July 1	July 26	13,625	25	.1
150	2329011	July 1	July 6	....	19,413	33	.1
72	17006	....	...do....	Aug. 3	23,707	37	.1
19	18455	June 24	July 1	July 14	11,310	30	.2
32	24178	June 21	....	July 22	12,694	31	.2
73	24940	...do....	June 26	...do....	13,063	28	.2
70	20467	June 26	June 30	...do....	18,495	45	.2
42	24262	June 16	June 23	July 17	9,792	33	.3
48	19389	June 23	June 28	July 24	22,960	80	.3
13	22040	July 1	July 9	Aug. 3	19,039	65	.3
41	17486	June 26	July 3	July 24	13,252	66	.4
7	22045	...do....	July 6	July 26	14,522	72	.4
55	12888A	June 30	...do....	....	10,477	43	.4
10	19786	...do....	July 3	July 26	11,939	59	.4
103	20382A	...do....	July 6	July 29	20,335	85	.4
44	19290	June 19	June 24	July 6	3,346	21	.6
17	21290	June 21	June 30	July 17	22,372	136	.6
54	16439	June 23	....	...do....	24,937	169	.6
148	23547	June 26	June 30	....	14,585	95	.6
49	17483	June 30	July 6	July 26	33,529	229	.6
104	19788A	...do....	...do....	....	16,509	107	.6
61	16437	June 26	...do....	July 29	9,350	63	.6
35	22043	...do....	...do....	July 26	20,588	145	.7
14	22038	July 3	...do....	...do....	20,255	145	.7
98	23850	June 19	June 26	July 17	13,971	138	.9
76	18456	June 23	...do....	....	13,639	131	.9
25	16130	...do....	July 1	Aug. 3	2,279	21	.9
80	10274A	July 9	July 17	Aug. 14	10,290	122	1.1
56	12887	June 26	June 30	July 22	9,848	119	1.2
87	23851	...do....	...do....	July 24	21,895	292	1.3
60	17483A	June 28	July 6	Aug. 3	9,400	127	1.3
90	20381	July 17	July 24	Aug. 13	8,887	118	1.3
69	23847	June 28	July 6	Aug. 3	19,007	302	1.5
58	22078	June 23	....	July 24	8,444	164	1.9
160	16436	June 24	June 30	July 22	18,724	382	2
37	22044	July 1	July 9	Aug. 3	18,555	411	2.2
12	22041	July 3	July 12	July 26	12,053	278	2.3
77	19787	July 2	July 9	....	14,699	389	2.6
82	19709	July 3	July 14	Aug. 9	14,713	387	2.6
15	22037	...do....	July 9	July 26	22,148	683	3
40	19785	June 26	July 6	...do....	10,447	346	3.3
159	16437A	June 28	...do....	...do....	7,105	244	3.4
36	22046	July 1	...do....	...do....	11,191	391	3.4
38	22042	July 3	July 9	...do....	13,822	502	3.6
88	22049	...do....	...do....	July 29	23,573	893	3.7
99	23848	June 26	July 3	Aug. 3	15,066	563	3.7
1/10 acre	16819	July 3	July 9	...do...	6,581	281	4.2
156	17483E	July 9	July 14	July 29	10,732	821	7.6

The diagram, figure 35, shows the maximum (solid line) and minimum (dotted line) percentage of seed damaged in all varieties which commenced blooming at any given time. It shows that varieties which began blooming during and after the last week in June were decidedly the most severely attacked.

Figure 36 shows similar data on all varieties in full bloom at any given time, besides very clearly showing that such varieties as were in full bloom between the first and last weeks of July were the most severely attacked.

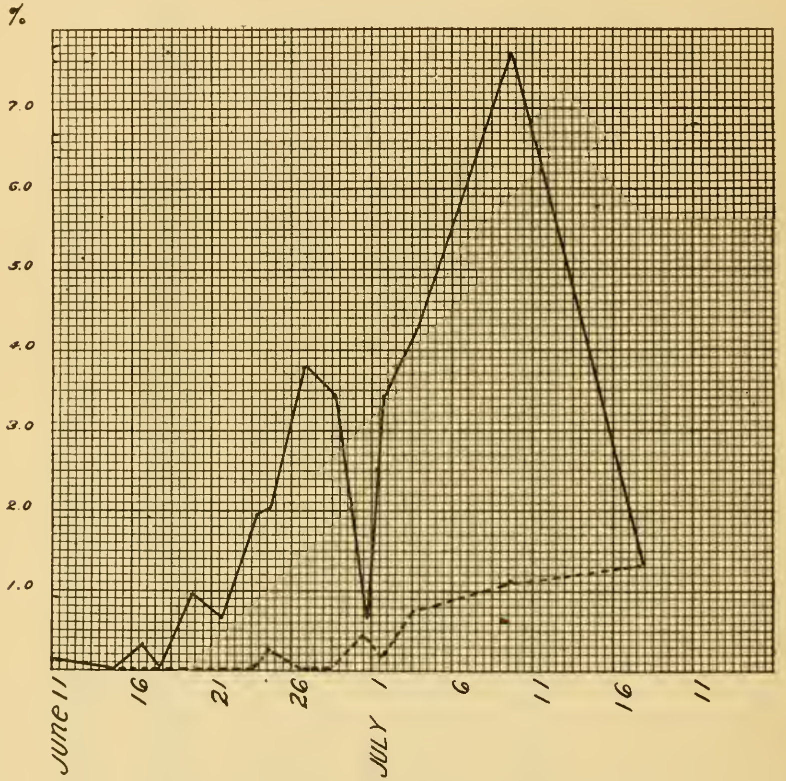


FIG. 35.—Diagram showing maximum and minimum damage done by the legume pod moth to varieties of peas commencing to bloom on a given date in 1910. (Original.)

Figure 37 shows similar data on all varieties which ceased blooming on any given date, and indicates that such varieties as had ceased blooming before the middle of July were only slightly damaged.

As the time the plants are in full bloom is very evidently of the greatest significance, Table 11 and figure 38 were arranged to show the mean percentage of damage done to all varieties in full bloom at any given time, which indicates very conclusively that varieties which were in full bloom from the 1st to the middle of July are by far the worst damaged by the legume pod moth.

TABLE 11.—*Mean percentage of damage done by the legume pod moth to all plats in full bloom on a given date in the season of 1910.*

Date of full bloom.	Mean per cent of seed damaged.	Number of plats.	Date of full bloom.	Mean per cent of seed damaged.	Number of plats.
June 16	0.1	1	July 1	0.2	7
June 17	.1	2	July 3	2.1	2
June 21	.0	3	July 6	1.1	15
June 23	.1	3	July 9	2.5	8
June 24	.3	2	July 12	2.3	1
June 25	.0	1	July 14	5.1	2
June 26	.4	6	July 17	1.1	1
June 28	.3	1	July 24	1.3	1
June 30	1.0	6			

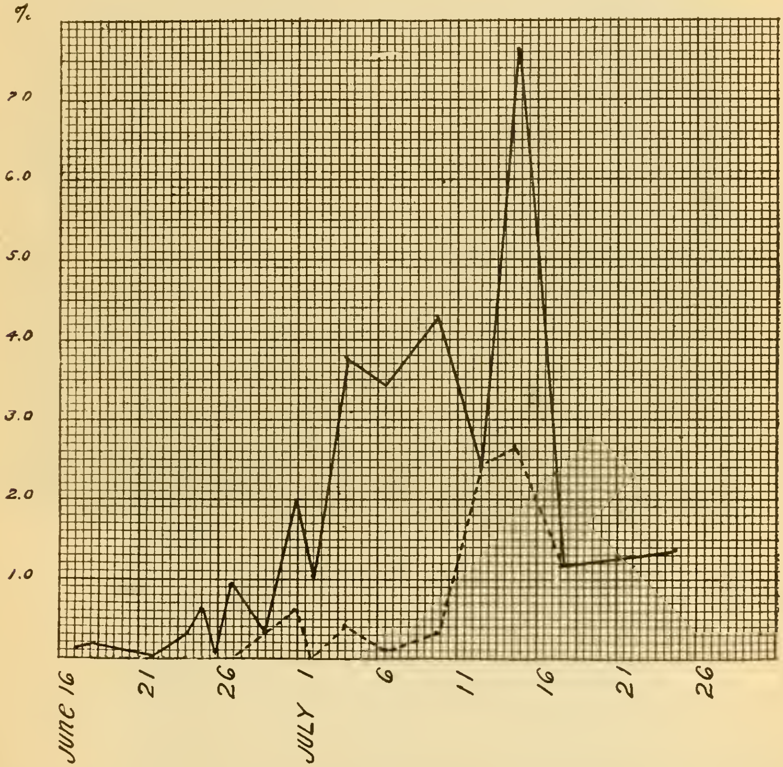


FIG. 36.—Diagram showing maximum and minimum damage done by the legume pod moth to varieties of peas in full bloom on a given date in 1910. (Original.)

EXPERIMENTAL WORK CARRIED ON DURING THE SEASON OF 1911.

Sixty-seven varieties of field peas were planted in 1911 on the farm of the State College at Pullman, Wash. The field selected was in a draw, or ravine, bordered on three sides by grain fields and on the fourth side by a clean cultivated orchard. The plats were 1 square rod in area, as they were the year before, and separated from each other by strips of oats 1 yard wide. Two plats of each variety were planted side by side. (See fig. 39.) Plate X shows a part of the experimental plats used this season. The moths were not quite so destructive this season as last, 2.5 per cent being the greatest damage done to any variety this year, while in 1910 as high as 7.6 per cent

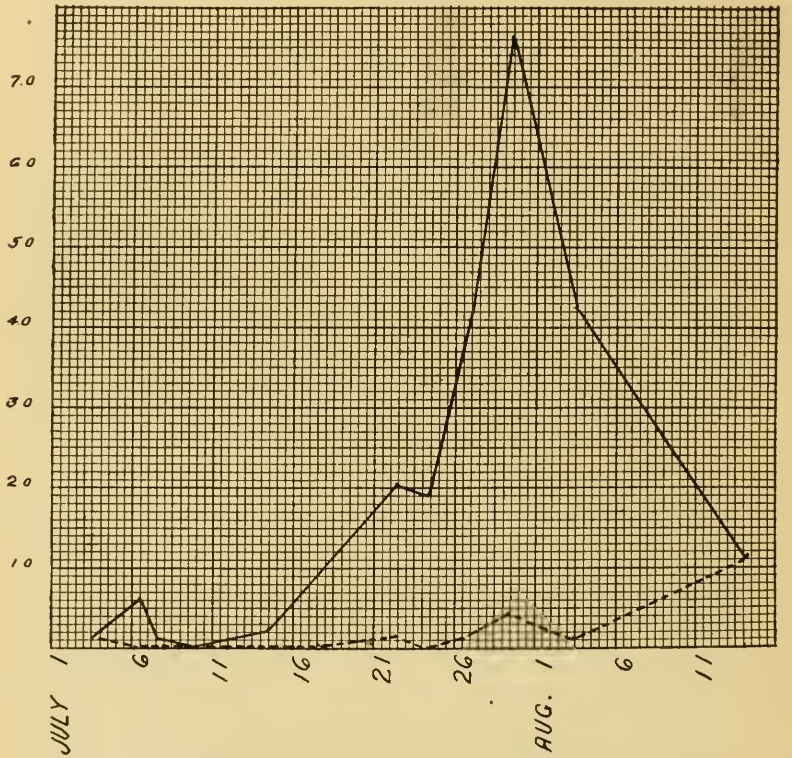
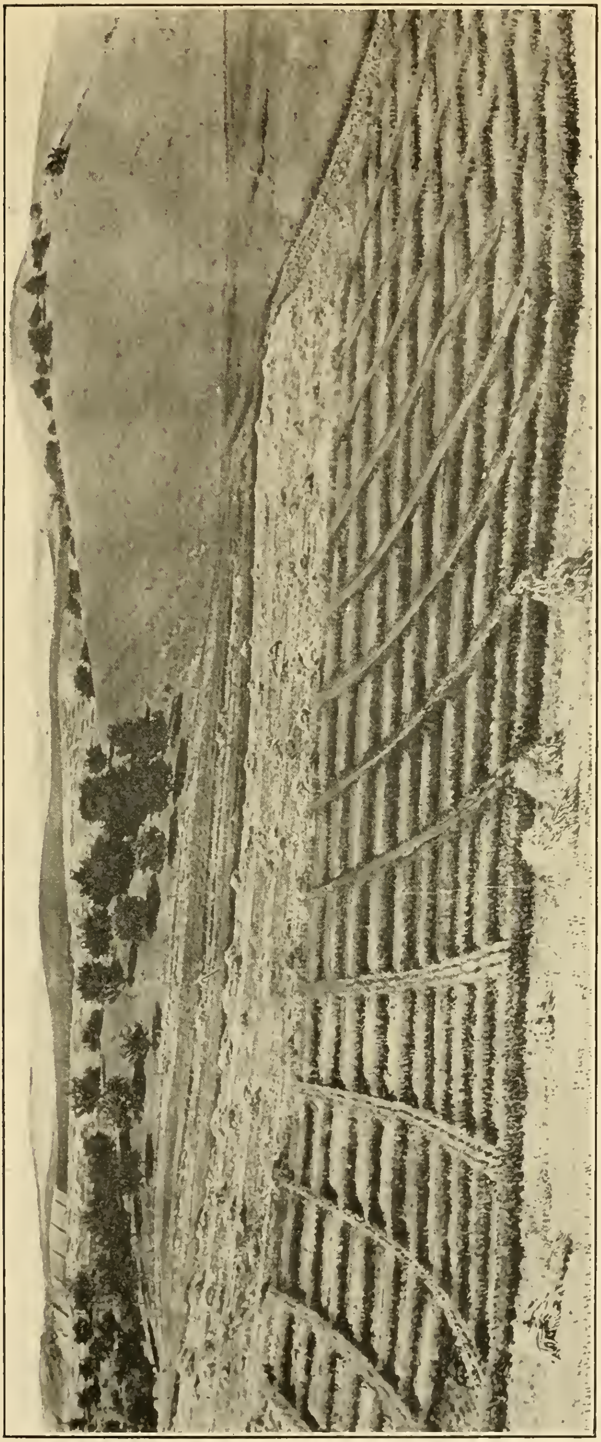


FIG. 37.—Diagram showing maximum and minimum damage done by the legume pod moth to varieties of peas which ceased to bloom on a given date in 1910. (Original.)

of one variety was destroyed. However, the results obtained are as conclusive as those recorded last year.

Table III gives the data of this season's work and is self-explanatory. Table IV is arranged to show the mean percentage of damage done to all plats which came into full bloom on any one date. Figure 40 graphically illustrates these results and very clearly shows that varieties which were in full bloom prior to June 28 were practically unmolested.



EXPERIMENTAL PLATS USED IN INVESTIGATIONS OF THE LEGUME POD MOTH DURING THE SEASON OF 1911. (ORIGINAL.)

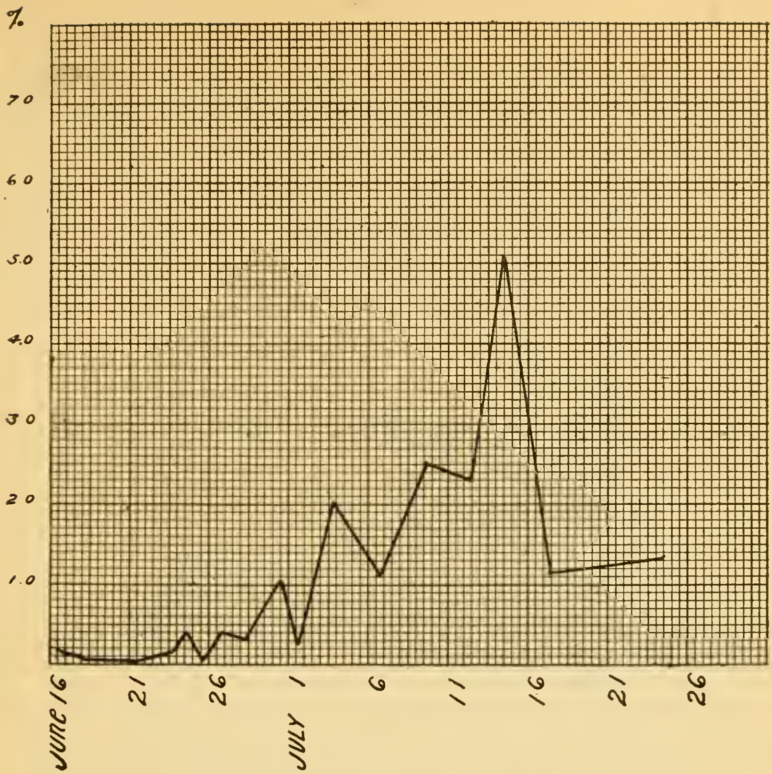


FIG. 38.—Diagram showing mean percentage of damage done by the legume pod moth to varieties of peas in full bloom on a given date in 1910. (Original.)

10	10	11	11	30	30	31	31	50	50	51	51		
9	9	12	12	29	29	32	32	49	49	52	52		
8	8	13	13	28	28	33	33	48	48	53	53		
7	7	14	14	27	27	34	34	47	47	54	54	67	67
6	6	15	15	26	26	35	35	46	46	55	55	66	66
5	5	16	16	25	25	36	36	45	45	56	56	65	65
4	4	17	17	24	24	37	37	44	44	57	57	64	64
3	3	18	18	23	23	38	38	43	43	58	58	63	63
2	2	19	19	22	22	39	39	42	42	59	59	62	62
1	1	20	20	21	21	40	40	41	41	60	60	61	61

FIG. 39.—Planting plan of plats used in investigations of the legume pod moth during the season of 1911. (Original.)

TABLE III.—*Record of experimental work on the legume pod moth for the season of 1911.*

Plat No.	B. P. I. No.	Date of planting.	Began blooming.	Full bloom.	Blooming ended.	Total number of seed.	Number of seed damaged.	Per cent damaged.
1	24895	Apr. 15	June 17	June 28	July 15	9,400	0	0.0
2	29366	...do.....	June 7	June 12	July 7	33,529	0	.0
3	22639	...do.....	June 16	June 19	July 15	23,797	5	.0
5	18806	...do.....	...do.....	...do.....	July 7	2,279	2	.0
12	29368	Apr. 17	June 22	June 28	July 15	28,417	7	.0
38	22638	Apr. 18	June 12	June 16	...do.....	19,899	4	.0
57	21288	...do.....	June 19	June 28	...do.....	22,462	8	.0
65	3182	...do.....	June 22	...do.....	...do.....	15,745	9	.0
4	17483B	Apr. 15	June 25	July 8	July 30	18,725	20	.1
8	23850	...do.....	June 16	June 28	July 21	16,380	18	.1
14	23547	Apr. 17	June 22	...do.....	July 15	19,725	21	.1
6	22540	Apr. 15	June 19	July 8	July 21	10,290	24	.2
21	232901D	Apr. 17	...do.....	July 3	July 15	22,823	46	.2
9	22044	Apr. 15	June 28	July 15	Aug. 1	14,463	104	.7
17	22043	Apr. 17	...do.....	July 13	July 29	8,416	68	.8
20	23414	...do.....	June 26	July 7	July 15	16,279	131	.8
30	29372	...do.....	June 19	June 28	...do.....	8,726	88	1.0
52	2329011	Apr. 18	June 28	July 10	...do.....	8,909	90	1.0
58	19389	...do.....	June 22	July 7	...do.....	10,080	101	1.0
10	17486	Apr. 15	June 28	...do.....	July 21	13,772	161	1.1
13	29365	Apr. 17	July 12	July 15	Aug. 1	21.795	242	1.1
39	25439	Apr. 18	June 28	July 7	July 21	20,224	223	1.1
56	24179	...do.....	June 19	July 1	July 10	13,406	148	1.1
62	11097	...do.....	...do.....	June 28	...do.....	31,369	377	1.2
59	24940	...do.....	June 22	July 5	July 15	22,259	268	1.2
54	23290E	...do.....	June 28	July 7	July 21	24,165	290	1.2
51	22049	...do.....	....	July 15	...do.....	12,514	151	1.2
47	21709	...do.....	June 22	June 28	July 15	3,235	42	1.3
48	22077	...do.....	June 12	...do.....	...do.....	14,303	201	1.4
34	16130	Apr. 17	June 28	July 8	July 26	22,857	320	1.4
44	16436A	Apr. 18	....	July 7	July 21	10,226	154	1.5
22	22037	Apr. 17	July 12	July 15	Aug. 1	19,761	299	1.5
23	17483	...do.....	July 7	July 13	July 30	12.814	193	1.5
63	11112A	Apr. 18	June 16	July 7	July 23	13,164	211	1.6
19	17006	Apr. 17	July 7	July 12	July 21	14,352	243	1.7
43	22042	Apr. 18	...do.....	July 15	Aug. 1	11,828	201	1.7
26	22046	Apr. 17	....	...do.....	July 30	13,141	224	1.7
16	29369	...do.....	June 26	July 7	July 15	10,112	184	1.8
31	2203	...do.....	July 7	July 13	July 21	15.373	277	1.8
35	22036	...do.....	June 26	July 7	...do.....	20,868	376	1.8
67	11112	Apr. 18	June 19	...do.....	July 15	16,234	294	1.8
28	29367	Apr. 17	June 24	...do.....	...do.....	9,399	188	2.0
42	21290	Apr. 18	...do.....	July 5	...do.....	14,588	292	2.0
33	29371	Apr. 17	June 28	July 7	July 21	26,239	527	2.0
46	25917	Apr. 18	July 7	July 15	...do.....	22,859	457	2.0
66	3179	...do.....	....	July 10	July 26	13,599	272	2.0
61	22048	...do.....	July 7	July 15	Aug. 1	19,140	383	2.0
11	22639A	Apr. 17	June 28	July 7	July 21	9,277	199	2.1
18	17483F	...do.....	July 12	July 15	...do.....	15,379	323	2.1
24	29323	...do.....	June 22	July 7	July 15	13.528	285	2.1
27	19786	...do.....	....	...do.....	July 25	10,621	223	2.1
36	27003	...do.....	July 7	July 13	July 26	22,266	468	2.1
40	16437A	Apr. 18	June 28	July 7	July 21	8,776	185	2.1
53	12887	...do.....	...do.....	...do.....	July 15	29,165	613	2.1
60	22041	...do.....	July 7	July 13	July 25	20,366	428	2.1
55	29370	...do.....	...do.....	July 15	...do.....	7,333	162	2.2
49	23847	...do.....	...do.....	...do.....	July 21	18,206	401	2.2
45	20467	...do.....	June 28	July 7	...do.....	14,602	322	2.2
25	19788	Apr. 17	July 7	July 15	Aug. 1	11,209	259	2.3
50	27004	Apr. 18	...do.....	...do.....	July 27	10,370	239	2.3
64	3184	...do.....	June 28	July 5	July 15	14,933	359	2.4
41	22040	...do.....	July 7	July 13	July 21	16,498	397	2.4
15	17483C	Apr. 17	...do.....	July 15	Aug. 1	1.871	45	2.4
32	26819	...do.....	....	July 18	...do.....	24.470	612	2.5
29	19787	...do.....	July 7	July 15	...do.....	15,473	387	2.5
7	19709	July 15	....	...do.....	...do.....	7,506	192	2.6
37	16436C	July 18	June 28	July 7	July 21	21,791	557	2.6

TABLE IV.—*Mean percentage of damage done by the legume pod moth to all plats in full bloom on a given date in the season of 1911.*

Full bloom.	Mean per cent of seed damaged.	Number of plats.	Full bloom.	Mean per cent of seed damaged.	Number of plats.
June 12	0.0	1	July 7	1.7	19
June 16	.0	1	July 8	.6	3
June 19	.0	2	July 10	1.5	2
June 28	.5	10	July 12	1.7	1
July 1	1.1	1	July 13	1.8	6
July 3	.2	1	July 15	1.9	15
July 5	1.9	3	July 18	2.5	1

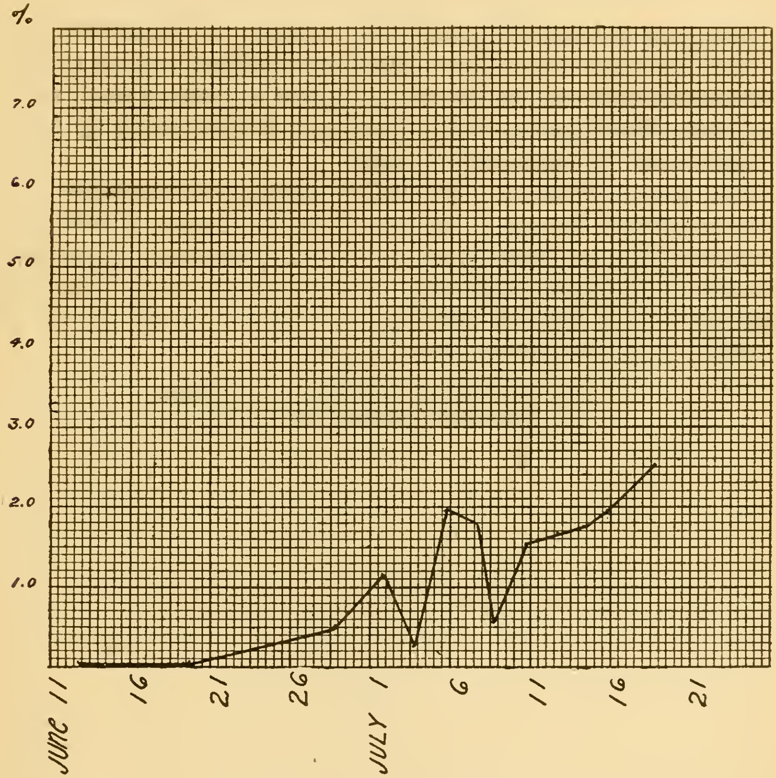


FIG. 40.—Diagram showing mean percentage of damage done by the legume pod moth to varieties of peas in full bloom on a given date in 1911. (Original.)

ARTIFICIAL DISSEMINATION.

On examining sacks of seed peas, September 14, 1911, a larva was found enclosed in a very tough silken cocoon. On October 24 another larva was found in a second sack. Mr. Evans also found a hibernating larva in a seed sack and kept it alive on his desk during the greater part of the winter. It seems as if this insect could very easily be introduced into regions where it does not at present occur, by being shipped with the seed field peas.

PARASITES.

Two hymenopterous parasites were reared from the larvæ of *Etiella zinckenella schisticolor* during the investigations at Pullman, Wash., viz, *Pseudapanteles etiellæ* Vier. and *Microbracon hyslopi* Vier.

Dr. F. H. Chittenden [1] records having reared *Bracon* sp. (determined by Viereck) from *Etiella schisticolor* on October 19, 1908, at Santa Ana, Cal., and Mr. C. L. Marlatt [2] records rearing a braconid from the larva of this moth at Nuecestown, Tex., on May 13, 1896.

REMEDIAL AND PREVENTIVE MEASURES.

The legume pod moth is readily controlled by preventive measures, and for this reason there have been no experiments with remedies. The transportation of the hibernating forms in sacks of seed, and the consequent dissemination of the pest, may be prevented by fumigation of the seed with carbon bisulphid.

Owing to the presence of the native lupines, extermination of the pest is impossible, but by planting such early varieties of field peas as come into full bloom before the last week in June it may be practically eliminated as a factor to be dealt with in seed growing in the Pacific Northwest. The date of planting, however, will vary in different localities and under different conditions.

---

[1] Bul. 82, Pt. III, Bur. Ent., U. S. Dept. Agr., p. 28, 1909.

[2] Bureau of Entomology Notes, No. 7044.

THE LEGUME POD MAGGOT.

(*Pegomya planipalpis* Stein.)

By James A. Hyslop,

Agent and Expert.

GENERAL ACCOUNT.

About the middle of July, 1909, a large number of larvæ of *Pegomya planipalpis* Stein were found leaving the pods of lupines that had been placed in rearing cages. On the 28th two pupæ were found in one of the cages. Within the next few days many more larvæ left the pods and pupated. A number of these puparia placed in a glass vial during the autumn of 1910 were kept in the field laboratory all winter. May 11 of the following year the first adult emerged and from that date others emerged daily throughout the remainder of the month. By a number of experiments it was found that humidity greatly facilitated the emergence of these flies.

These flies were first believed to be scavengers, feeding on the frass and decaying seed of the lupine and field peas in the wake of the legume pod moth. However, investigations in 1910 proved that the insect, though often found with Etiella, was quite capable of independently infesting seed pods and was itself an actual seed destroyer. Many pods were found to contain from one to three of these larvæ.

Dr. F. H. Chittenden,[1] of this bureau, notes this species as attacking radishes at San Francisco, Cal.

The larvæ molt at least twice, as two pairs of pharyngeal hooks were found in a pod with one larva. Though several of these dipterous larvæ were found in field-pea pods with the head capsules of larvæ of the legume pod moth, we hardly believe this species to be parasitic, as larvæ confined in small vials with pod-moth larvæ would not attack the latter.

In cages with earth in the bottom the pupæ were always to be found below the surface at distances ranging from 1 to 3 inches. The larvæ contract just before forming a puparium. The puparium is at first creamy yellow, turning brown at the ends first and finally becoming entirely ferruginous. A larva that contracted on the morning of July 31, 1911, assumed the usual puparium form by 9.30 a. m. of the same day. It was still pale yellow, but by 2.30 p. m. it had become brownish at the ends and deep orange-yellow at the middle, while next morning the puparium was uniformly ferruginous brown.

[1] Bul. 66, Pt. VII, Bur. Ent., U. S. Dept. Agr., p. 95, 1909.

DESCRIPTION.

THE LARVA.

(Fig. 41.)

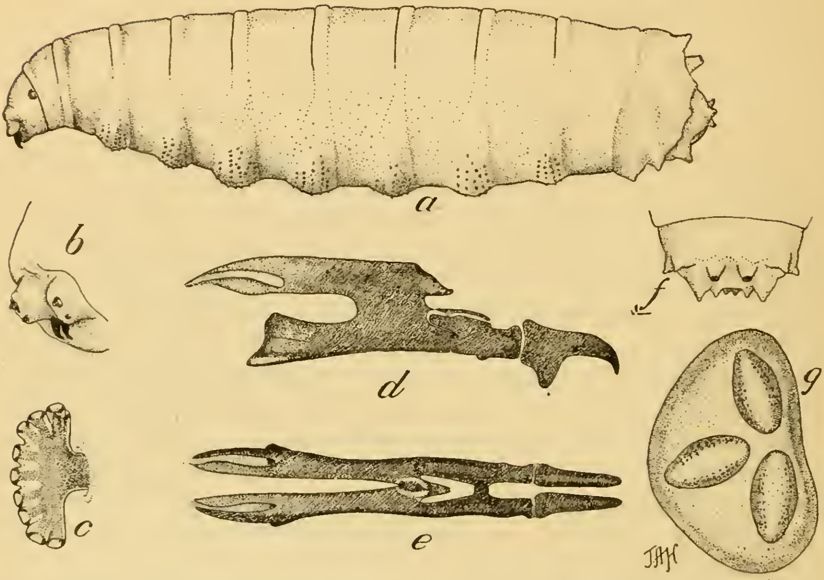


FIG. 41.—The legume pod maggot (*Pegomya planipalpis*). Larva: *a*, Side view; *b*, oblique aspect of head; *c*, thoracic spiracle; *d*, *e*, pharyngeal hooks, lateral and dorsal aspect; *f*, dorsal aspect of caudal segment; *g*, anal spiracle. *a*, Much enlarged; *b–g*, highly magnified. (Original.)

Larva cream-white, 7.9 mm. in length and 1.9 mm. in diameter. Broadly blunt posteriorly, conically tapering to anterior end. Hook jaws black. At base of second thoracic segment a pair of fan-shaped thoracic spiracles which are pale yellow and ten-lobed. Anal spiracles on rather long papilliform tubercles; spiracular orifices of each spiracle three in number and arranged to form a letter T, the stem directed laterad and slightly ventrad. Four small tubercles below the spiracles are arranged in a row across the end of the caudal segment, the outer pair the larger. In front and to the side of this row is a pair of larger tubercles and in front of this pair is a ring of twelve tubercles around the segment; the two dorso-lateral and the two ventro-lateral tubercles large and conspicuous, the others smaller. Ventral swellings on segments 3 to 9, inclusive, armed with many small spinous papillæ.

FIG. 42.—The legume pod maggot: Puparium. Much enlarged. (Original.)

THE PUPARIUM.

(Fig. 42.)

Puparium ferruginous, dark brown at ends. Cylindrically oval, finely wrinkled. Hook jaws of larva visible. Length 6.4 mm.; width 2.3 mm.

THE PUPA.

(Fig. 43.).

White, head large, front protruding. Legs and wing pads free. Third pair of legs under wing pads except tarsi.

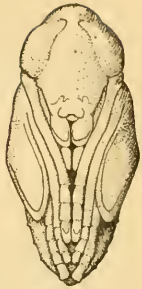


Fig. 43.—The legume pod maggot: Pupa. Much enlarged. (Original.)

THE ADULT.

(Fig. 44.)

The following is a translation of the original description by P. Stein, published in the Berliner Entomologische Zeitschrift, volume 42, page 234, 1897.

Pegomya (*Chortophila*) *planipalpis*. ♂ ♀. Size, shape, and color similar to *Ch. cilicrura* Rd. Cinereous; eyes cohering closely on inside, frontal triangular stripe practically straight, reddish; front and epistoma laterally moderately prominent, cinereo-rufous, peristome moderately broad, grayish; antennæ black, third joint twice as long as second, base of arista thickened, very slightly pubescent,

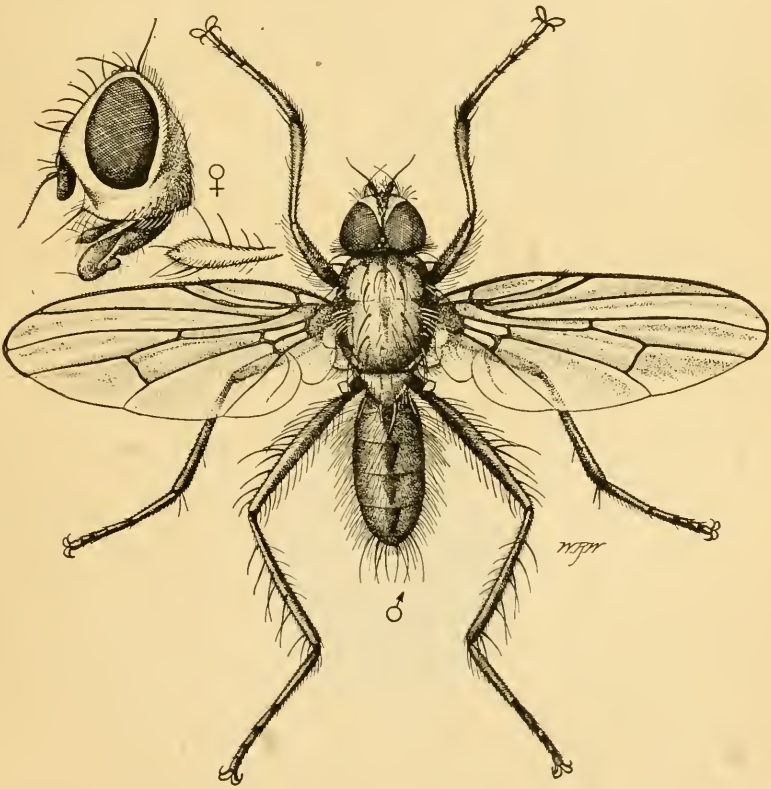


Fig. 44.—The legume pod maggot: Adult male, enlarged; side of head of female, much enlarged. (Original).

palpi black, apex a little dilated; thorax cinereous, less so on the sides, median line narrow and lateral stripes hardly perceptibly wider; abdomen elongate, depressed, median stripe and incisures narrowly black; tarsi black; pulvilli and ungues, the anterior ones moderately and the posterior one slightly, elongate; wings nearly hyaline, longitudinal veins 3 and 4 parallel, anterior cross-vein perpendicular and nearly straight, costal spines small; squamæ equal and white, halteres yellowish. Female yellowish-gray; eyes with frontal stripe broad, dirty reddish, and quite broadly separated with yellowish gray; palpi distinctly dilated at apex; thorax nearly immaculate; abdomen oblong, median stripe and small areas shining indistinct yellowish brown; base of wings yellowish. Size ♂ 5, ♀ 6 mm.

PARASITES.

Pegomya planipalpis is attacked by two chalcidid parasites. One (*Holaspis* n. sp.) belongs to a genus of which there are two known species, *Holaspis parellina* Boh. and *H. papaveris* Thoms., recorded [1] as parasitic on *Cecidomyia* spp. The other parasite (not yet determined) reared from the legume pod maggot is probably also new to science.

REMEDIAL AND PREVENTIVE MEASURES.

This maggot has not as yet become a serious factor in field-pea seed growing in the Pacific Northwest. The dissemination as hibernating puparia can be readily prevented by fumigation. As is the case with the legume pod moth, it can not be exterminated because of the native lupines.

[1] Dalla Torre, Catalogus Hymenopterorum, vol. 5, p. 291, 1898.

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE ALFALFA LOOPER.

BY

JAMES A. HYSLOP,
Agent and Expert.

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BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
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GEO. I. REEVES, W. J. PHILLIPS, C. N. AINSLIE, E. O. G. KELLY, T. D. URBAHNS, HARRY S. SMITH, GEO. G. AINSLIE, J. A. HYSLOP, W. R. WALTON, J. T. MONELL, J. J. DAVIS, T. H. PARKS, R. A. VICKERY, HENRY FOX, V. L. WILDERMUTH, R. W. MCCONNELL, E. G. SMYTH, HERBERT T. OSBORN, PHILIP LUGINBILL, C. W. CREEL, E. J. VOSLER, R. N. WILSON, VERNON KING, GEO. I. SMITH, E. H. GIBSON, L. P. ROCKWOOD, IRVING CRAWFORD, *entomological assistants.*
NETTIE S. KLOPFER, ELLEN DASHIELL, *preparators.*
MIRIAM WELLES REEVES, *collaborator.*

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U. S. D. A., B. E. Bul. 95, Part VII. Issued October 16, 1912.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE ALFALFA LOOPER IN THE PACIFIC NORTHWEST.

(*Autographa gamma californica* Speyer.)

By J. A. Hyslop,
Agent and Expert.

INTRODUCTION.

The first record of this moth of economic importance is an unpublished note by Mr. Theodore Pergande[1] made June 29, 1895, wherein he records having received from Mr. E. W. Baker, of Grand Junction, Colo., a few specimens of the larvæ of a Plusia, determined on the note as "*Plusia gamma* (?)," with the statement that the larvæ do much damage to the leaves and blossoms of alfalfa. Material was not preserved, so actual specific determination is impossible. As *Plusia gamma* L. is a European species, presumably it was *P. gamma californica* Speyer, now known as *Autographa gamma californica.*

The depredations of this species have not as yet been sufficiently serious to cause damage in the Palouse region of Washington and Idaho, although its attacks on alfalfa and clover have attracted the attention of many ranchers. The larvæ are usually very numerous in the early spring and gradually increase in numbers until the first hay cutting, when they appear to reach the maximum. They do not seem to be inconvenienced by the removal of the hay crop, but immediately turn their attention to the young second growth, on which larvæ are to be found throughout the summer until the early frosts.

The alfalfa looper in this locality has been held in check by a number of parasites and a disease, but any change in environmental conditions which might tend to reduce the efficiency of these natural checks or accelerate the reproduction of these moths would undoubtedly cause a serious outbreak, such as occurs periodically with the highly parasitized white-marked tussock moth, *Hemerocampa leucostigma* S. & A. It does, however, offer an excellent illustration of the statement, so often made, that many injurious insects are held in check by their parasites. Such cases as the above justify the arti-

[1] Bureau of Entomology Notes, No. 6692.

ficial introduction of parasites as one of the efficient measures to be taken in the control of a serious pest.

That *Autographa gamma californica* may appear in enormous numbers is evidenced by one of the earliest biological records on this species. A note in the Bureau of Entomology files, made by Mr. Koebele[1] in 1886, states that on the morning of April 30 he examined a mass of material collected from within an electric light globe at Los Angeles, Cal. Of 4,161 moths examined, 2,005 were *Autographa gamma californica*. He further states that the larvæ were numerous on a variety of plants. In anticipation of such an outbreak the biological notes and other data at hand in this office are herewith published.

DISTRIBUTION.

Specimens of this moth (*Autographa gamma californica*) in the United States National Museum were collected in Los Angeles County, Kern County, Placer, Alameda, and Fresno, Cal.; Colorado; Nevada; Seattle, Pullman, and Easton, Wash.; and along Kaslo Creek, in British Columbia. Mr. T. H. Parks, of this office, has collected larvæ of this species at Cokeville, Wyo., and Idaho Falls and Blackfoot, Idaho, in all cases feeding on alfalfa.

SEASONAL HISTORY.

This insect, in the Palouse region of Washington, passes the winter as hibernating pupa and probably also as the adult moth, since much-battered adults are to be seen early in the spring. Late in May and throughout June the adults are to be seen in the alfalfa and clover, darting rapidly away when disturbed. They are active in bright sunlight, feeding on the nectar from the clover and alfalfa blossoms. The flight, though short, is very direct and so rapid as to render the insect almost invisible.

May 2, 1887, Mr. Koebele[1] records observing one of these moths, at Alameda, Cal., ovipositing on *Malva rotundifolia* at 3 o'clock in the afternoon. Definite data relative to the length of the egg stage of this species have not been obtained, though several female moths were confined for that purpose. They fed greedily on sugar sirup but refused to oviposit. However, Mr. E. O. G. Kelly, of this bureau, captured a female of *Autographa brassicæ* Riley in an alfalfa field at Wellington, Kans., on October 27, 1909. This moth died the following day, after laying eight eggs. These began hatching on November 2 and were all hatched the next day. This limits the egg stage of *Autographa brassicæ* to seven days, and this is very likely the time of incubation of the other species of this genus.

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[1] Bureau of Entomology Notes, No. 95 K.

Early in June the young larvæ become numerous in the fields, walking very much as do geometrid larvæ or "measuring worms." This is due to the fact that the larvæ have prolegs on only the fifth, sixth, and ninth abdominal segments. If disturbed they curl up and drop to the ground, the older larvæ lying there tightly curled up and refusing to move when irritated, but larvæ of the second and third instars when touched alternately straighten out and curl up very suddenly, thus jumping about spasmodically. The larvæ while young feed upon the epidermis of the leaves, skeletonizing them and giving to the attacked plant a brownish appearance. The older larvæ—that is, after the third molt—eat from the edge of the leaf toward the midrib, entirely consuming the leaves. The larval period lasts about two weeks, there being five molts with periods of about three days elapsing between each. When ready to pupate the larva spins a loose white silken cocoon (Pl. XI, fig. 2) among a number of leaves, usually well up in the plants, incorporating two or three leaves in its structure. The larva completes the cocoon in about half a day and, at least in the case of specimens reared in our insectary, pupates the day following that on which the cocoon is completed. The length of the pupal stage of specimens reared in our laboratory was very uniformly 10 or 11 days. Dr. H. G. Dyar[1] gives 12 days as the length of this period, and Mr. Koebele[2] records the length of the pupal stage as from 10 to 15 days. He gives an exact rearing record[3] wherein he mentions a larva collected at Piedmont, Cal., February 24, 1888, which pupated on March 5, the moth emerging March 22, making a pupal period of 17 days. Dr. F. H. Chittenden, of this bureau, gives from 6 to 22 days as the pupal period of a closely related species, *Autographa brassicæ.*

Thus the time elapsing from egg laying until the adult emerges covers a period of from 26 to 48 days, probably being about 30 days in the Palouse country of Washington.

The first adults of the second generation appear in early July, and adults continue quite numerous throughout this month, belated individuals having been collected as late as August 3. There are two generations, and probably three in the case of the earlier appearing individuals, and larvæ in all instars are to be found in the field as late as the end of August, but these very late larvæ probably succumb during the winter.

Mr. T. H. Parks, of this office, records finding the larvæ of this species about half grown in the alfalfa fields about Salt Lake City, Utah, as early as May 22, in 1911. Larvæ were found throughout June. The first pupa found in this locality was obtained on June 5

[1] Entomologica Americana, vol. 6, p. 14, 1890.
[2] Bureau of Entomology Notes, No. 95 K.
[3] Bureau of Entomology Notes, No. 389 K.

from a larva in one of the rearing cages. Mr. Parks records obtaining an adult in his cages on July 7, and observed another adult in the alfalfa fields near the Salt Lake City Field Laboratory on August 2. On August 23 one of these moths was found under a board lying along a fencerow adjoining an alfalfa field near Salt Lake City.

FOOD PLANTS.

Mr. Koebele[1] records the larva of this species as feeding on cabbage, barley, and elder (*Sambucus* sp.) at Los Angeles, Cal.; on dock (*Rumex* sp.) at Piedmont,[2] Cal., and records collecting a female while ovipositing and also larvæ while feeding on *Malva rotundifolia* at Alameda, Cal. We have collected the larvæ and reared adults from red clover, alfalfa, and garden peas at Pullman, Wash.

DESCRIPTIONS.

THE EGG.[3]

"Egg hemispherical, rounded at the base, the apex with a rounded depression. Finely creased vertically; color pale yellow."

THE LARVA.

First instar (?).—Body slender, pale creamy white, with long black hairs; head conspicuously large, shining black; thoracic legs blackish; only three pair of prolegs, situated on abdominal segments 5, 6, and 9, prolegs concolorous with body. Length, 1.8 mm.

Second instar.—Body segments 7 and 8 enlarged, 9 small; color pale green, marked with cream-colored longitudinal lines as follows: A subdorsal line, very fine and wavy; a stigmatal line, broader, straight, sharply defined dorsally, and fading out ventrally; segments ornamented with transverse row of black papillæ bearing black hairs; head cream-color; thoracic legs cream-color, with tips of claws ferruginous. Length, 3 mm. to 5 mm.

Third instar.—Body papillæ white, with black dots at base of hairs; three longitudinal lines in subdorsal space, the more dorsal one fine, clearly defined and wavy, the middle one broad and indistinct, and the third one about as fine as the first but less wavy; stigmata on first thoracic and first to eighth abdominal segments, pale, with oval black margins, that on eighth abdominal segment much larger than others; mandibles pale reddish brown; eyes with series of six black dots arranged in a ventrally directed semicircle near the base of the antennæ. Length, 6 mm. to 9 mm.

Fourth instar.—Body darker green, papillæ in two transverse rows, the papillæ of one row alternating with those of the other; head green, paler than body, mandibles and palpi brownish; thoracic legs infuscate; marginal hooks of prolegs ferruginous-brown. Length, 10 mm. to 14 mm.

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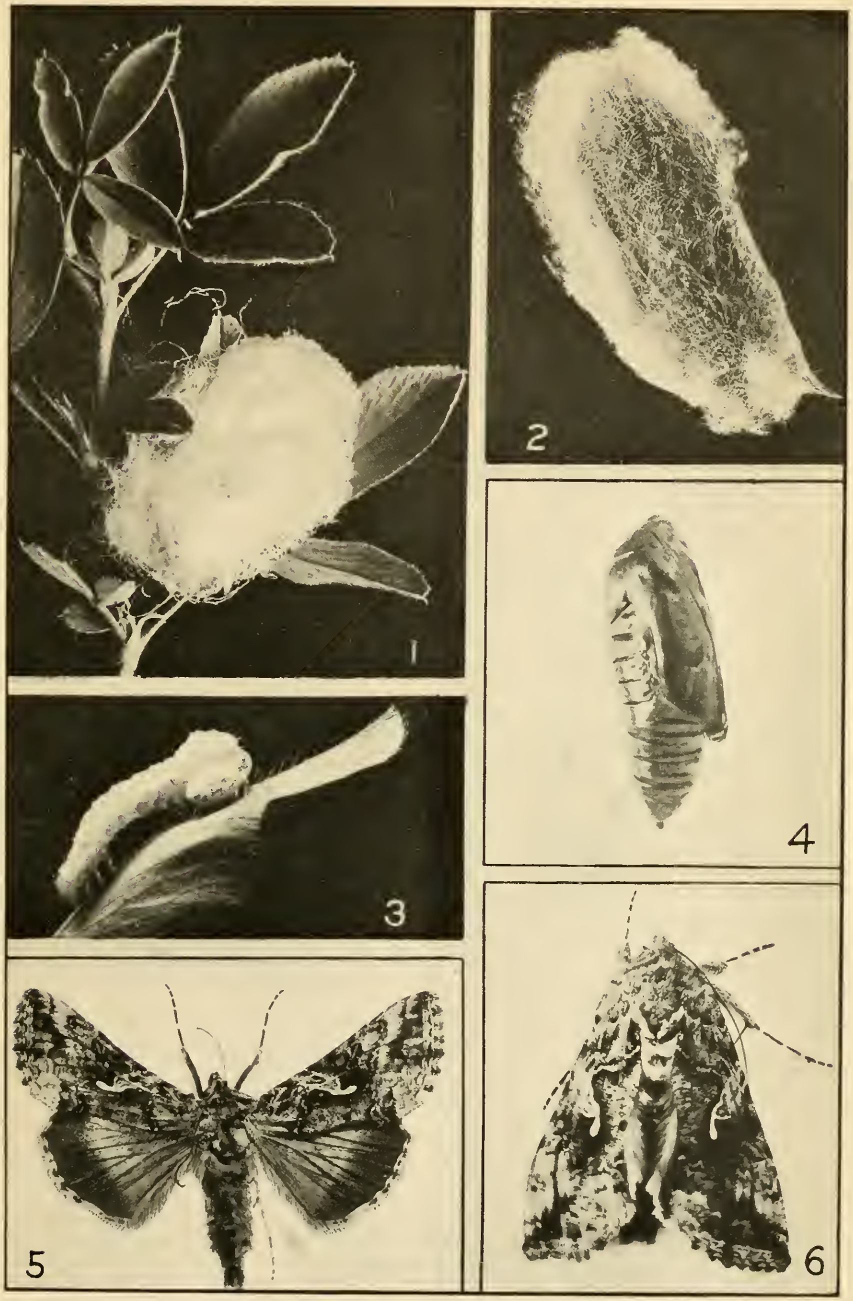
[1] Bureau of Entomology Notes, No. 95 K.
[2] Bureau of Entomology Notes, No. 389 K.
[3] Entomologica Americana, vol. 6, p. 14, 1890.



THE ALFALFA LOOPER AND ITS PARASITES.

Fig. 1.—Cocoon cluster of *Apanteles hyslopi*. Fig. 2.—Cocoon of alfalfa looper (*Autographa gamma californica*). Fig. 3.—Larva of alfalfa looper with cocoon of *Microplitis alaskensis*. Fig. 4.—Pupa of alfalfa looper. Fig. 5.—Adult alfalfa looper. Fig. 6.—Adult alfalfa looper at rest. All enlarged. (Original.)

Fifth instar (fig. 45).—Body dark olive-green, dorsal edge of stigmatal line opposed by an almost black line which fades into the general body color dorsally; head brilliant green, mandibles and palpi brown, a black oblong patch on posterior margin of eye extending from near median line almost to base of mandibles; thoracic legs almost black. Length, 21 mm. to 28 mm.

THE PUPA.

(Pl. XI, fig. 4.)

"Pupa depressed somewhat above the wing cases at back of the thorax, the eyes prominent, the tongue case projecting below the wing cases, forming a round prominence over the first abdominal segment. The cremaster is short and blunt, and the hooks with which it is furnished are fastened in the silk of the cocoon. Wing cases slightly creased. Color brownish-black, but paler at the joinings of the parts and between the abdominal joints. In occasional instances the whole pupa is pale."

The above description of the larval stages of this moth agrees in substance with that published by Dr. H. G. Dyar[1] for this species in California. The larvæ, however, are not constant in the matter of coloration. Adult larvæ were found without the characteristic black markings, while others had the entire head black. Some larvæ were of the same pale-green color in the fifth instar as in the fourth, while others were almost white.

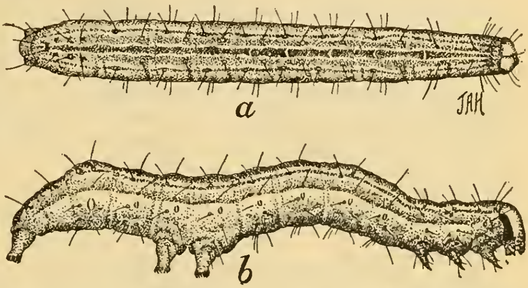


FIG. 45.—The alfalfa looper (*Autographa gamma californica*): *a*, Larva, dorsal aspect; *b*, same, lateral aspect. Enlarged 2½ diameters. (Original.)

That we had the first instar is only an assumption from the number of subsequent molts obtained. Dr. Dyar's description of the pupa is used, as it agrees identically with those found in the Northwest. The pupa is dark olive-green, with brown shadings and pale intersegmental bands when first formed, but soon becomes uniformly brown.

THE ADULT.[2]

(Pl. XI, figs. 5, 6.)

The following is a translation of Speyer's original description:

Two California males from Moschler's collections differ from the European *gamma* (which I can, however, only compare with native specimens) in the following points: The color of the dorsal surface of the forewings is a clear, light-blue gray, except the punctuation which is rose colored or rust colored; this is exhibited in all the *gamma* found here by me, and also in several distinct variations.

[1] Entomologica Americana, vol. 6, p. 14, 1890.
[2] Stett. Ent. Zeit., vol. 36, p. 164, 1875; syn: *russea* Hy Edwards.

The *gamma* mark is somewhat differently shaped: Both its upper arms diverge, thus cutting off a broader equilateral triangle, through the upper median border, between them. The outer arm of this figure forms at its inner side an obtuse angle and is directed parallel with the hind edge (of the wing) while in the European species it is more basally directed. The lower arm of the *gamma* sign runs nearly horizontal. In this direction the black enclosed part, supported by the two outer arms, is more snout-shaped while in the German forms this form is approximately a rectangular space, rounded at its apex. The ring spot is surrounded by a whitish margin, elongate, and inclined very obliquely basally. The posterior diagonal band runs from the subcostal to the inner branch of the median (branch 2), not in a smooth curve as in *gamma* but in an unbroken straight line and is not so strongly curved basally opposite the lower arm of the *gamma* sign as in the latter. On the under surface, as in the French forms, the wings are clear white with, especially on the forewings, sharp black mottlings. The remainder of the border of the underside, as is also the color of the hind wings, is lighter colored than the European forms. This form may be easily separated from moderately light varieties in color and design by these important distinctions—the *gamma* sign and the posterior diagonal band.

Whether we have to do with a distinct species, a local variety, or merely an accidental variety, must be proved by more extensive comparisons.

Specimens of *gamma* from the Atlantic States, where they are said to be indigenous by Ruhordem, Koch, and Grote, I have not yet seen. They are, when the *californica* form is considered with them, spread over the whole northern hemisphere from Greenland to Abyssinia. They should be found even in New Holland [Australia], cf., my Geographical Distribution of the Butterflies of Germany, etc., Volume II, page 219.

PARASITES.

This moth is severely parasitized.. At the field laboratory in Pullman, Wash., we obtained five hymenopterous and two dipterous parasites and observed a disease during the seasons of 1909 and 1910.

On July 12, 1909, two small larvæ of the alfalfa looper, measuring about 14 mm. in length, had contracted to 8 mm., became turgid, quite hard, and changed to a rich ferruginous brown. On July 22 of the same year two specimens of *Rhogas autographæ* Vier. (fig. 46) emerged. On close examination of this improvised puparium it is found to be almost entirely made up of the abdominal segments 7 to 12 of the lepidopterous larva (see fig. 47). The thoracic and anterior abdominal segments 1 to 6 contract to form an almost black annulated cap over one end of the puparium, with the transparent head shield terminating this cap. Segment 13, bearing the anal prolegs, terminates the other end of the puparium and is also transparent. Segments 9 and 10 each bear the transparent skin of their respective prolegs. The hair papillæ on segments 7 to 10 are pale and collected in a darker elevated band around the middle of their respective segments. The adult in emerging gnaws a smooth, circular hole through the dorsum of the eleventh and twelfth segments.

On July 29, 1909, a larva was observed with a cocoon fastened between the middle and anal prolegs (Pl. XI, fig. 3). The moth larva was still alive, though unable to move from the cocoon, and died the following day. On August 1 an adult hymenopteron, *Micro-*

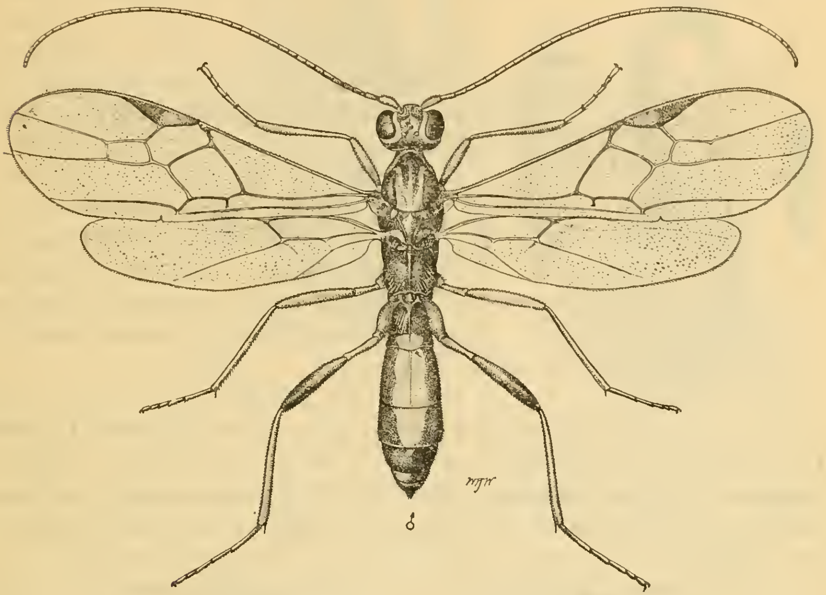


FIG. 46.—*Rhogas autographæ*, a hymenopterous parasite of the pupal stage of the alfalfa looper. Greatly enlarged. (Original.)

plitis alaskensis Ashm., emerged from this cocoon. The cocoon of this parasite (fig. 48, *c*) is pale green, 5 mm. long, cylindrically ovoid, and slightly pointed at the anterior end. In emerging the adult very neatly cuts a cap from the anterior end, this cap often remaining fastened to the cocoon by a few threads. On August 12 another larva was found bearing one of these cocoons, and on August 14 an adult parasite emerged.

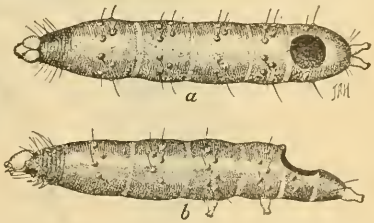


FIG. 47.—Larval skin of alfalfa looper from which *Rhogas autographæ* has issued: *a*, Dorsal aspect; *b*, lateral aspect. Enlarged 6 diameters. (Original.)

Microplitis n. sp., determined by Mr. H. L. Viereck, was reared from the larvæ of these moths on June 28, 1910. This parasite spins a tan-colored cocoon which measures 3.53 mm. in length (fig. 48, *a*).

Sargaritis websteri Vier. is one of the most numerous parasites of the alfalfa looper at Pullman, Wash. The first specimen obtained emerged on August 14, 1909. The following year specimens emerged June 21, July 5, and July 25. This species spins a cocoon (fig. 48, *b*) which is bluntly oval, mottled with brown, and measures 6.53 mm. in length.

On August 27 a dead larva of the alfalfa looper with a mass of hymenopterous cocoons fastened to it (Pl. XI, fig. 1) was found in an alfalfa field in Pullman, Wash. The cocoons were enveloped in a loose, white, silken ball 18 mm. in diameter. On August 29, 34 specimens of *Apanteles hyslopi* Vier. (fig. 49) emerged from this mass.

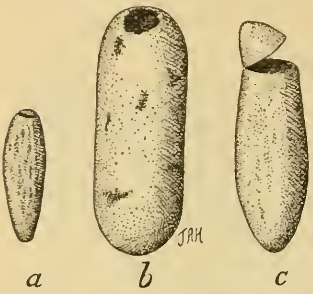


FIG. 48.—Cocoons of alfalfa looper parasites: *a, Microplitis* sp.; *b, Sargaritis websteri; c, Microplitis alaskensis.* Enlarged 5 diameters. (Original.)

Ameloctonus n. sp., determined by Mr. H. L. Viereck, was reared from the larva of this moth at Salt Lake City, Utah, in 1911, by Mr. T. H. Parks, of this office. The cocoon of the parasite was spun on August 17, and the adult parasite emerged on August 23.

One of the alfalfa looper larvæ in the insectary rearing cages started to spin a cocoon on January 11, 1909. On examining the cocoon two days later it was found to contain puparia of *Plagia americana* Van der Wulp, one entirely and one partly within the dried larval skin. On July 23 one adult emerged,

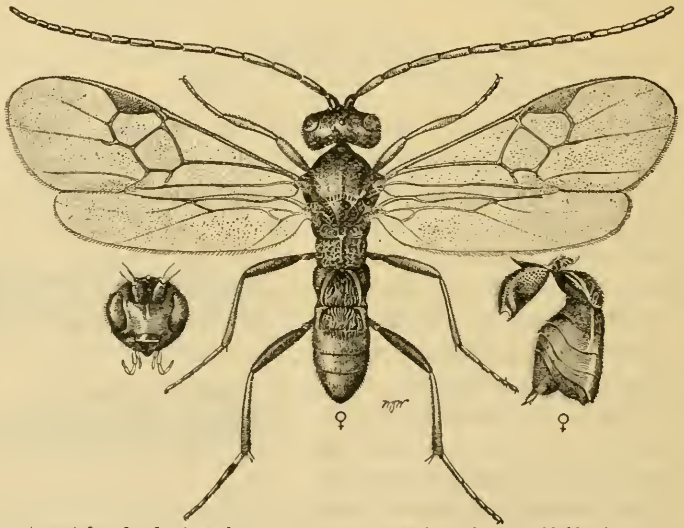


FIG. 49.—*Apanteles hyslopi,* a hymenopterous parasite of the alfalfa looper. Greatly enlarged. (Original.)

and on either July 24 or 25 another emerged (fig. 50). Several more of these flies were reared, and the number that would emerge from a larva was always directly associated with the size of the larva. A very small larva in our cages produced one fly, a medium-sized larva two, and a full-grown larva produced five of these parasites.

Two specimens of a dipterous fly, *Phorocera saundersii* Will. (fig. 51), were reared from a larva of the alfalfa looper on May 18, 1910.

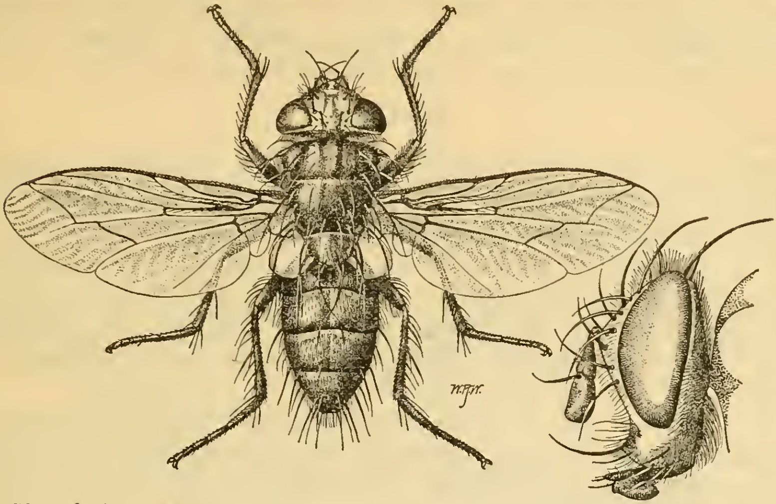


FIG. 50.—*Plagia americana*, a dipterous parasite of the alfalfa looper. Greatly enlarged. (Original.)

Mr. Koebele[1] records having reared 14 parasitic flies from a single larva of this moth at Los Angeles; but as the material is not now available, determination is impossible. These were probably not flies but Hymenoptera and very likely *Apanteles hyslopi* Vier. On

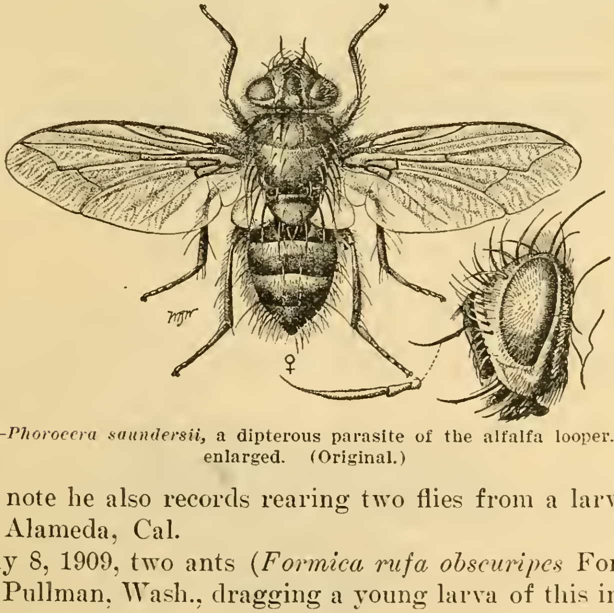


FIG. 51.—*Phorocera saundersii*, a dipterous parasite of the alfalfa looper. Greatly enlarged. (Original.)

the same note he also records rearing two flies from a larva of this moth at Alameda, Cal.

On July 8, 1909, two ants (*Formica rufa obscuripes* Forel) were found at Pullman, Wash., dragging a young larva of this insect that was alive and struggling.

[1] Bureau of Entomology Notes, No. 95 K.

Mr. T. H. Parks, of this office, also made a similar record near Salt Lake City, Utah, on August 16, 1911, wherein he observed a "number of large ants (*Formica subpolita* Mayr) dragging one of these half-grown larvæ to their nest in a field of alfalfa. The larva fought to free itself but was finally overcome and killed by the ants."

DISEASES.

Early in July, 1909, many of the larvæ in our rearing cages at Pullman, Wash., were killed by a disease. First, they became sluggish and contracted, and then turned dark brown, often being reduced to a black purulent mass. In other cases they became mummified. Specimens of these diseased larvæ were sent to Dr. Flora W. Patterson, Mycologist of the Bureau of Plant Industry, who reported that while she could find no fungi, the specimens were swarming with bacteria.

A note made by Mr. Theodore Pergande[1] February 21, 1883, records a fungous disease (*Botrytis rileyi*), having been found parasitic on *Plusia brassicæ*, by Mr. W. G. Farlow, of Cambridge, Mass.

REMEDIES AND PREVENTIVES.

Attention has already been called to the fact that in this species we have an illustration of the influence of natural enemies of a pest in protecting the interests of farmers by keeping the insect so reduced in numbers as to prevent injury to his crops. So effectually was this being done in the case of the present species as actually to prevent the conducting of experiments for warding off such injuries; hence no recommendations can be given. The time may come, however, when these natural enemies may themselves suffer reverses and temporarily fail to hold the pest in check; then the information here given will become of the utmost importance as a basis for experiments with restraining measures.

[1] Bureau of Entomology Notes, No. 294^{02}.

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