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GARDEN FLEA-HOPPER IN ALFALFA AND ITS CONTROL.

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CONTENTS.

INTRODUCTION.

Little information has been recorded regarding the biology, habits, and control of *Halticus citri*, known as the garden flea-hopper. Dr. F. H. Chittenden was the first to attach to *Halticus citri* (Ashmead), then known as *Halticus uhleri* (Giard), the common name, chosen because of the insect's injuries to truck crops and its saltatory power.

In addition to other leguminous plants the insect attacks alfalfa, injuring the plant by sucking the juices, and in fields where heavy infestation occurs may cause the loss of 50 to 60 per cent of the crop. As little was known of the insect outside of its depredations on truck crops, observations and life-history studies on the garden flea-hopper on alfalfa were conducted during the years 1915, 1916, and part of 1917, at Columbia, S. C., and also a series of control experiments for the purpose of determining the most effective means of combating outbreaks of the pest. The bulletin, therefore, gives the results accomplished by means of a combination of field and laboratory experiments.

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ORIGIN AND DISTRIBUTION.

The present known range of the garden flea-hopper covers a large portion of the United States (fig. 1). This insect belongs to the family Capsidae of the Heteroptera, is quite generally distributed throughout the eastern half of the United States, and in most instances has been reported as injurious to crops.

The garden flea-hopper is apparently American in origin. There are, however, two cases on record where it is reported as being destructive to crops outside of the United States, viz, Brazil and French Cochin China. In the latter region it seriously infested the peanut crop.[1]

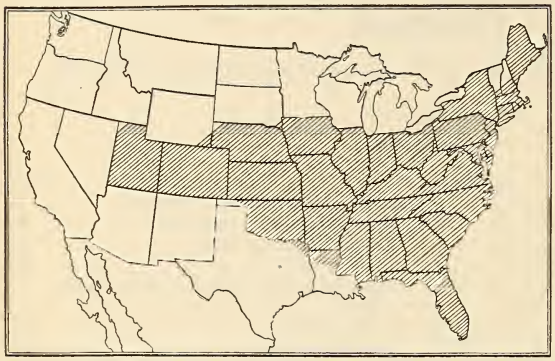

FIG. 1.—Map showing States where the garden flea-hopper (*Halticus citri*) has been found.

During the summer of 1916 the writer made numerous observations with a view of determining what effect altitude might have upon the distribution of this species. Sweepings made at the points mentioned below showed the presence of the adults and nymphs in the highest as well as the lowest altitudes where collections were made. The trip included visits during the month of August, 1916, to alfalfa and clover fields at Macon, Ga.; Gray, Ga.; Sylva, N. C.; Waynesville, N. C.; Asheville, N. C.; Statesville, N. C.; Columbia, S. C.; and Gainesville, Fla. The territory covering these points included a range of altitude from 180 feet to 2,700 feet. Gray, Ga., which has an altitude of 500 feet, was the center of the 1915 outbreak.

[1] The following notes on the garden flea-hopper (*Halticus citri*) and list of localities have been compiled from field studies in the United States and from specimens contained in the collections of the U. S. National Museum: Orange Springs, Fla., 1887 (W. H. Ashmead); Riley Co., Kans., Sept. 10, 1892 (C. L. Marlatt); Washington, D. C., June 22, 1897; Columbia, Mo., no date (C. V. Riley); Berkeley Springs, W. Va. (P. R. Uhler); Auburn, Ala., no date (P. R. Uhler); Experiment Station, Manhattan, Kans., 1889 (E. A. Smith); Experiment Station, Hartford, Conn., Sept., 1914 (W. E. Britton); Stillwater, Okla., Oct., 1912 (C. E. Sanborn); Topeka, Kans., Aug. 30, 1917 (E. A. Popenoe); Chicago, Ill., July 13, 1908 (J. J. Davis); Clemson College, S. C., July 16, 1909 (G. G. Ainslie); Nashville, Tenn., Sept. 5, 1910 (G. G. Ainslie); Experiment Station, Utah, 1893 (P. R. Uhler); Winchester, Va., July 13, 1913 (E. B. Blakeslee); Washington, D. C., 1917 (F. H. Chittenden); Gray, Ga., 1915 (R. J. Stewart); Gray, Ga., May 26, 1915 (A. H. Beyer); Macon, Ga., May 27, 1915 (A. H. Beyer); Lafayette, Ind., Aug. 11, 1916 (J. J. Davis); Atlanta, Ga., Aug. 25, 1916 (A. H. Beyer); Statesville, N. C., Aug. 31, 1916, Waynesville, N. C., Aug. 27, 1916 (A. H. Beyer); Asheville, N. C., Aug. 28, 1916 (A. H. Beyer); Charlotte, N. C., Aug. 31, 1916 (A. H. Beyer); Hagerstown, Md., Sept. 12, 1912 (H. L. Parker); Columbia, S. C., Oct. 5, 1915 (A. H. Beyer); Ithaca, N. Y., Oct., 1915 (H. H. Knight); Boston, Mass., Sept., 1915 (H. H. Knight); Springfield, Mo., July, 1915 (H. H. Knight); Quincy, Fla., May 23, 1916 (F. H. McDonough); Lakeland, Fla., Dec. 16, 1916 (A. H. Beyer); Fulton Co., N. Y., Aug., 1911 (C. P. Alexander); Indianapolis, Ind., Aug. 25, 1916 (H. F. Dietz); Gainesville, Fla., Feb. 28, 1917 (A. H. Beyer); Charleston, Mo., May 26, 1916 (E. H. Gibson); Hot Springs, Ark., May, 1916 (E. H. Gibson); Chapel Hill, N. C., Sept. 21, 1915 (P. Luginbill).

P. R. Uhler (*5*)[2] recorded the garden flea-hopper as having been found at the experiment station at Logan, Utah, which point has an approximate altitude of 4,700 feet above sea level.

SYNONYMY.

The garden flea-hopper was first named and described by Ashmead (*1*) as *Rhinocloa citri*. E. A. Popenoe (*2*) in 1890 called it "*Halticus minutus* Uhler MS." During the same year Giard (*3*) renamed the species *uhleri*, since there was already a *Halticus minutus* Reuter. Distant (*4, p. 430*) in 1893 redescribed the species as *Calocoris canus*, not recognizing its true affinities.

Reuter (*12*) in 1909 first pointed out that *Rhinocloa citri* Ashmead and *Halticus uhleri* Giard were the same, but he left the species under the latter name until 1914, when H. G. Barber (*15*) used the combination "*Halticus citri* (Ashm.)" in print.

The synonymy, therefore, is as follows:

Halticus citri (Ashmead) Barber.

Rhinocloa citri Ashmead (*1*).
Halticus minutus (Uhler MS) Popenoe (*2*).
Halticus uhleri Giard (*3*).
Calocoris canus Distant (*4*).
Halticus citri Barber (*15*).

HISTORY OF THE SPECIES AND ITS INJURIES.

Halticus citri seems first to have received economic mention in 1887, by W. H. Ashmead (*1*), who found it on orange trees in Florida.

In 1892 A. Giard (*3*) recorded it as being destructive to peanut and rice crops of French Cochin China and Singapore, Straits Settlements.

This species, with *Agalliastes bractatus* Say, was reported from Kansas in 1890 (*2*) as follows:

> We have the past season observed two species of Capsidæ, or plant-bugs, living in great numbers on the underside of the leaves of the garden bean, puncturing the tissues and sucking the sap, and by these punctures causing the death of the tissues in small, irregular patches, that appear upon the upper surface of the leaf as white spots.

It was found by J. B. Smith (*6, p. 133*) in New Jersey during 1900 injuring truck crops at the following places: New Brunswick, Jamesburg, Swedesboro, Madison, Camden County, and Vineland.

In 1900 F. M. Webster (*7*) reported it from Wooster, Ohio. F. H. Chittenden (*8*) states:

> In May and June, 1900, this insect was observed in some numbers on beans in different localities, and some leaves were found to have been killed by its attacks. Beets and cabbage were also affected, but injury was less noticeable to these crops. In 1901 the writer noticed severe injury to ornamental morning-glory in the city of Washington.

[2] Reference is made by number (italic) to "Literature cited," p. 27.

W. E. Britton (*9*) of Connecticut, during September, 1904, received specimens of the insect from Southport, Conn., with the statement that much injury was being done by it to smilax growing under glass. Injury to beans, beets, red clover, cowpeas, potatoes, chrysanthemums, morning-glories, eggplant, cabbages, and pumpkins also occurred at that time.

In 1907 F. H. Chittenden (*10, p. 118*) reported that the insect "lives in great numbers on the leaves, puncturing them so as to cause the death of the tissues in small irregular white patches. In its short-winged form it resembles the black flea-beetles, which affect potato, alike in appearance, in the nature of its work, and in its saltatory power. Other food plants include potato, pumpkin, cabbage, ornamental plants, clover, and many weeds."

In 1907 F. M. Webster recorded *H. uhleri* as destructive to alfalfa over small areas at Topeka, Kans.

In the Yearbook of 1908 Dr. Chittenden (*11*) gives the following account of *H. citri:*

> The garden flea-hopper (*Halticus uhleri* Giard) was more or less injurious to cucumbers, squash, and beans in New Jersey; to beans in the District of Columbia, and to lettuce and sweet potato in the trucking region of Norfolk, Va.

C. E. Sanborn (*14*) found the species destructive to alfalfa in Oklahoma in 1912. During the same year J. J. Davis (*13*) gives the following account of *Halticus citri:*

> This flea-hopper did much damage to smilax in several greenhouses around Chicago in 1908 . . . and just outside of the house the weeds were much infested with it—the latter fact probably accounting for its presence indoors. Early in the spring of 1909 the adults—fully winged males and females as well as the short-winged form—were found abundant in one greenhouse at a date which would preclude any possibility of their having developed out-of-doors that spring; and they did not develop inside the greenhouses from eggs deposited the fall before, as the houses had been examined during the winter and not an active "hopper" found. It was also observed that the individuals became adult in the fall, as cold weather set in. From these observations it appears that the adults hibernate in greenhouses or out-of-doors and become active in the spring, when they deposit their eggs for that season's generation—instead of doing it in the fall before, as has heretofore been supposed.

Following are from the notes of Mr. G. G. Ainslie, of the Bureau of Entomology:

> Clemson College, S. C., July 16, 1909: The alfalfa is conspicuously whitened by the adults and larvæ of this bug which have come there from the adjoining peas. The habitats of the insect seem to be the same on alfalfa as peas. The adults are found on both sides of the leaves but mainly the lower, while the larvæ are confined to the lower side.
>
> Nashville, Tenn., September 5, 1910: Found a field of alfalfa badly whitened by the attacks of this species. The plants looked sickly from the work of these bugs.

July 13, 1913, Mr. E. B. Blakeslee of Winchester, Va., reported to Prof. A. L. Quaintance of the Bureau of Entomology the occurrence of enormous numbers of *H. citri* in alfalfa fields, both in the adult and

nymphal stages. Mr. J. R. Stewart, of Gray, Ga., under the date of May 9, 1915, reported severe injury by the garden flea-hopper to a field of alfalfa that had yielded fine crops for two years.

Mr. E. H. Gibson on May 26, 1916, reported it as being injurious to alfalfa at Charleston, Mo.

RECENT INJURIES.

During the year 1915 serious attacks by *Halticus citri* on cereal and forage crops in the South Atlantic States, and especially in Georgia,

FIG. 2.—Alfalfa showing the effect of injury by the garden flea-hopper on the leaves.

directed the attention of the Bureau of Entomology to the need of investigational work with respect to this insect. The late Prof. F. M. Webster, entomologist in charge of cereal and forage insect investigations, immediately instituted researches for the purpose of determining suitable control measures.

The writer began his investigations at Gray, Ga., May 26, 1915. In walking through the alfalfa fields at this place infestation by the garden flea-hopper was found exceedingly abundant, the insect being present in all stages of its life cycle; the distribution of the pest in

each field was found to be quite uniform excepting along the fences, where the plants were most seriously affected, leaves being discolored and dropping off, and the plants dying in frequent instances.

It was observed that the injury caused to alfalfa by *Halticus citri* very closely resembled that of the red spider (*Tetranychus bimaculatus* Harv.).

All the cereal and forage and truck crops, wild mulberry trees, peach trees, and a large number of weeds, including the briar and

FIG. 3.—At the right, normal healthy leaves of red clover. At the center and left, leaves seriously affected by the garden flea-hopper.

species of the mint family, were found infested with this insect. More noticeable damage, however, was shown by alfalfa, cowpeas, and clover than by other growing crops.

DAMAGE TO ALFALFA.

The injury which is inflicted on alfalfa and other plants is caused by both adults and nymphs. Damage is done by means of their sharp pointed mouth-parts which are inserted into the plant tissues. The short chitinized beak is thrust through the surface of the leaf or its

petiole and sap is extracted, giving the leaves a bleached appearance and often killing them. In extreme cases the stems of the plants are attacked in like manner. The greatest amount of damage results from the loss of plant sap or juices. The leaves die and in many instances drop from the stems and cause the infested plants to appear as bunches of stubble. (See figs. 2 to 6.)

The loss to the crop has been estimated by the writer as high as 50 to 60 per cent in several severely infested fields where the alfalfa had been cut and the cured hay removed. The damage is quite noticeable

FIG. 4.—White clover showing the effect of injury on the leaves by the garden flea-hopper.

in the field, since the plants have not the green color and freshness characteristic of plants that are uninjured, and have become fibrous, contrasting with other plants of luxuriant growth and thrifty condition. The extraction of the plant juices checks the growth of the plant, causing it to shrivel up and in a number of instances to die. After the crop has been cut and the hay removed from the field an inspection of the alfalfa field shows that a large number of the leaves have fallen from the plants and been left lying on the ground, causing a loss of much of the food

value of the hay. This is due in large measure to the injury resulting from the feeding of the garden flea-hopper upon the petioles, leaves, and tender stems.

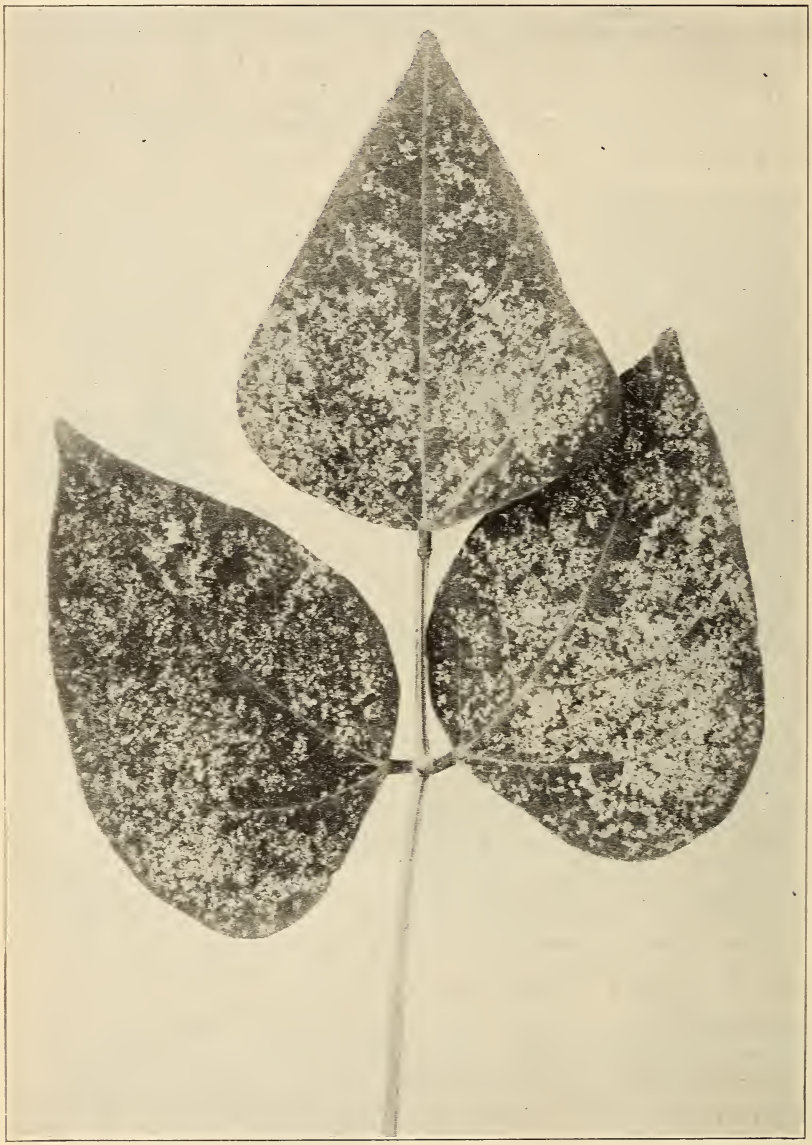

FIG. 5.—Cowpeas showing the effect of injury by the garden flea-hopper on the leaves.

HOST PLANTS.

Throughout the South Atlantic States the species was found prevalent on alfalfa, the clovers, cowpeas, and some of the common

weeds. All common garden truck was also found to be among the favorite host plants with the possible exception of the red pepper plant which showed very slight attack or injury. It was found on

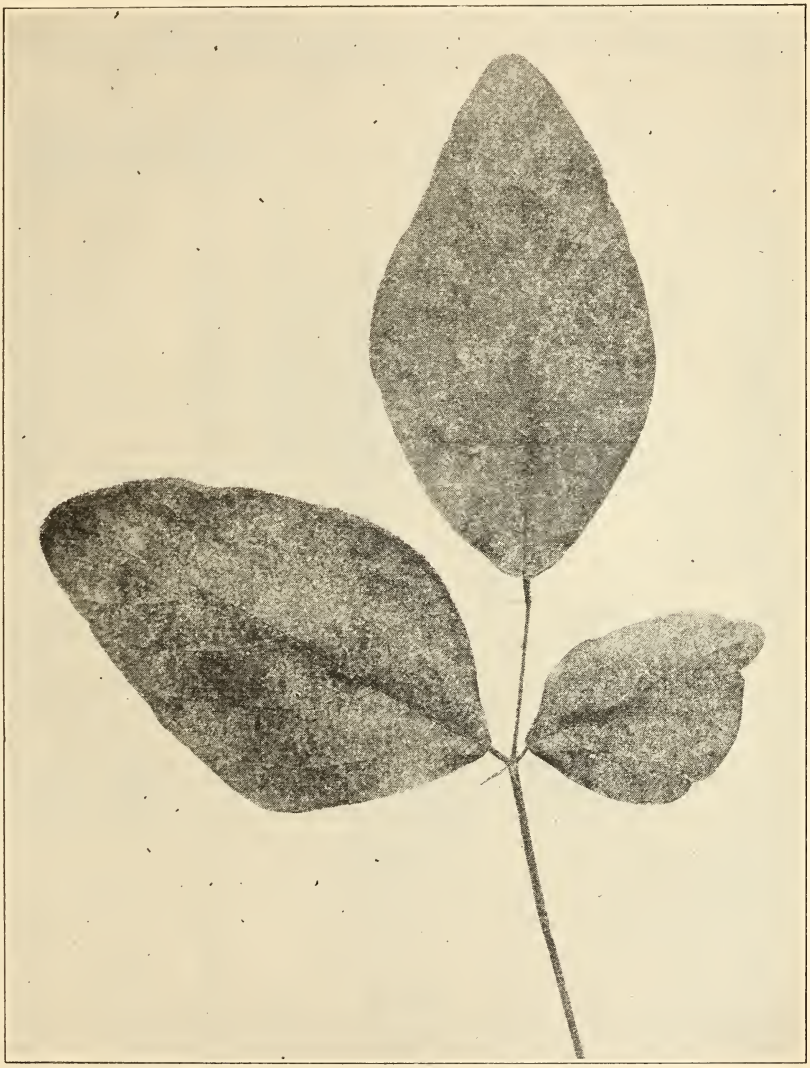

FIG. 6.—Beggar-weed (*Meibomia tortuosa*) showing the effect of feeding of the garden flea-hopper upon the leaves.

plants in greenhouses the year round, and on the out-of-door flowering plants it was especially noticeable in the early spring and late fall, although also common throughout the summer.

Tables I, II, and III were prepared after a close examination of the most seriously infested host plants collected from the fields in which outbreaks occured, and show that alfalfa is most frequented by *Halticus citri* for egg laying.

TABLE I.—*Infestation in alfalfa by Halticus citri, showing the number of eggs in each leaf and where deposited.*

Leaf No.	Eggs deposited in upper surface.	Eggs deposited in lower surface.	Total number of eggs deposited.	Leaf No.	Eggs deposited in upper surface.	Eggs deposited in lower surface.	Total number of eggs deposited.
1	3	1	4	27	3	0	3
2	11	0	11	28	2	0	2
3	12	7	19	29	3	0	3
4	5	1	6	30	16	2	18
5	2	1	3	31	30	0	30
6	1	1	2	32	53	0	53
7	7	0	7	33	10	7	17
8	3	0	3	34	31	0	31
9	15	0	15	35	6	0	6
10	4	0	4	36	23	0	23
11	5	0	5	37	15	1	16
12	1	0	1	38	23	15	38
13	28	1	29	39	2	0	2
14	4	0	4	40	3	0	3
15	5	10	15	41	5	0	5
16	0	0	0	42	2	1	3
17	1	0	1	43	2	0	2
18	2	5	7	44	3	0	3
19	10	1	11	45	5	0	5
20	2	0	2	46	3	0	3
21	12	4	14	47	7	1	8
22	2	2	4	48	1	1	2
23	1	0	1	49	20	1	21
24	6	1	7	50	9	0	9
25	8	1	9				
26	1	0	1	Total	428	65	493

TABLE II.—*Infestation in clover by Halticus citri, showing the number of eggs in leaf and where deposited.*

Leaf No.	Eggs deposited in upper surface.	Eggs deposited in lower surface.	Total number of eggs deposited.	Leaf No.	Eggs deposited in upper surface.	Eggs deposited in lower surface.	Total number of eggs deposited.
1	2	0	2	27	0	0	0
2	0	0	0	28	1	0	1
3	3	1	4	29	8	6	14
4	7	3	10	30	5	1	6
5	11	1	12	31	14	0	14
6	9	0	9	32	9	3	12
7	14	2	16	33	2	4	6
8	2	0	2	34	13	2	15
9	0	0	0	35	1	0	1
10	10	0	10	36	0	3	3
11	1	0	1	37	0	1	1
12	4	0	4	38	6	0	6
13	0	0	0	39	4	0	4
14	1	1	2	40	2	4	6
15	3	0	3	41	1	0	1
16	5	0	5	42	10	1	11
17	8	2	10	43	0	0	0
18	0	1	1	44	1	0	1
19	2	0	2	45	5	0	5
20	4	0	4	46	2	0	2
21	1	0	1	47	7	1	8
22	6	2	8	48	4	0	4
23	0	0	0	49	9	2	11
24	1	0	1	50	3	0	3
25	10	3	13				
26	11	1	12	Total	222	45	267

TABLE III.—*Infestation in cowpeas by Halticus citri, showing the number of eggs in the leaf and where deposited.*

Leaf No.	Eggs deposited in upper surface.	Eggs deposited in lower surface.	Total number of eggs deposited.	Leaf No.	Eggs deposited in upper surface.	Eggs deposited in lower surface.	Total number of eggs deposited.
1	4	1	5	27	9	0	9
2	0	0	0	28	3	6	9
3	1	0	1	29	1	0	1
4	2	0	2	30	2	0	2
5	0	0	0	31	0	0	0
6	6	0	6	32	6	0	6
7	1	6	7	33	1	0	1
8	0	0	0	34	4	1	5
9	6	2	8	35	1	0	1
10	9	0	9	36	11	2	13
11	10	2	12	37	0	3	3
12	4	0	4	38	2	0	2
13	1	0	1	39	7	0	7
14	2	0	2	40	3	1	4
15	5	0	5	41	2	0	2
16	0	0	0	42	0	0	0
17	8	1	9	43	1	0	1
18	1	4	5	44	0	0	0
19	0	8	8	45	4	1	5
20	6	1	7	46	2	0	2
21	4	0	4	47	1	0	1
22	6	0	6	48	3	0	3
23	1	0	1	49	2	1	2
24	12	2	14	50	1	0	1
25	7	0	7				
26	2	4	6	Total	164	46	210

In the field observations and laboratory studies it was found that *Halticus citri* prevails on a wide range of species of host plants. The following is a list of the host plants, as noted by the writer, together with those recorded in the literature:

Alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), cowpeas (*Vigna sinensis*), ragweed (*Ambrosia artemisiaefolia*), hollyhock (*Althaea rosea*), ground cherry (*Physalis pubescens*), sorghum (*Andropogon sorghum*), prickly lettuce (*Lactuca scariola*), burdock (*Arctium lappa*), thistle (*Cnicus arvensis*), crab-grass (*Syntherisma sanguinale*), Kentucky bluegrass (*Poa pratensis*), oats (*Avena sativa*), rye (*Secale cereale*), wheat (*Triticum vulgare*), corn (*Zea mays*), rape (*Brassica napus*), barley (*Hordeum vulgare*), Jerusalem artichoke (*Helianthus tuberosus*), Johnson grass (*Andropogon halepensis*), celery (*Apium graveolens*), wild mulberry (*Morus rubra*), bur clover (*Medicago arabica*), sweet clover (*Melilotus alba*), wild morning-glory (*Convolvulus arvensis*), hackberry (*Celtis occidentalis*), cocklebur (*Xanthium* sp.), eggplant (*Solanum melongena*), Irish potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), peach (*Amygdalus persica*), cucumber (*Cucumis* sp.), tomato (*Lycopersicon lycopersicon*), tobacco (*Nicotiana tabacum*), bean (*Phaseolus* sp.), May-pops (*Passiflora incarnata*), marigold (*Calendula officinalis*), verbena (*Verbena incisa*), cotton (*Gossypium hirsutum*), beggar-weed (*Meibomia tortuosa*), white clover (*Trifolium carolinianum*).

DESCRIPTION.

ADULT.

On first sight the brachypterous female adult of this species (fig. 7) is likely to be confused with that of a flea-beetle, since both are saltatorial and resemble each other in color and general appearance, even though they represent two different orders.

The male (fig. 8) has the normal form of the Hemiptera, while the brachypterous female may easily be taken for another species. The macropterous female (fig. 9) resembles the male, having long wings but is somewhat larger than the male.

H. H. Knight, of the department of entomology, Cornell University, Ithaca, N. Y., has kindly drafted the following redescription of the adult, from specimens furnished by the writer from Columbia, S. C.

Slightly smaller and less shining than *apterus* L.; in addition to the vestiture of very fine pale pubescence, having on the dorsum deciduous tomentose patches which give silvery to greenish reflections as in *intermedius* Uhler.

FIG. 7.—*Halticus citri:* Brachypterous female. Greatly enlarged.

MALE (MACROPTEROUS).

Length 2.1 mm. (1.9 to 2.1 mm.), width 0.74 mm.; slightly smaller and more slender than the female.

Head.—Length 0.22 mm., width across eyes 0.56 mm., vertex 0.31 mm. Nearly vertical, front prominent, more or less sulcate at the base of the tylus; black, shining; carina formed by a sharp basal margin of the head. Rostrum reaching to the posterior margin of the middle coxæ; first two segments black, the third and all but the apex of the fourth pale.

Antennæ.—Long and slender, reaching beyond the tip of the membrane; segment I, length 0.25 mm., pale, sometimes darkened at the apex, two or three prominent bristles just before the tip; II, 1.05 mm., black, linear, and slender; III, 0.83 mm., fuscous to black, usually pale at the base, more slender than the second; IV, 0.54 mm., fuscous, very slender.

Pronotum.—Length 0.40 mm., width at base 0.74 mm., collar and calli not apparent; black, moderately shining, the disk having patches of deciduous tomentose pubescence as on the hemelytra. Scutellum, sternum, and pleuræ black, moderately shining.

Hemelytra.—Sides nearly parallel; black, the clavus and corium having patches of deciduous tomentose pubescence, the patches arranged in more or less definite rows; cuneus black, the apex pale yellowish. Membrane pale, tinged with fuscous, one cell apparent but not distinct.

Legs.—Long and slender, the hind femora saltatorial, coxæ black, front and middle femora pale yellow, the hind pair black with the apex pale; tibiæ pale yellow, the hind pair fuscous near the base; tarsi pale yellowish, the tips fuscous, claws black.

Venter.—Black, moderately shining, genital claspers small but distinctive of the species.

FEMALE (MACROPTEROUS).

Length 2.17 mm., width 0.95 mm., very similar to the male but more robust and having the second antennal segment and the femora differently colored.

Head.—Length 0.25 mm., width across eyes 0.57 mm., vertex 0.31 mm.; not differing from the male.

Antennæ.—Segment I, length 0.22 mm., fuscous to blackish, paler at the base; II, 0.98 mm., pale with the basal and apical one-fourth blackish; III, 0.77 mm., fuscous, pale toward the base; IV, 0.48 mm., fuscous.

Pronotum.—Length 0.40 mm., width at base 0.85 mm., similar to the male.

Hemelytra.—Width 0.97 mm., similar to the male.

Legs.—Differing from the male in having the front and middle femora black with only the tips pale.

Venter.—Black, moderately shining; ovipositor extending from a point near the tip of the hind coxæ.

FEMALE (BRACHYPTEROUS).

Length to tip of venter 1.6 mm., width 1.05 mm. Distinguished at once by its small ovate form and abbreviated hemelytra. Not differing from the macropterous female except in the form of the hemelytra and the absence of hind wings.

FIG. 8.—*Halticus citri:* Male. Greatly enlarged.

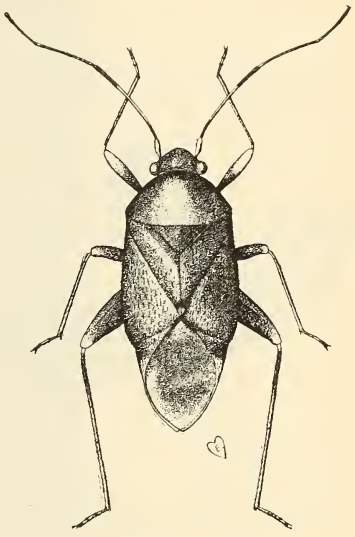

FIG. 9.—*Halticus citri:* Macropterous female. Greatly enlarged.

Antennæ.—Segment I, length 0.22 mm., pale fuscous, paler at the base; II, 0.97 mm., pale, blackish at the base and apex; III, 0.85 mm., pale, fuscous toward the apex; IV, 0.57 mm., fuscous.

Hemelytra.—Length 0.94 mm., not reaching to the tip of the venter; width 1.03 mm.; rounded and convex, the membrane and the hind wings absent.

The comparative lengths of adults of both sexes are shown in the following table:

TABLE IV.—*Comparative length of male and of brachypterous and macropterous female adults of the garden flea-hopper (Halticus citri).*

Specimen No.	Length of—			Specimen No.	Length of—		
	Male.	Brachypterous female.	Macropterous female.		Male.	Brachypterous female.	Macropterous female.
	Mm.	*Mm.*	*Mm.*		*Mm.*	*Mm.*	*Mm.*
1	2.2	1.7	2.15	6	2.0	1.6	2.17
2	2.0	1.5	2.17				
3	2.2	1.6	2.19	Average length	2.1	1.6	2.17
4	2.2	1.5	2.15	Average length of 8 adults			1.95+
5	2.0	1.7	2.19				

EGG.

Fig. 10.

Egg cylindrical, roundly pointed at caudal end, broadly truncate at cephalic end. One side decidedly convex, opposite side slightly concave. Chorion smooth, lustrous, pearly white, semitransparent, free from sculpture, except surface of truncate end, which is roughly shagreened. Truncate end apparently with a collar, below which the egg is slightly constricted, end ellipsoidal in outline. Dimensions, long diameter, 0.21 mm., short diameter, 0.10 mm. Length of egg, outer angle 0.71 mm., length of inner angle, 0.56 mm. Diameter at widest point, 0.20 mm.

NYMPH.

Figs. 11–15.

The nymph resembles the adult in general outline and structure but differs in color, and has, in the place of wings such as the adults

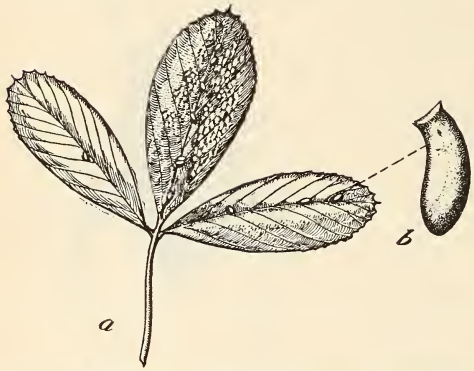

FIG. 10.—*Halticus citri: a,* Eggs in alfalfa leaf: *b*; egg greatly enlarged.

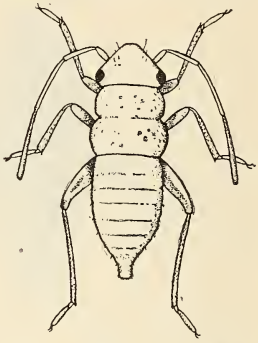

FIG. 11.—*Halticus citri:* First nymphal instar. Greatly enlarged.

have, dark-colored wing pads, these being most pronounced in the fifth stage. In the first nymphal instar the body is less robust and of a pale clay-yellow color at hatching which turns to pale green after feeding. During the period from the second to the fifth instars, inclusive, the thorax and abdomen increase in size laterally. The body gradually becomes more robust, and at the fifth instar it has assumed almost the shape and form of the adult. The color of the body varies from a light to a dark green.

The period of time consumed in the development of the nymph ranges from 10 to 18 days, or an average of 14 days, as shown in Table V.

FIRST INSTAR.

Fig. 11

Length 0.70 mm., width 0.19 mm. (average of 6 specimens). Number of body joints 13. Segments of abdomen 10. Head, thorax, abdomen, and all appendages pale clay color. Head as wide as body, as long as wide. Eyes lateral and prominent, oval shaped, with hexagonal facet structure, carmine in color. Beak 0.21 mm. long; three joints, dark at apex. Antennæ tubular; composed of four joints, first slightly swollen, length 0.08 mm., second 0.15 mm., third 0.20 mm., fourth 0.25 mm.; total length 0.68 mm.

tober, 1915, at Columbia, S. C.

Date of egg deposit.	Date of	h molt.	Length of stage V.		Total length of nymphal period.			Mean average temperature.
					Sex.	Period.		
			Days.	*hours.*		*Days.*	*hours.*	° *F.*
June 18	June 26	a. m.	5	0	Male	11	19	76.6
Do	do	a. m.	4	0	Female	17	19	78.7
Do	do	p. m.	1	5	do	15	0	77.4
Do	June 26	a. m.	4	0	Male	17	0	78.1
Do	do	a. m.	3	0	Female	14	0	77.4
Do	do		3	0	Male	14	0	77.4
Do	do		3	0	Female	14	0	77.4
Do	do	p. m.	3	0	Male	14	5	77.4
Do	do	a. m.	2	19	Female	15	0	77.8
Do	do	a. m.	3	0	do	14	0	77.4
Do	do	a. m.	3	19	Male	15	0	77.8
Do	do	a. m.	3	0	Female	14	0	77.4
Do	do		4	19	Male	14	0	77.4
Do	do		4	19	do	14	0	77.4
Do	do	. m.	3	0	Female	12	5	77
Do	do	a. m.	4	0	do	16	0	78.1
Do	do	. m.	4	0	Male	13	0	77.2
Do	do	a. m.	5	0	do	15	0	77.8
Do	do	a. m.	4	0	do	14	0	77.4
Do	do	a. m.	4	0	do	16	0	78.1
Do	do	. m.	4	0	do	13	14	77.2
Do	do	a. m.	5	0	do	18	0	77.8
Average			3.6	0		14.1	0	77.66
July 24	July 30,	a. m.	3	0	Female	10	0	79
July 30	Aug. 7,	a. m.	3	0	do	10	19	80
Do	do		3	0	do	11	0	80
Do	do	a. m.	2	19	Male	10	0	80
Do	do	p. m.	2	5	Female	10	5	80
Do	do	a. m.	2	19	Male	11	0	80
Do	do	p. m.	2	0	do	10	5	80
Do	do	a. m.	2	19	do	11	0	80
Do	do	a. m.	2	19	Female	10	0	80
Do	do	a. m.	4	5	Male	11	5	80
July 31	Aug. 8,	a. m.	3	1	do	13	1	80
Aug. 1	Aug. 9,	p. m.	3	5	do	10	5	80
Do	do	a. m.	2	0	do	10	0	80
Do	do		4	0	do	12	0	80
Do	do	a. m.	3	19	do	11	0	80
Aug. 2	Aug. 10	a. m.	3	17	Female	13	0	80
Do	do		3	0	Male	13	0	80
Aug. 3	Aug. 11	p. m.	3	0	Female	11	5	80
Aug. 4	do	a. m.	2	1	do	12	1	80
Do	do	p. m.	3	0	do	11	5	80
Aug. 5	Aug. 16	a. m.	3	0	Male	11	0	80
Do	do	p. m.	3	0	do	11	0	80
Aug. 6	Aug. 17	a. m.	4	19	do	11	19	80
Do	Aug. 19		3	0	Female	12	0	80
Average			3.04	0		12	0	79.95
Oct. 2	Oct. 11,	a. m.	5	0	Male	16	0	71
Oct. 3	do	a. m.	4	0	Female	14	0	71
Oct. 2	do	a. m.	5	0	Male	16	0	71
Oct. 3	do		5	0	do	16	0	71
Oct. 2	do	ad.						
Oct. 3	do	a. m.	5	0	Female	17	0	71
Average			4.8	0		15.8	0	71

TABLE V.—*Number of instars, their length, and length of nymphal life of Halticus citri during the months of June, July, August, and October, 1915, at Columbia, S. C.*

Date of egg deposit.	Date of hatching of egg.	Date of first molt.	Length of stage I.		Date of second molt.	Length of stage II.		Date of third molt.	Length of stage III.		Date of fourth molt.	Length of stage IV.		Date of fifth molt.	Length of stage V.		Total length of nymphal period.			Mean average temperature.
																	Sex.	Period.		
			Days.	*hours.*		*Days.*	*hours.*		*Days.*	*hours.*		*Days.*	*hours.*		*Days.*	*hours.*		*Days.*	*hours.*	°*F.*
June 18	June 26, 2 p. m.	June 28, 2 p. m.	2	0	June 29, 2 p. m.	1	0	June 30, 2 p. m.	1	0	July 2, 9 a. m.	1	19	July 7, 9 a. m.	5	0	Male	11	19	76.6
Do	do	July 1, 2 p. m.	5	0	July 4, 9 a. m.	3	19	July 8, 9 a. m.	4	0	July 9, 9 a. m.	1	0	July 13, 9 a. m.	4	0	Female	17	19	78.7
Do	do	June 28, 2 p. m.	2	0	July 1, 2 p. m.	4	0	July 3, 9 a. m.	1	19	do	6	0	July 10, 2 p. m.	1	5	do	15	0	77.4
Do	June 26, 9 a. m.	do	2	5	July 1, 9 a. m.	2	19	July 4, 9 a. m.	3	0	July 8, 9 a. m.	4	0	July 12, 9 a. m.	4	0	Male	17	0	78.1
Do	do	June 29, 2 p. m.	3	5	July 2, 9 a. m.	2	19	do	2	0	July 7, 9 a. m.	3	0	July 10, 9 a. m.	3	0	Female	14	0	77.4
Do	do	do	3	5	July 3, 9 a. m.	3	19	July 5, 9 a. m.	2	0	do	2	0	do	3	0	Male	14	0	77.4
Do	do	do	3	5	July 2, 9 a. m.	2	19	do	3	0	do	2	0	do	3	0	Female	14	0	77.4
Do	do	do	3	5	do	2	19	July 5, 2 p. m.	3	5	July 7, 2 p. m.	2	0	July 10, 2 p. m.	3	0	Male	14	5	77.4
Do	do	do	3	5	July 2, 2 a. m.	3	0	do	3	0	July 8, 2 p. m.	3	0	July 11, 9 a. m.	2	19	Female	15	0	77.8
Do	do	do	3	5	July 3, 9 a. m.	3	19	July 4, 2 p. m.	1	5	July 7, 9 a. m.	2	19	July 10, 9 a. m.	3	0	do	14	0	77.1
Do	do	do	3	5	July 1, 2 p. m.	2	0	do	3	0	July 7, 2 p. m.	3	0	July 11, 9 a. m.	3	19	Male	15	0	77.8
Do	do	do	3	5	July 2, 9 a. m.	2	19	July 5, 9 a. m.	3	0	July 7, 9 a. m.	2	0	July 10, 9 a. m.	3	0	Female	14	0	77.4
Do	do	June 28, 2 p. m.	2	5	June 30, 2 p. m.	2	0	July 2, 2 p. m.	2	0	July 5, 2 p. m.	3	0	do	4	19	Male	14	0	77.4
Do	do	do	2	5	do	2	0	do	2	0	do	3	0	do	4	19	do	14	0	77.4
Do	do	do	2	5	July 2, 2 p. m.	4	0	July 3, 2 p. m.	1	0	do	2	0	July 8, 2 p. m.	3	0	Female	12	5	77
Do	do	do	2	5	June 30, 2 p. m.	2	0	July 2, 9 a. m.	1	19	July 8, 9 a. m.	6	0	July 12, 9 a. m.	4	0	do	16	0	78.1
Do	do	do	2	5	July 1, 2 p. m.	3	0	July 2, 2 p. m.	1	0	July 5, 9 a. m.	2	19	July 9, 9 a. m.	4	0	Male	13	0	77.2
Do	do	June 28, 9 a. m.	2	0	June 30, 2 p. m.	2	5	July 3, 2 p. m.	3	0	July 6, 9 a. m.	2	19	July 11, 9 a. m.	5	0	do	15	0	77.8
Do	do	do	2	0	do	2	5	July 2, 2 p. m.	2	0	do	3	19	July 10, 9 a. m.	4	0	do	14	0	77.4
Do	do	June 29, 9 a. m.	3	0	July 1, 2 p. m.	2	5	July 4, 2 p. m.	3	0	July 8, 9 a. m.	3	19	July 12, 9 a. m.	4	0	do	16	0	78.1
Do	do	June 28, 9 a. m.	3	0	June 30, 2 p. m.	1	19	July 2, 9 a. m.	1	19	July 5, 9 a. m.	3	0	July 9, 9 a. m.	4	0	do	13	14	77.2
Do	do	June 29, 9 a. m.	3	0	July 1, 2 p. m.	2	5	July 5, 9 a. m.	3	19	July 9, 9 a. m.	4	0	July 14, 9 a. m.	5	0	do	18	0	77.8
Average			2.77	0		2.68	0		2.27	0		3	0		3.6	0		14.1	0	77.66
July 24	July 30, 9 a. m.	Aug. 1, 9 a. m.	1	0	Aug. 3, 9 a. m.	2	0	Aug. 5, 9 a. m.	2	0	Aug. 7, 9 a. m.	2	0	Aug. 10, 9 a. m.	3	0	Female	10	0	79
July 30	Aug. 7, 9 a. m.	Aug. 10, 9 a. m.	3	0	Aug. 11, 2 p. m.	1	0	Aug. 13, 2 p. m.	2	0	Aug. 15, 9 a. m.	1	19	Aug. 18, 9 a. m.	3	0	do	10	19	80
Do	do	do	3	0	Aug. 12, 9 a. m.	2	0	do	1	5	do	1	19	do	3	0	do	11	0	80
Do	do	do	3	0	Aug. 11, 2 p. m.	1	5	do	2	0	Aug. 14, 2 p. m.	1	0	Aug. 17, 9 a. m.	2	19	Male	10	0	80
Do	do	do	3	0	Aug. 11, 9 a. m.	1	0	Aug. 13, 9 a. m.	2	0	Aug. 15, 9 a. m.	2	0	Aug. 17, 2 p. m.	2	5	Female	10	5	80
Do	do	do	3	0	do	1	0	do	2	0	Aug. 15, 2 p. m.	2	5	Aug. 18, 9 a. m.	2	19	Male	11	0	80
Do	do	Aug. 9, 9 a. m.	2	0	do	2	0	do	2	0	do	2	5	Aug. 17, 2 p. m.	2	0	do	10	5	80
Do	do	Aug. 10, 9 a. m.	3	0	do	1	0	do	2	0	do	2	5	Aug. 18, 9 a. m.	2	19	do	11	0	80
Do	do	Aug. 9, 9 a. m.	2	0	do	2	0	Aug. 12, 2 p. m.	1	5	Aug. 14, 2 p. m.	2	0	Aug. 17, 9 a. m.	2	19	Female	10	0	80
Do	do	do	2	0	Aug. 10, 9 a. m.	1	0	Aug. 12, 9 a. m.	2	0	Aug. 14, 9 a. m.	2	0	Aug. 18, 9 a. m.	4	5	Male	11	5	80
July 31	Aug. 8, 9 a. m.	Aug. 10, 9 a. m.	2	0	Aug. 13, 9 a. m.	3	0	Aug. 16, 9 a. m.	3	0	Aug. 18, 9 a. m.	2	0	Aug. 21, 10 a. m.	3	1	do	13	1	80
Aug. 1	Aug. 9, 9 a. m.	Aug. 11, 9 a. m.	2	0	Aug. 12, 2 p. m.	1	5	Aug. 14, 9 a. m.	1	19	Aug. 16, 9 a. m.	2	0	Aug. 19, 2 p. m.	3	5	do	10	5	80
Do	do	do	2	0	Aug. 13, 9 a. m.	2	0	Aug. 15, 2 p. m.	2	5	Aug. 17, 9 a. m.	1	19	Aug. 21, 9 a. m.	2	0	do	10	0	80
Do	do	do	2	0	Aug. 13, 2 p. m.	2	5	do	2	0	do	1	19	do	4	0	do	12	0	80
Do	do	do	2	0	Aug. 13, 9 a. m.	2	0	Aug. 14, 4 p. m.	1	7	Aug. 16, 2 p. m.	1	22	Aug. 20, 9 a. m.	3	19	do	11	0	80
Aug. 2	Aug. 10, 9 a. m.	Aug. 13, 9 a. m.	3	0	Aug. 15, 2 p. m.	2	5	Aug. 18, 2 p. m.	3	0	Aug. 19, 4 p. m.	1	2	Aug. 23, 9 a. m.	3	17	Female	13	0	80
Do	do	do	3	0	do	2	5	Aug. 17, 9 a. m.	1	19	Aug. 20, 9 a. m.	3	0	do	3	0	Male	13	0	80
Aug. 3	Aug. 11, 9 a. m.	do	2	0	do	2	5	do	1	19	Aug. 19, 2 p. m.	2	5	Aug. 22, 2 p. m.	3	0	Female	11	5	80
Aug. 4	do	do	2	0	do	2	5	Aug. 18, 9 a. m.	2	19	Aug. 21, 9 a. m.	3	0	Aug. 23, 10 a. m.	2	1	do	12	1	80
Do	do	do	2	0	do	2	5	Aug. 17, 9 a. m.	1	19	Aug. 19, 2 p. m.	2	5	Aug. 22, 2 p. m.	3	0	do	11	5	80
Aug. 5	Aug. 16, 9 a. m.	Aug. 17, 9 a. m.	1	0	Aug. 19, 4 p. m.	2	7	Aug. 23, 9 a. m.	2	17	Aug. 25, 9 a. m.	2	0	Aug. 28, 9 a. m.	3	0	Male	11	0	80
Do	do	Aug. 17, 2 p. m.	1	5	Aug. 20, 9 a. m.	2	0	Aug. 23, 2 p. m.	3	5	Aug. 24, 2 p. m.	1	0	Aug. 27, 2 p. m.	3	0	do	11	0	80
Aug. 6	Aug. 17, 2 p. m.	Aug. 20, 9 a. m.	2	19	Aug. 23, 2 p. m.	1	5	Aug. 24, 2 p. m.	1	0	Aug. 26, 2 p. m.	2	0	Aug. 31, 9 a. m.	4	19	do	11	19	80
Do	Aug. 19, 9 a. m.	Aug. 21, 2 p. m.	2	5	do	2	0	Aug. 25, 2 p. m.	2	0	Aug. 28, 9 a. m.	2	19	do	3	0	Female	12	0	80
Average			2.25+	0		1.79+	0		2	0		2	0		3.04	0		12	0	79.95
Oct. 2	Oct. 11, 9 a. m.	Oct. 13, 2 p. m.	2	5	Oct. 16, 9 a. m.	2	19	Oct. 19, 9 a. m.	3	0	Oct. 22, 9 a. m.	3	0	Oct. 27, 9 a. m.	5	0	Male	16	0	71
Oct. 3	do	do	2	5	do	2	19	Oct. 18, 9 a. m.	2	0	Oct. 21, 9 a. m.	3	0	Oct. 25, 9 a. m.	4	0	Female	14	0	71
Oct. 2	do	Oct. 16, 9 a. m.	5	0	Oct. 17, 2 p. m.	1	5	Oct. 19, 9 a. m.	1	19	Oct. 22, 9 a. m.	3	0	Oct. 27, 9 a. m.	5	0	Male	16	0	71
Oct. 3	do	Oct. 13, 2 p. m.	2	5	Oct. 17, 9 a. m.	3	19	do	2	0	do	3	0	do	5	0	do	16	0	71
Oct. 2	do	do			do			Oct. 22, 9 a. m.			Molt still attached			Oct. 27, dead						
Oct. 3	do	do	2	5	Oct. 16, 9 a. m.	2	19	Oct. 19, 9 a. m.	3	0	Oct. 23, 9 a. m.	4	0	Oct. 28, 9 a. m.	5	0	Female	17	0	71
Average			2.6	0		2.6	0		2.2	0		3.2	0		4.8	0		15.8	0	71

Body: Widest at the head and thorax, caudal end bluntly pointed when viewed from the dorsum.

Legs: Femur covered with long sparse hairs; tibia covered with numerous short, stiff, appressed hairs; tarsi covered with numerous short, stiff hairs, end of tarsi having two small hooks.

SECOND INSTAR.

Fig. 12.

Length 0.81 mm., width 0.27 mm. at widest part of the body. Thorax and abdomen pale green, appendages clay color. Eyes lateral and prominent, oval shaped, with hexagonal facet structure, color carmine. Beak 0.32 mm.; of three joints, dark at apex, sucking tube brownish. Antennæ tubular, of four joints, the first slightly swollen; amber colored, pubescent, hairs somewhat appressed; first joint 0.08 mm. in length, second 0.22 mm., third 0.25 mm., fourth 0.24 mm., total 0.79 mm.

Body: Each segment with sparse, short, stiff hairs. Body widest at fifth abdominal segment, tapering bluntly at posterior extremity.

Legs: Amber colored, femur covered with long, sparse hairs; tibia bearing short, stiff, appressed hairs; tarsi bearing numerous short, stiff hairs, end of tarsi having two small hooks.

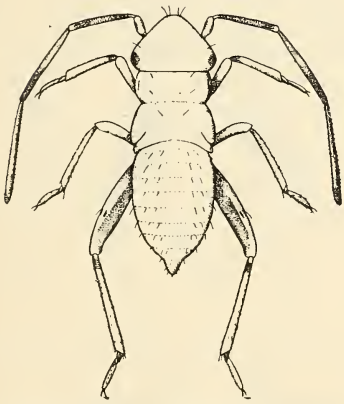

FIG. 12.—*Halticus citri:* Second nymphal instar. Greatly enlarged.

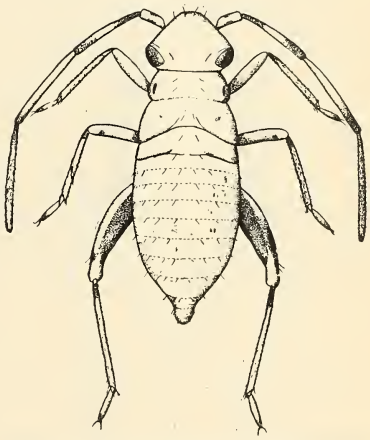

FIG. 13.—*Halticus citri:* Third nymphal instar. Greatly enlarged.

THIRD INSTAR.

Fig. 13.

Length 1.03 mm., greatest body width 0.32 mm., width of head at widest point 0 29 mm.

Head brownish, thorax and abdomen varying in color from pale to dark green, appendages amber colored. Eyes lateral and prominent, oval shaped, with hexagonal facet structure, color carmine. Beak 0.38 mm. long, three-jointed, amber colored, terminal joints dark at apex. Sucking tube brownish. Antennæ tubular, four-jointed, amber colored, pubescent, hairs somewhat appressed; first joint 0.29 mm. in length, second 0.31 mm., third 0.22 mm., fourth 0.13 mm., total length 0.95 mm.

Body: Number of joints as in preceding instar. On dorsum of each joint one short, stiff hair and on lateral side of dorsum one stiff hair. Color pale green. Body widest at fifth abdominal segment, tapering bluntly at posterior extremity.

Legs: Femur covered with long, sparse hairs; tibia bearing short, stiff, appressed hairs, tarsus bearing numerous short, stiff hairs, end of tarsi having two small hooks.

FOURTH INSTAR.

Fig. 14.

Length 1.21 mm., width of body at widest point 0.44 mm., width of head at widest point 0.32 mm. Thorax and abdomen light to dark green, head brownish. Eyes lateral and prominent, oval shaped, with hexagonal facet structure, color carmine. Beak 0.56 mm. long, of three joints, terminal joints dark at apex, sucking tube dark brown. Antennæ tubular, of four joints, the first slightly swollen; amber colored, pubescent, hairs somewhat appressed; first joint 0.15 mm. in length, second 0.38 mm., third 0.42 mm., fourth 0.40 mm., total 1.35 mm.

Body: Number of joints as in preceding instar. On dorsum of each joint are short, sparse, stiff hairs and on the side one short, stiff hair. Body light to dark green, wider than head at widest point, and tapering bluntly at posterior end.

Legs: Straw colored, femur covered with long, sparse hairs; tibia covered with numerous short, stiff, appressed hairs; tarsus bearing numerous short, stiff hairs.

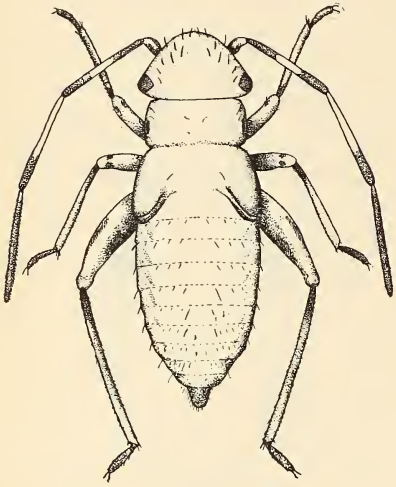

FIG. 14.—*Halticus citri:* Fourth nymphal instar. Greatly enlarged.

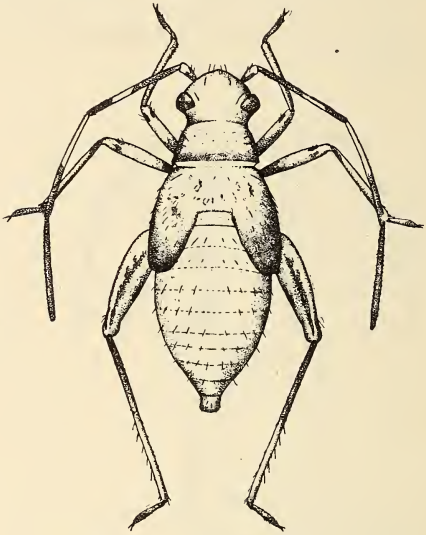

FIG. 15.—*Halticus citri:* Fifth nymphal instar. Greatly enlarged.

FIFTH INSTAR.

Fig. 15.

Length 2 mm., width 0.98 mm. at widest point two-thirds of the way back from anterior end, height or depth of head 0.40 mm., widest point of head over the eyes 0.51 mm. Color of head brownish, of thorax and abdomen pale to dark green. Eyes lateral and prominent, oval shaped, with hexagonal facet structure, color carmine. Beak 0.95 mm. long, of three joints, terminal joints dark at apex, sucking tube dark brown. Antennæ tubular, of four joints, amber colored, pubescent, more densely at apex, hairs somewhat appressed; first joint 0.19 mm. in length, slightly swollen; second 0.64 mm., tubular, slightly enlarged, and brown; third 0.64 mm., tubular, slender, pale; fourth 0.56 mm., tubular, slender, tapering acutely; total length 2.03 mm.

Body: Abdomen with each joint bearing a short, stiff hair. Body dark green with dark wing pads, wider than head at widest point and tapering bluntly at posterior end.

Legs: Femur bearing long, stiff hairs; tibia bearing numerous short, stiff, appressed hairs; tarsus bearing numerous short, stiff hairs.

LIFE HISTORY AND HABITS.

Difficulty was experienced in securing life-history records during the months of June, July, and August, because of excessive heat. Much patience was needed to bring the adults through the months of January and February, the natural hibernating period. To have the specimens under close observation it was necessary to confine them under more or less artificial conditions. The death rate under these conditions was very high. The combined lengths of the egg, nymphal, and adult stages under conditions at Columbia, S. C., varied with the temperature, being from 58 to 94 days, with an average of 76 days for all conditions.

MATING.

Mating usually takes place soon after the individual reaches maturity. In the series of experiments conducted by the author it took place from 5 minutes to 2 hours and 30 minutes after the last instar matured, usually occurring in the daytime. The time covered in the process of mating as recorded in a series of six experiments ranged from 30 minutes to 1 hour and 35 minutes. After mating, the individuals in each case were observed to move in opposite directions and seek suitable places for feeding.

The brachypterous females are much more abundant throughout the year and were used in nearly all of the life-history experiments. The macropterous female, however, which is very rare, was found to be fertile and to deposit fertile eggs as does the brachypterous form.

OVIPOSITION.

During the spring, summer, and fall, oviposition begins about 4 days after mating according to Tables VI and VII, and was observed to take place principally during the night or early morning (see Table VII).

Individuals of *Halticus citri* almost invariably oviposit on those portions of the plant where previously they have been feeding, the leaves usually being selected with a preference for the upper side (see Tables I, II, and III). In some instances, however, during the late fall and winter in cage experiments (see fig. 16) it was observed that oviposition took place in the stem of the plant and also in the cork which constitutes the bottom of the cages.

TABLE VI.—*Incubation records of eggs obtained from one female of the garden flea-hopper, Columbia, S. C., 1915*

Cage 15–631.

Deposited—		Hatched—		Incubation period.	Deposited—		Hatched—		Incubation period.
Date.	Number of eggs.	Date.	Number of eggs.		Date.	Number of eggs.	Date.	Number of eggs.	
				Days.					*Days.*
July 28	4	Aug. 5	All.	8	Aug. 17	0			
29	2	...do	All.	7	18	0			
30	2	...do	All.	6	19	0			
31	6	Aug. 8	All.	8	20	0			
Aug. 1	4	Aug. 11	All.	10	21	0			
2	7	...do	All.	9	22	0			
3	2	Aug. 9	All.	6+	23	3	Sept. 2	All.	10
4	4	Aug. 14	All.	10–	24	0			
5	2	Aug. 11	All.	6+	25	1	Sept. 2	All.	7
6	1	Aug. 14	All.	8	26	0			
7	0				27	0			
8	0				28	[1]1♀	Sept. 5	All.	8
9	[1]0♂				29	0			
10	4	Aug. 19	All.	9	30	0			
11	0				31	0			
12	0				Sept. 1	[1]0♂			
13	0								
14	0				Total	43			
15	0				Average incubation				8
16	0								

[1] Dead.

General average of 1.34 per day for 32-day period.

TABLE VII.—*Daily and total production of eggs deposited by one female of H. citri, time of hatching, and length of incubation period, Columbia, S. C., 1916.*

Cage 15–1080.

Deposited—				Hatched—		Incubation period.
Date.	Number of eggs.			Date.	Number of eggs.	
	Day.	Night.	Total.			
						Days.
Sept. 4	1		1	Sept. 14	All.	10
5		1	1	Sept. 15	All.	10
6		6	6	...do	All.	8
7		3	3	Sept. 14	All.	8
8		1	1	Sept. 16	All.	8
9	3	2	5	Sept. 18	All.	9
10		4	4	...do	All.	8
11	7	2	9	Sept. 20	All.	9
12		3	3	...do	All.	9
13	9	3	12	Sept. 22	All.	9
14	4		4			
15	6	2	8	Sept. 24	All.	9
16	4	1	5	Sept. 25	All.	9
17	4	6	10	Sept. 26	All.	9
18		1	1	Sept. 27	All.	9
19		2	2	Sept. 28	All.	9
20	3	2	5	Sept. 29	All.	9
21		1	1	...do	All.	8
22		4	4	Sept. 30	All.	9
23		1	1	Oct. 1	All.	7
24		1	1	Oct. 2	All.	7
25	0	0	0		0	0
26	3	3	6	Oct. 5	All.	10
27	3	3	6	Oct. 6	All.	10
28		2	2	Oct. 13	0	
29		3	3	Oct. 9	All.	10
30		3	3	Oct. 10	All.	10
Oct. 1	0	0	0			
2		2	2	Oct. 10	All.	9
3	2		2	Oct. 11	All.	9
4		2	2	Oct. 12	All.	8
5	2		2	Oct. 14	All.	8
6	2		2	...do	All.	8
7	0	0	0			
8		1	1	Oct. 15	All.	8
9		2	2	Oct. 17	All.	8
Nov. 3	♂	Dead.				
Total	53	67	120			
Average						8.04

The female assumes the usual feeding position in which the body is parallel with the surface of the leaf. Apparently after a desirable place is located with the proboscis a puncture is made; the curved or swordlike ovipositor is then advanced to the puncture made by the proboscis immediately after the removal of the proboscis; the ovipositor penetrates the puncture to its full length, and an egg is deposited in the cavity. After the ovipositor is withdrawn a large drop of clear fluid exudes from it, covering the exposed truncate end of the egg.

The process of oviposition requires about 15 to 20 seconds, only one egg being placed in each hole.

EFFECT OF TEMPERATURE ON OVIPOSITION.

It was found that oviposition ceased when the temperature fell below 70° F., and there were no records of oviposition at temperatures above 90° F. In a number of cages (fig. 16) each containing two male and one female flea-hoppers were placed in a well-ventilated basement room of the laboratory, the temperature of which ranged between 75° and 90° F., most of the eggs were deposited in the daytime when a temperature of about 80° F. was reached, which usually occurred in the early morning.

EGG STAGE AND PROCESS OF HATCHING.

Several days before hatching the egg changes from its original pearly white to a pale clay-yellow color, this change being evidence of its fertility. The color of the egg resembles that of the nymph at emergence. The shape and position of the nymph, including the segments of the abdomen, the thorax, the head, the appendages, and the carmine-colored eyes, are distinguishable under a lens. In the egg the nymph is found with its head at the truncate end a short time before hatching, the covering of this end being broken at the edge or through the middle, and opening, in most cases, like a trapdoor. The head appears through the opening followed by the thorax and abdomen. The body moves backward and forward in an effort to disengage the appendages from the chorion. The appendages are all laid snugly against the ventral side of the body. The proboscis is the first appendage to be released, followed by the prothoracic and mesothoracic legs. These are then utilized to free the antennæ and metathoracic legs. The entire process requires about one hour.

The egg is slightly swollen before hatching. Following the emergence of the nymph the eggshell collapses and is semitransparent with red pentagonal to polygonal markings. The body and legs of the freshly emerged nymph are pale clay-yellow color, the antennæ straw color, and the eyes carmine. The egg period was found to range from a minimum of 6 days to a maximum of 16 days in the experiments carried out, with an average incubation period of 11 days.

NUMBER AND LENGTH OF INSTARS.

There are five instars. The length of the instars as well as the total length of the nymphal life is slightly variable, as may be noted by reference to Table V. What slight variations there were in the length of these instars may have been due, in large measure, to differences of temperature and food supply.

The intervals between each two instars gradually increases as maturity is reached. There was found to be no relation between the length of the periods and the sex of the individual.

LENGTH OF LIFE OF THE ADULT.

Adults of *Halticus citri* lived for from 9 to 94 days in the rearing experiments, as is shown in Table VIII. The sexual development was found to be complete as soon as they became adults. The females are shown to have lived longer than the males.

TABLE VIII.—*Length of life of adults of Halticus citri.*

No.	Male.			Female.		
	Emerged.	Died.	Days.	Emerged.	Died.	Days.
1	July 10	Aug. 9	30	July 13	Aug. 29	42
2	July 13	Aug. 26	44	...do	Aug. 10	28
3	July 10	July 19	9	July 15	Aug. 31	47
4	...do	...do	9	July 12	Aug. 6	25
5	July 13	July 26	13	Aug. 15	Sept. 10	26
6	Aug. 17	Aug. 30	13	Aug. 17	Sept. 2	16
7	Aug. 18	Sept. 10	23	Aug. 31	Nov. 3	64
8	Oct. 27	Dec. 22	26	Oct. 27	Jan. 13	78
9	...do	Jan. 29	94	Oct. 28	Jan. 16	70
	Av.		29.3			44

HIBERNATION.

In experiments carried out by the writer, the last remaining individuals of the adults which had emerged on October 27, 1915, died on January 29, 1916. Other adults of both sexes issued December 18, 1915, and hibernated until March 14, 1916, when they became active again. Eggs were found in the cage on this date. First-stage nymphs were discovered on April 2, 1916.

The garden flea-hopper is found in greatest abundance during August and September, and gradually decreases in number as winter approaches. In the latitude of Columbia, S. C., mortality is greatest in December, very small numbers being found after this date. Many of the adults apparently are killed by the cold weather, and the remainder seek winter protection under the thickest bunches of their favorite host plants, along fences and other well-protected places, where they continue to winter until the plants become green again in the spring, and then deposit eggs [illegible] more perishing.

SPRING APPEARANCE AND NUMBER OF GENERATIONS.

The adults of the garden flea-hopper in the latitude of Columbia, S. C., usually appear about the middle of March. Much depends upon the season, however, and they have been found soon after the host plants become green and spring is well in evidence. The adults appeared and deposited eggs as early as March 14, 1915, in the field experiments at Columbia, which was the earliest date recorded of the discovery of eggs in the outdoor experiments. Eggs have been secured in the outdoor cages throughout the year, beginning with the middle of March and continuing until the last of November. From five to six generations were reared at the Columbia laboratory. The length of life of each individual is determined largely by the length of life of the adult stage, this being the longest period of the life cycle.

The first generation was found to extend from March 14, 1915, when fertile eggs were first deposited, to May 15, 1915; the second generation extended from May 15 to July 12, 1915; the third from July 12 to September 11; the fourth from September 11 to November 18, and the fifth from November 18, 1915, to February 10, 1916.

FEEDING HABITS.

In almost every instance noted the youngest plants are attacked in preference to the older and more vigorous growths, and when the insects start feeding on a plant they apparently continue until all the sap is extracted, giving the plant a bleached appearance. During the warm seasons the tendency is to feed at the top of the plants, but during cool days and seasons they feed rather at the bases of the plants. It has been noticed that during warm days the individuals seem to show no particular inclination for protection from the sun by seeking the shady side of the leaf. When they are disturbed, however, they immediately seek a place of concealment on the plant or hop to the ground in quest of protection.

In feeding on the host plant, the individual places itself in a position parallel to the surface of the leaf, preferably on the upper surface, with its legs resting on the surface. Then the proboscis is swung down from the ventral side of the body to a perpendicular position and the apex is thrust into the epidermis of the leaf at a point midway between the prothoracic legs, the proboscis is hinged at the second articulation, the head and thorax being bent slightly downward to allow the first and third articulations to meet, the sucking tube remains straight as the open sheaths of the second and third segments leave the sucking tube, and a slight pressure is placed on the apex of the proboscis. A mechanical procedure ensues similar to the pumping process, in which the head and thorax move slightly upward and downward, not sufficiently, however, to straighten the

second and third joints of the proboscis. Probably in this pumping procedure the food is taken into the body through the proboscis. After continuing this process for several minutes at a time the proboscis is straightened and drawn from the tissue of the leaf and swung to its natural position on the ventral surface of the body for a short time; then it is again swung down and cleansed by a stroking process with the forelegs which clasp the proboscis between the tarsal joints. After gradually sliding the proboscis through them the insect starts feeding again.

This habit has been noted alike in all ages of the nymph and adults, both males and females.

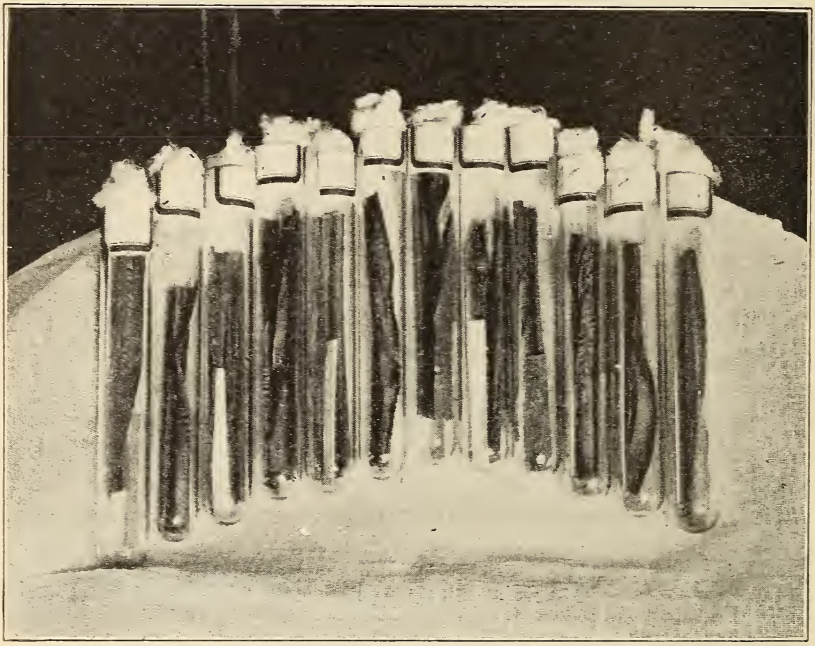

FIG. 16.—Type of cage used in conducting molting experiments with the garden flea-hopper.

PROTECTIVE HABITS.

Both the males and females are saltatorial, as the metathoracic legs are much longer and stronger than the others. The male is found to be decidedly more active than the brachypterous female, a fact probably due to the possession, in addition, of true wings. The adult individuals generally are active and strong as runners and hoppers. When they are only slightly disturbed they hasten immediately for concealment to the opposite side of the leaf of the plant. If the approaching object, however, appears with a violent disturbance, the individual will hop many times its own length to the ground or to another plant where immediate protection may be found.

In a number of experiments different individuals were placed on a large horizontal screen within the room, and the distance of jumps made on the screen ranged from three inches to nearly three feet. In the latter instances they seemingly sustained themselves in the air by the aid of their wings.

The nymphs of the first stage are not saltatorial until nearly time for molting; when disturbed, then, they show slight saltatorial tendencies but are usually very quiet even when disturbed, and merely move slowly to another position on the plant out of danger. They feed on the same place sometimes through several instars. The last three or four instars of the nymph have the same habits of locomotion and are as active as the adults.

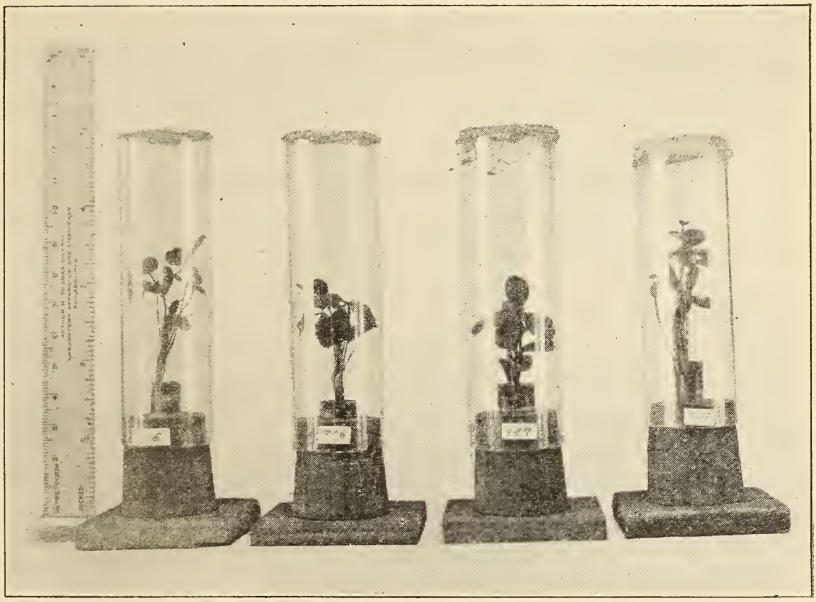

FIG. 17.—Type of cage used in conducting rearing experiments with the garden flea-hopper.

REARING METHODS.

Some difficulty was experienced in acquiring a satisfactory and serviceable rearing cage for the different experiments carried on with this species. Test tubes (fig. 16) were first used as containers for molting experiments and lamp-chimney cages for life-history work. The inaccuracy of the results with these rearing cages necessitated the substitution of one which would be more convenient. The best results were obtained with rearing cages constructed of 1 and 2-inch glass cylinders with cork bases and cloth tops sealed at the edges with glue (fig. 17), each cork base containing 9 by 36 mm. vials with water, and plant food for the insects. The 1-inch cages were attended with greatest success in molting experiments, while the 2-inch cages were used with advantage in life-history work.

NATURAL ENEMIES.

Repeated observations have shown that because of the alertness and saltatorial habits of the nearly grown nymphs and adults of the garden flea-hopper their chances of being attacked by natural enemies are somewhat meager. The nymph in the earlier stages, however, is known to be less active and is frequently attacked by the larva of a small red predacious mite of the family Erythraeidae. The writer also reared a number of egg parasites which have been determined by A. G. Gahan as representing the following species:

Anaphes perdubius Girault.
Gonatocerus sp.
Westwoodella americana Ashm.
Tetrastichus sp.
Anagrus armatus nigriventris Gir.
Abbella subflava Gir.

These species have been reared from the eggs of the garden flea-hopper collected from the alfalfa fields where the outbreaks occurred, and the parasites were believed to have rendered an appreciable amount of good.

REMEDIAL AND PREVENTIVE MEASURES.

Since the garden flea-hopper has an extremely wide range of food plants, though alfalfa is one of its favorite hosts, rotation as a remedy would be out of the question. Clean culture, however, to prevent hibernation in weeds and trash was found to result favorably in controlling the overwintering adults and is the most adequate means thus far devised of reducing the numbers of the pest.

In alfalfa fields where outbreaks of the garden flea-hopper occurred it was observed that timing the removal of the crop so as to destroy the eggs was a vital factor in control. Although a small percentage of the eggs is laid near the ground, the larger proportion is deposited in the delicate leaves and petioles. Some of these leaves containing eggs drop to the ground, it is true, and in numerous cases these eggs hatch; nevertheless, timely cutting will remove the larger number, and this measure is recommended in controlling an outbreak.

DUSTING AND SPRAYING TESTS IN THE FIELD.

A dusting experiment was conducted in one of the alfalfa fields where an outbreak of the garden flea-hopper occurred, the damaged crop being cut and removed from the infested field. An area of 100 square feet was selected and treated thoroughly with a mixture of air-slaked lime and flowers of sulphur in equal proportions. The mixture was thoroughly applied with a hand duster, one application being made in the morning and another at midday. Repeated observations by the writer after the dusting was completed failed to show that the treatment had been effective on any stages of the flea-hopper.

In the same field a plat of similar size was treated with a spray solution composed of potassium sulphid and water at the rate of 1

ounce of the potassium sulphid to 5 gallons of water, a hand sprayer of the compressed-air type being used. The plat was thoroughly sprayed in the morning and also at midday, but even when a stronger solution was employed there was little appreciable benefit from the application.

A spray of kerosene emulsion was next tried on three experimental plats of alfalfa, each having an area of 100 square feet. The alfalfa had been cut and removed a few days before, and the moist weather was causing the new crop to grow rapidly. The stock emulsion was prepared by the following method: One-half pound of laundry soap was dissolved in 1 gallon of hot water; the solution was then removed from the fire, and after 2 gallons of kerosene had been added the material was violently agitated. The table of strengths, as applied in their order on the three plats, follows:

7 per cent strength, 8½ gallons of water added to 1 gallon of stock solution.
10 per cent strength, 5⅔ gallons of water added to 1 gallon of stock solution.
12 per cent strength, 4½ gallons of water added to 1 gallon of stock solution.

Observations were continued for one day after the spraying experiments were started, and the following results were recorded: The 7 per cent kerosene emulsion was very effective in destroying the garden flea-hopper in all stages; the 10 per cent solution killed practically all the flea-hoppers and did not materially affect the alfalfa; the 12 per cent solution destroyed all of the insects but damaged the alfalfa crop noticeably.

In the campaign against the garden flea-hopper about 12 acres of fields where the most severe outbreaks occurred were sprayed with 10 per cent kerosene emulsion with great success. The solution was applied with an orchard power sprayer having two nozzles, the spray being delivered from the machine at a gauge pressure of 80 pounds and covering a strip 18 feet wide. The machine was driven by a team of mules, and the nozzles were operated by two men at the rear of the machine. An average of 30 gallons was applied to each acre. The cost per gallon of the solution was about 4 cents, thus making the estimated cost per acre $1.20, nothing being added for labor and machinery, since the farmers had these at their immediate disposal. Since it was estimated that the yield of hay would be a ton per acre under normal conditions, and since spraying with kerosene emulsion as described costs approximately $1.20 per acre and effects an almost complete saving of the crop, the market price of which has been $20 per ton, this treatment may be recommended as a satisfactory and economical measure of control.

The only other method of control which effectively overcame the pest was the plowing under of the infested crop, which was done in a number of cases where many of the plants had been killed by the

insect. There are objections to this measure, however, particularly in fields having a good stand. Much labor and expense are required to make a seed bed and to crop the land, and a measure which would involve repetition of these operations would tend to discourage the growing of alfalfa.

SUMMARY.

One of the most striking hemipterous forms of the family Capsidae is the garden flea-hopper, *Halticus citri* Ashm. The male adult has the typical capsid form with long wings, while the female adult differs in appearance, being wingless with a convex robust figure suggesting to the observer a new species. Rarely, female adults are found which resemble the males in general appearance, except that they are more robust and have long wings; this form, however, upon close observation is found to be a trifle larger with a more robust body together with a more perfectly shaped head and thorax, and its genitalia resemble those of the wingless female.

The individuals hop and jump about in the meadow in the manner of leafhoppers. The males are more active than the females, probably because they have functional wings.

In South Carolina and Georgia these insects become abundant in early summer and continue so until late fall, when they gradually disappear, the older individuals dying and the younger seeking hibernation quarters under or at the base of their favorite host plants and in protected places such as fences, terraces, or shrubbery.

Both nymphs and adults suck sap from punctures made in the leaves, petioles, and stems of the plants, causing discoloration, wilting, and, in severe infestation, death.

Leguminous plants appear to constitute its favorite foods and places for breeding, although its range of host plants is extremely wide.

The eggs are deposited in the leaves and petioles of the food plants, usually in places where adults have been feeding.

The incubation period of the egg at Columbia, S. C., covered from 6 to 16 days with an average of 11 days. The five instars of the nymph stage together cover from 10 to 18 days with an average of 14 days. The combined length of nymph and adult stages was 25 days.

In the latitude of South Carolina there are from five to six generations annually. The species was found to hibernate in the adult stage.

The garden flea-hopper is little affected by natural enemies, but changes in weather reduce its numbers during the winter months.

Hibernation and subsequent multiplication are prevented where weeds and plants that remain green late in the fall and resume growth in the spring are cleaned up in the fall and destroyed.

In the case of severe outbreaks of the garden flea-hopper it is advisable to cut and remove the invaded crop and then spray the field with a 10 per cent solution of kerosene emulsion.

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