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DIVISION OF ENTOMOLOGY

THE COTTON FLEA HOPPER

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SYNOPSIS

This Bulletin contains a report on the life history and habits of the cotton flea hopper in the vicinity of College Station. This insect is widely distributed over Texas and occurs in many other states. By means of cage experiments the cotton flea hopper is shown to be definitely associated with a new type of injury to cotton. This injury is characterized by the excessive blasting of small squares, the suppression of fruiting branches, and the tendency of plants to abnormally tall growth. All stages of the insect are described, and a list of thirty-eight food plants is given. The insect hibernates in the egg stage. The winter host plants vary in different regions of the State; however, sageweed or goatweed is the most important. The results of preliminary experiments on control of this insect indicate that cultural measures are most important and effective in preventing infestation. These consist of good farming practices, including destruction of cotton stalks and especially weed eradication. Sulphur applied as a dust is an efficient insecticide in controlling this pest.

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THE COTTON FLEA HOPPER

H. J. REINHARD

In the localities where the cotton flea hopper has demonstrated its ability to produce injury to the cotton crop, the unanimous opinion of growers has been that this insect is more destructive than the boll weevil.

The insect has been present in Texas for many years but attracted no attention as an economic pest until 1920. At that time there was a question as to the responsibility of the cotton flea hopper for the appearance of a new type of damage to cotton which was manifested by the excessive shedding of minute squares. Investigations in this connection proved the insect to be definitely associated with the damage to cotton. The facts established by these investigations are given in this Bulletin. Inasmuch as the cotton flea hopper may become suddenly a very destructive pest in practically any section of the cotton-growing regions, this information is considered timely and pertinent especially to the cotton growers of Texas.

SCIENTIFIC NAME

The cotton flea hopper was first named and described in 1876 by Reuter as *Atomoscelis seriatus* (6), from specimens collected in Texas by Belfarge. The species was referred to by this name in all subsequent literature until 1916, when Van Duzee placed it in the genus *Psallus* (10). This arrangement obtains at the present time and is accepted by authorities as best expressing the taxonomic position of the species.

COMMON NAMES

The common name "cotton flea" was first applied to this insect by growers in the coastal region of Texas, where the injury to cotton first became noticeable. Undoubtedly, the size and appearance of the insect in connection with its habit of jumping influenced the layman in choosing this name. Among cotton growers in Texas the name has become definitely associated with this insect. The late Dr. W. D. Hunter, in an effort to secure a more appropriate common name from an entomological viewpoint, was the first to suggest and use the term "cotton hopper". This was a distinct improvement over the original name, because it described better the taxonomic position of the species. To incorporate this desirable feature and at the same time retain the original term, a combination of the two names, "cotton flea hopper", is used in this Bulletin as the common name of the insect.

DESCRIPTION

Egg

The egg is elongate, considerably enlarged and broadly rounded at the caudal end; with a constricted curved neck and truncate cap. The truncate end is somewhat compressed in plane of curvature, cap concave, the projecting edge or rim ellipsoidal in outline when viewed dorsally. When first laid the egg is glistening white, but it assumes a yellowish tinge before hatching. The chorion is lustrous, apparently

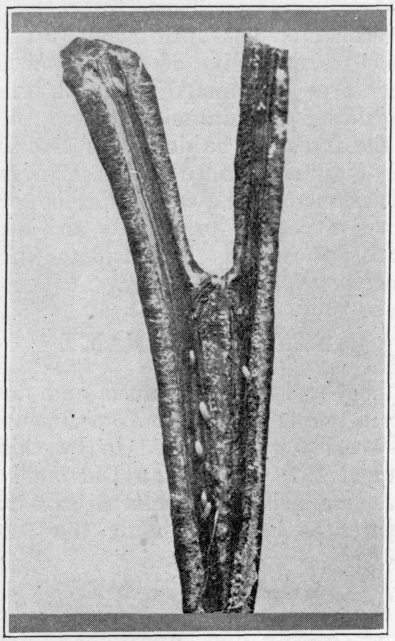

Figure 1. Stem of sageweed or goatweed plant with bark removed showing eggs of cotton flea hopper in natural position. Enlarged about three times.

smooth, but under magnification it shows distinct irregular hexagonal reticulations. In size the egg is slightly variable, averaging 0.87 mm. and 0.20 mm. in greatest dimensions.

Nymphal Stages

There are five nymphal stages in the development of the cotton flea hopper. The first instar is characterized by the narrow elongated body and slender legs. It bears less resemblance to the adult insect in outline and general appearance than any of the succeeding stages. From

the second to the last instar the thorax and abdomen increase rapidly in width, and the body becomes more compact and robust. After the fourth molt the nymph closely resembles the adult in appearance, excepting the wings, which are not yet fully developed.

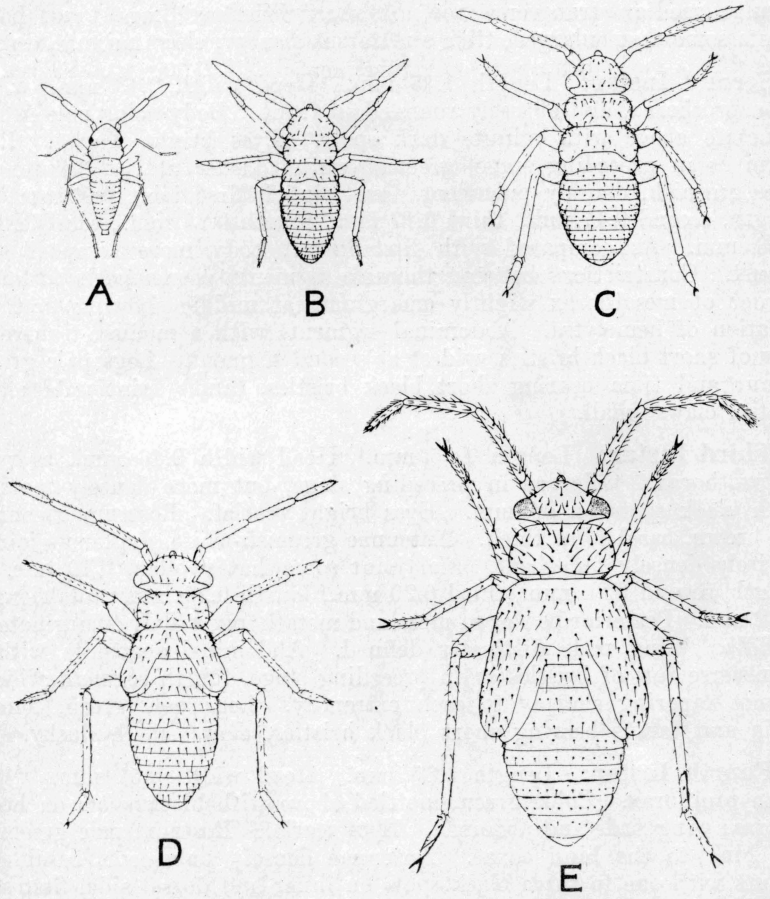

Figure 2. Nymphs of the cotton flea hopper. (a) First instar. (b) Second instar. (c) Third instar. (d) Fourth instar. (e) Fifth instar. Greatly enlarged.

First Instar: Length 1 mm. Head width 0.25 mm., as wide as prothorax and broadly rounded in front. Body color translucent white after hatching, becoming pale green soon after feeding begins. Eyes prominent, bright scarlet in color. Rostrum apparently three-jointed, rather thick and long, extending slightly beyond the hind coxae, tip faintly dusky. Antennae densely pubescent, four-jointed, first joint

slightly thickened, length 0.6 mm., second 0.12 mm., third 0.12 mm., fourth 0.20 mm.; total length 0.50 mm. Thoracic and abdominal segments distinct. Abdomen narrow, elongate, tapering to caudal extremity and strongly constricted before tip. Body sparsely clothed with short hairs and each abdominal segment bearing a more or less regular median transverse row of short bristles. Legs long, basal joints somewhat enlarged, tibia and tarsus slender, claws minute, dusky.

Second Instar: Length 1.15 mm. Head width 0.43 mm., wider than prothorax, and obtusely rounded in front. Body color pale green, punctate above with minute dark spots. Eyes bright scarlet. Rostrum as in preceding stage, greenish-white, darker at tip. Antennae pale greenish, densely pubescent, four-jointed, first joint 0.07 mm. in length, second 0.17 mm., third 0.17 mm., fourth 0.25 mm.; total length 0.66 mm. As compared with first instar, body more compact and robust. Constrictions between thoracic segments pronounced, posterior border of mesothorax slightly emarginate at middle showing first indication of hemelytra. Abdominal segments with a median transverse row of short black bristles, widest at second segment. Legs pale green, femur and tibia bearing short black bristles, tarsus faintly darkened at tip, claws small.

Third Instar: Length 1.55 mm. Head width 0.46 mm., as wide as prothorax. Color as in preceding stage, but more densely mottled with black spots on dorsum. Eyes bright scarlet. Rostrum greenish, tip brown, basal joint thick. Antennae greenish-white, darker at joints, entirely densely pubescent, basal joint somewhat swollen, 0.10 mm. in length, second 0.26 mm., third 0.20 mm., fourth 0.26 mm.; total length 0.82 mm. Posterior border of meso and metathorax widely emarginate at middle. Wing pads distinctly defined. Abdominal segments with a transverse row of bristles as in preceding stage, fourth segment widest, thence tapering sharply to each extremity. Legs pale green, femur, tibia and tarsus bearing short black bristles, claws small, dusky.

Fourth Instar: Length 1.85 mm. Head width 0.57 mm., wider than prothorax. Color green, mottled above with black spots on head, thorax, wing pads and abdomen. Eyes scarlet. Rostrum pale greenish, reaching to the hind coxae. Antennae densely pubescent, basal segments with one to three black spots on inner and dorsal side, first segment 0.11 mm. in length, second 0.39 mm., third 0.34 mm., fourth 0.30 mm.; total length 1.14 mm. Wing pads extending to or slightly beyond base of second abdominal segment. Entire dorsum densely covered with bristles, the larger ones surrounded at base by black spots. Legs pale green, the larger bristles on exterior and anterior margins of femur and tibia surrounded by black spots at base, tarsus densely covered with short hairs, claws darker, small.

Fifth Instar: Length 2.20 mm. Head width 0.69 mm., hardly as wide as prothorax. Color green, head, thorax, wing pads and ab-

domen densely mottled with black spots, and covered with suberect black bristles. Eyes scarlet. Rostrum greenish, extending to hind coxae, tip brown. Antennae green, paler towards apical segment, markings as in preceding stage, first segment 0.15 mm. in length, second 0.58 mm., third 0.46 mm., fourth 0.35 mm.; total length 1.54 mm. Wing pads extending to about middle of abdomen, metathoracic pair slightly longer. Legs greenish-white, with rows of spines and black spots on femur and tibia, tarsus thickly covered with short stiff hairs, claws dusky.

Adult

Body outline obovate or more or less elongate, subshining, pale green, color pattern variable, usually densely punctate on entire dorsum with small fuscous spots; moderately clothed with black appressed bristly hairs, intermixed with whitish pilosity on margins and shorter tufts of silvery semiscale-like hairs on the clavus, corium and embolar margin.

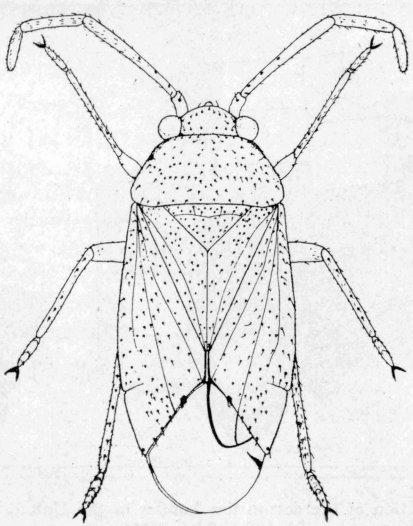

Figure 3. Adult cotton flea hopper. Greatly enlarged.

Male: Lenth 3.4 mm.; width 1.01 mm.

Head: Width 0.65 mm., vertex 0.33 mm.; pale to yellowish or darker green, sparsely covered with rather long bristly hairs arising from dark spots on vertex and to lesser degree on frons. Eyes reddish to brown. Rostrum reaching to or a little beyond hind coxae, pale green, apical joint brownish, apex almost black. Antennae four-jointed, densely covered with a pale sericeous pubescence; first segment length 0.17 mm., with two black spots near apex on dorsal and inner side; second 0.76 mm., usually with three black irregular spots on dorsal

surface, first spot located near base and distal one at or slightly beyond middle, three or more similar spots on ventral or inner side; third 0.54 mm., pale greenish, with narrow dark rings on base; fourth 0.38 mm., entirely pale or faintly darkened on narrow base; total length 1.85 mm.

Thorax: Pleura pale green, subshining, bearing a few scattered white hairs. Pronotum, mesoscutum and scutellum concolorous, pale to darker green, clothed with black bristly hairs intermixed with shorter white flattened or scale-like hairs, margins of pronotum rather densely pilose. Hemelytra green, paler or almost colorless along the embolar margins, densely punctate with small fuscous spots and clothed with black appressed bristly hairs, with a conspicuous strigose tuft of longer bristles located on margin anterior to the large areole, membrane with a dark triangular spot shortly posterior to cuneus extending linearly inward from outer margin, tips faintly cloudy, veins white.

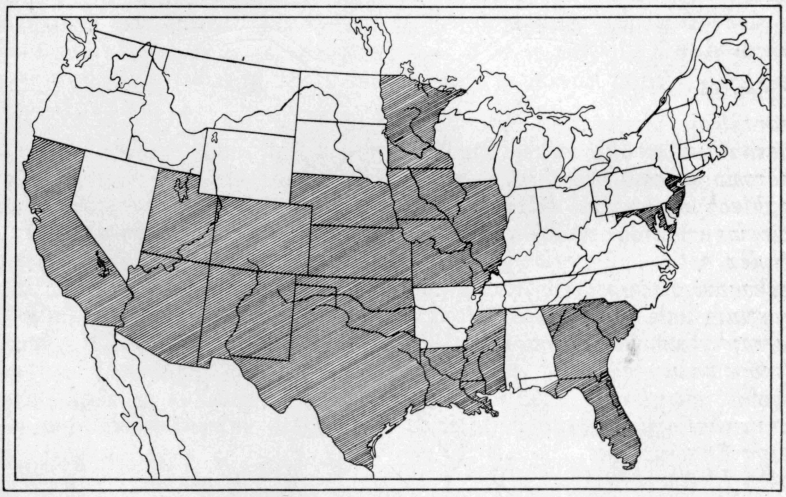

Figure 4. Distribution of the cotton flea hopper in the United States is indicated by the shaded areas.

Abdomen: Venter green, usually without any markings, but sometimes sparsely punctate with small dark spots on caudal half, sparsely covered with pale hairs.

Legs: Whitish or pale green, hind femur considerably thickened, with a row of fuscous spots on dorsal margin extending almost to base, outer side with spots irregularly arranged and usually becoming indistinct on basal half, front and middle pair with similar spots on outer side but generally less distinct; tibia bearing three rows of prominent black spines surrounded at base with black spots usually becom-

ing obsolete on apical portion of segment, tarsus pale, darker on apical portion, claws small, dusky.

Female: Length 3.5 mm., width 1.07 mm. Very similar to male in structure and coloration.

GEOGRAPHICAL DISTRIBUTION

According to the available references, the cotton flea hopper is widely distributed within the United States. The geographical distribution is shown by the shaded areas in Figure 4, which include twenty states, besides the District of Columbia. It is interesting to note that this distribution covers a wide range in latitude and extends from the Atlantic to the Pacific borders of this country. Undoubtedly the species is also present in many other states from which it is not here recorded.

FOOD PLANTS

The following list includes the food plants of the cotton flea hopper recorded from different sections of the State during the course of these studies:

Scientific name.	Common name.
Amaranthus blitoides	Pigweed
Amaranthus viridis	Pigweed
Ambrosia psilostachya	Ragweed, hogweed
Amphiachyris dracunculoides	Broomweed
Asclepias viridula	Milkweed
Atriplex sp.	Orach
Boerhaavia viscosa	———
Cerastium vulgatum	Mouse-ear chickweed
Chaerophyllum Floridanum	Wild caraway
Chenopodium album	Lamb's Quarters, pigweed
Citrullus citrullus	Watermelon
Croton capitatus	Sageweed or goatweed
Croton Engelmannii	Sageweed or goatweed
Croton Lindheimerianus	Sageweed or goatweed
Croton monanthogynus	Sageweed or goatweed
Croton Texensis	Sageweed or goatweed
Geranium Carolinianum	Wild geranium
Gossypium herbaceum	Cotton
Helenium tenuifolium	Sneezeweed, bitterweed
Helianthus Maximilianii	Wild sunflower
Hibiscus esculentus	Okra
Ipomoea trifida	Morning-glory, tie-vine
Kallstroemia hirsutissima	Caltrop
Lamium amplexicaule	Henbit
Lepidium Virginicum	Peppergrass
Lippia nodiflora	Fog-fruit

Scientific name.	Common name.
Malvaviscus Drummondii	May apple
Melilotus officinalis	Sweet clover
Monarda fistulosa	Horsemint
Monarda punctata	Horsemint
Panicum Texanum	Texas millet, Colorado-grass
Portulaca oleracea	Purslane, pursley
Solanum elaeagnifolium	Horsenettle
Solanum rostratum	Yellow horsenettle
Stachys cordata	Hedgenettle
Trianthema portulacastrum	———
Tribulus terrestris	Ground-bur, bur-nut
Vigna sinensis	Cowpea

Apparently the cotton flea hopper is able to subsist on a large variety of succulent weeds, and further studies in this connection undoubtedly will result in the addition of many other food plants to the present list. In the laboratory newly hatched nymphs were placed on thirty-two widely related plants represented in the above list, and reared to maturity. When the insects were migrating from *Croton* during October 1925, adults were repeatedly taken on bitterweed, broomweed, cowpea, milkweed, okra, and watermelon, apparently feeding either on the foliage or on the blooms. No nymphs were observed or reared on these plants.

The principal food plants are the various species of *Croton,* which are commonly known to the farmer as goatweed or sageweed. These are distributed generally throughout the State; however, some species are more or less restricted to certain kinds of soil. Sixteen species of *Croton* from Texas are listed by Small[1]; of this number *capitatus, Engelmannii, Lindheimerianus, monanthogynus* and *Texensis* have been collected from a number of eastern and southern counties of this State, and all were found to be infested with eggs, nymphs, and adults. It may be safely assumed that other members of this group of plants found in Texas are also attacked by the insect. In the vicinity of College Station, *capitatus* is the most abundant species of *Croton,* and one of the commonest weeds. Every year under favorable conditions it produces a copious crop of seed, and the possibility of its eradication over any considerable area is very remote.

In the black-land sections of Texas, horsemint is one of the important food plants in addition to the *Crotons* which occur throughout this region. It is interesting to note that, while horsemint is not restricted to the black-lands in distribution, it is largely within these limits that it appears to be especially attractive to the insect. During June 1925, two species of horsemint, *Monarda fistulosa* in Navarro County, and *Monarda punctata* in Nueces County, were found heavily infested with adult cotton flea hoppers and nymphs in all stages of development.

[1]Flora of the Southeastern United States, pp. 694-8.

In Hunt County, wild sunflower *Helianthus Maximilianii* was found infested with cotton flea hopper eggs on November 18, 1925. The relative importance of wild sunflower as a food plant of this insect is not known at present. It may prove to be of some importance, however, in connection with the hibernation of the insect in localities where the plant is abundant. Besides *Croton* and cotton, sunflower is the only plant in the black-land section in which overwintering eggs of the cotton flea hopper have been found.

From the name cotton flea hopper it might be inferred that the insect feeds generally on cotton. The contrary, however, appears to be true. In the laboratory, cotton is readily accepted as food, but when growing in the field it is attacked sporadically in more or less localized areas, the extent of infestation apparently depending upon a combination of factors which are at present only partially understood. At no time during the period of these observations has cotton ever been found as severely attacked as sageweed, horsemint, or *Atriplex*. Normally cotton appears to be most attractive as a food plant in the spring and fall.

Atriplex is another important food plant of the cotton flea hopper. However, in Texas this weed is restricted largely to the Rio Grande Valley in distribution. In Hidalgo County, *Atriplex* occurs abundantly in cultivated fields as well as on waste lands. During the late summer and fall of 1925, the plant in this locality was found to be heavily infested with cotton flea hopper eggs and all stages of developing insects. Aside from its importance as a food plant, *Atriplex* also serves as a winter host in which the insect eggs deposited late in the fall are carried through to the next spring.

METHODS OF STUDY

All laboratory records on the cotton flea hopper were made under conditions approximating, as nearly as possible, those obtaining in the field. *Croton capitatus* was used as the host plant for the purpose of observing the details of the life history.

Individual pairs of hoppers were confined in glass cylinder cages (150 mm.x 25 mm.), the ends of which were covered with cheese-cloth to permit a free circulation of air. An uninfested seedling plant, with roots inserted into a small vial of water to keep it fresh, was supplied the insects for food and oviposition. Additional food was supplied by means of a small piece of sponge moistened in a sugar solution. At the end of each 24-hour period throughout the life of the insects, a fresh plant and a new supply of food were placed in the cage. As the plants were removed from the cages they were isolated and kept in good condition, during the incubation period of the eggs, by submerging the roots in water which was renewed once or twice daily. One or two days before the nymphs were expected to hatch, the plants were placed singly in 4-ounce tin salve boxes which contained a

small piece of moistened blotting paper. These boxes were examined twice each day for hatched nymphs, which were removed and isolated on *Croton* heads in glass shell vials (100 mm. x 25 mm.), for complete records on each individual. During hot weather the *Croton* heads dried up quickly and it was necessary to replace them each morning and afternoon, in order to secure a uniform development of the nymphs.

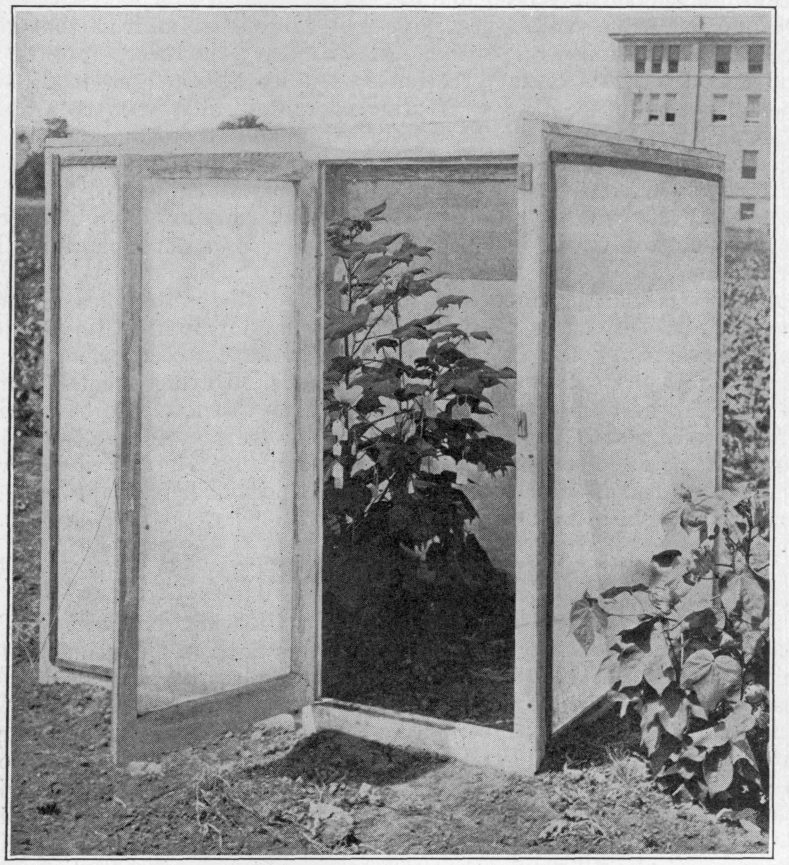

Figure 5. Type of cage used for making observations on the injury caused by the cotton flea hopper.

For the purpose of studying the relation of the insect to injury to cotton, field plants were grown under cages designed to protect them from attack, and at the same time approximate conditions which would permit normal growth. The type of cage used measures 4x4x4 feet. The entire cage was covered with fine mesh sheeting, except a 12-inch

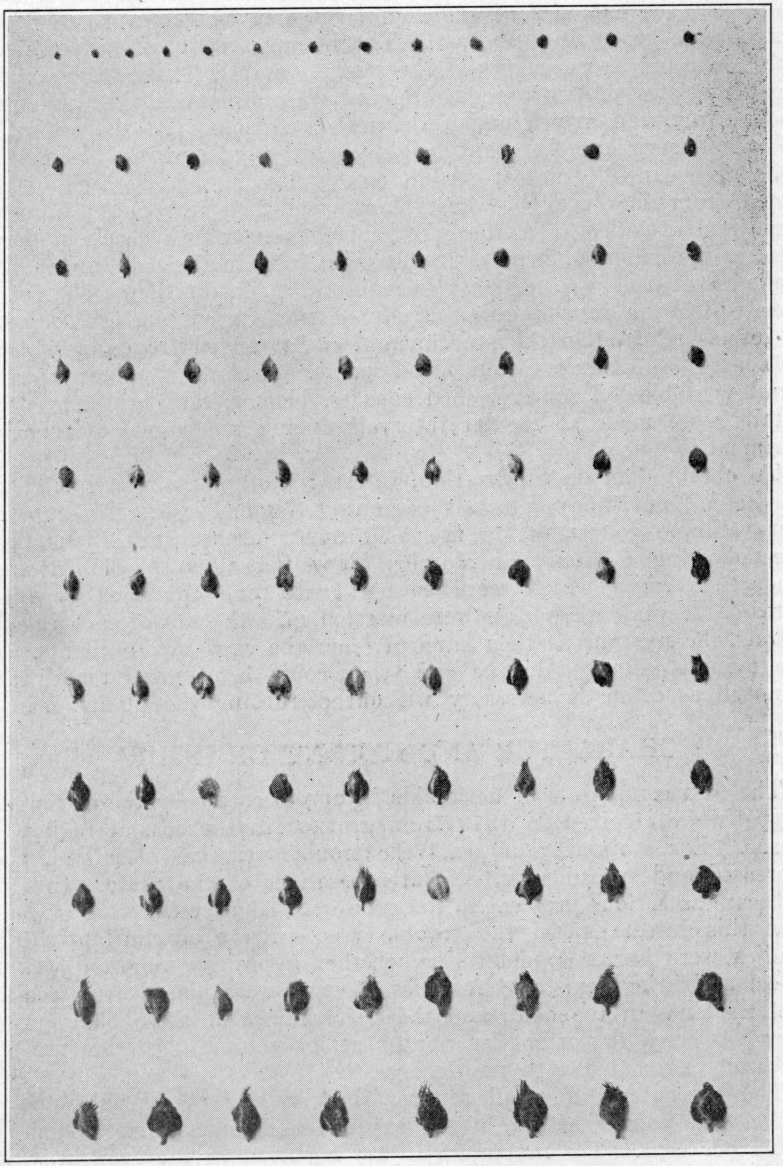

Figure 6. A series of blasted squares from cotton plants attacked by the cotton flea hopper. Natural size.

strip around the top of the sides, which was covered with Cel-O-Glass to permit the entrance of sufficient light for normal growth. Three plants were grown in each cage. The insects used in the experiments were collected from sageweed, horsemint, and cotton. Each experiment consisted of two cages containing cotton plants of the same age and variety, and grown under identical conditions. At the beginning of each experiment the plant heights, number of squares, blooms and bolls were carefully noted. Adult cotton flea hoppers or nymphs collected from one species of host plant were then introduced into one cage, and excluded from the other, which served as a check in determining the extent of injury. Subsequent introductions of insects were made as often as was necessary to maintain an infestation. The period over which the insects were introduced was varied, and the number of insects released in the experimental cages ranged from few nymphs to nearly 7000 adult cotton flea hoppers. Records of plant heights, number of blasted squares, shed squares, blooms, set fruits and other details were made at regular intervals during the course of each experiment.

To obtain data on hibernation, infested host plants were pulled up in the fall at 14-day intervals beginning September 1. These plants were allowed to remain in the field under natural conditions until the following February or March. They were then placed in small emergence cages which were covered with one thickness of black percale. Several glass vials were inserted near the top of each cage to attract the nymphs as they hatched from the eggs in the plants. As the nymphs collected in the vials they could be counted readily and removed as often as necessary without disturbing the plants.

CHARACTER AND EXTENT OF INJURY

The first complaints of noticeable injury to cotton by the cotton flea hopper were received in 1919 from growers in the coastal regions of Texas. For a number of years the trouble remained localized, then increased and spread rapidly to other sections of the State. In 1923 it became a serious problem to the growers. At that time the evidence that this insect caused the trouble was entirely circumstantial and studies were begun to determine whether a positive relation between insect and injury existed. A series of cages were placed over seedling cotton plants in the field, and the performance of these plants when later subjected to cotton flea hopper attack showed that the insect is definitely associated with the damage.

The percentage of small squares shed by the plants subjected to cotton flea hopper attack in the experimental cages ranged from 15 to 53 per cent. The maximum injury occurred in the cage in which 1725 nymphs were introduced over a period of 69 days. The minimum injury occurred in the cage in which 135 nymphs were introduced over a period of 18 days. The plants in the two check

cages of these experiments shed 3 and 4 per cent of the small squares. In one experiment 6291 adults were liberated in the cage over a period of 51 days, with the result that only 31 per cent of the small squares were shed. However, the temperatures were abnormally high during this period and the rate of mortality of the insects in the cage

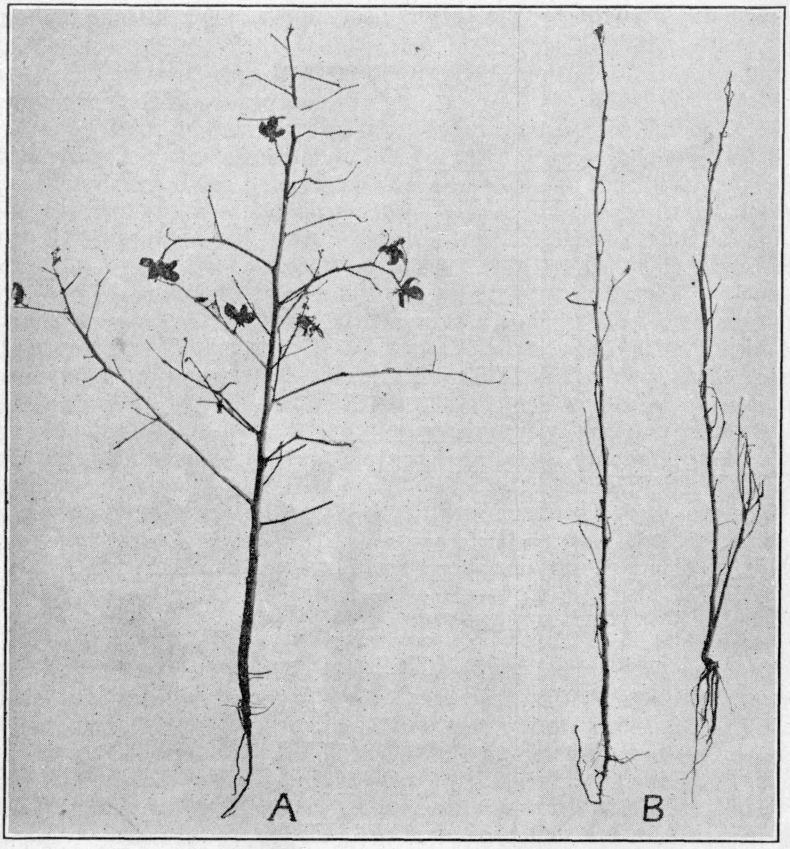

Figure 7. (a) Uninjured cotton plant with normal fruiting branches. (b) Cotton plants injured by the cotton flea hopper, showing the suppression of fruiting branches and whip-like growth.

was so great that it was impossible to maintain an infestation. Without exception there was a much larger percentage of small squares shed by plants in the cages in which insects were liberated, as compared with the percentage shed by the plants in cages from which the insects were excluded. While some shedding of small squares occurred in the check

cages there seems to be no doubt that the cotton flea hopper is the main factor in causing the injury.

The injury to cotton resulting from cotton flea hopper attack is manifested by characteristic symptoms, the most striking of which are: the excessive shedding of very small squares, the suppression of fruiting branches, and the tendency to abnormally tall growth. Infested fields often exhibit a variety of interesting features in connection with the damage wrought by the cotton flea hopper. For instance, plants

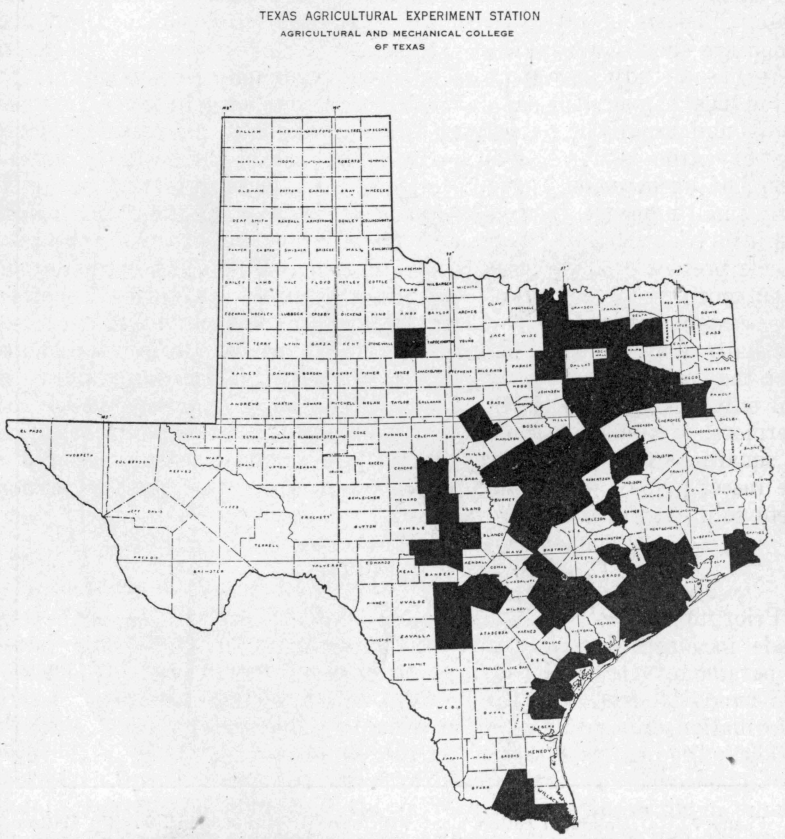

Figure 8. Counties from which injury by the cotton flea hopper has been reported.

may shed small squares excessively in some fields in the early part of the season where there appear to be few insects; and conversely, very few blasted squares may be found in other fields in the latter part of the season where the infestation is fairly abundant. On the other hand, apparently normal well fruited stalks are often found surrounded by barren plants showing every characteristic of the injury, while in

another locality exactly the opposite may be true. Excessive shedding of squares may continue in the absence of insects after the initial attack; however, under certain conditions plants occasionally recover from the effects and retain squares to maturity. The result is that such plants may have a normal number of bolls and squares on the lower and uppermost branches and the intermediate ones without a single fruit. Apparently every variety of upland cotton is subject to attack, regardless of the type of soil on which it is growing. However, the damage appears to be more severe in the black-land section of the State. Reports of injury have been noted in fifty counties of Texas, which are shown in Figure 8.

As has already been pointed out, the principal food plants of the cotton flea hopper consist of a number of our most common roadside weeds, and usually it persists on these throughout the season. Migration to cotton is not a definite procedure; quite the contrary appears true, but unfortunately even when the insect attacks cotton in apparently small numbers, the result may be a heavy loss in yield. Invariably the injury appears to be greatly out of proportion to the number of insects present. These observations, in addition to the fact that plants often continue to shed minute squares excessively long after the insects have ceased to attack them, have resulted in the theory that the insect transmits a toxic virus. This theory is further supported by the fact that the cotton flea hopper has been present in Texas for many years, and only recently has it attracted attention as an economic pest. Furthermore, it seems incredible that the condition of excessive shedding of squares could be the result of only mechanical injury inflicted by the insect punctures. Additional research is necessary before the complete solution of this problem can be determined.

LIFE HISTORY

Prior to the year 1920 no mention of the cotton flea hopper was made in economic literature. Since that time it has become a pest of paramount importance to the cotton growers of Texas. Life history and biological studies of the insect were made at this Station to obtain information on which to base satisfactory remedial or control measures.

These studies were begun in the summer of 1924 and continued throughout the following year. The most important features of the results obtained up to the present time are included in the following pages. Much additional information is needed to explain how the injury to cotton is effected and why this insect, which has been present in the State for many years (6) without doing any appreciable damage, has now become an important enemy of cotton.

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Table 1. Life Cycle in Spring

No.	Date Laid	Date Hatched	Date of First Molt	Date of Second Molt	Date of Third Molt	Date of Fourth Molt	Date of Fifth Molt	Total Days	Average Mean Temp.
22	May 6	May 14	May 16	May 18	May 20	May 22	May 27	21	78.7
31	May 10	May 18	May 21	May 24	May 28	May 31	June 3	24	80.0
34	May 13	May 20	May 23	May 27	May 31	June 6	June 9	27	81.3
36	May 13	May 20	May 23	May 26	May 29	June 3	June 7	25	81.0
39	May 13	May 21	May 23	May 27	May 31	June 4	June 7	25	81.0
41	May 13	May 21	May 25	May 29	June 1	June 4	June 7	25	81.0
45	May 13	May 22	May 27	May 30	June 2	June 6	June 9	27	81.3
47	May 13	May 22	May 26	May 29	June 1	June 4	June 8	26	81.3
48	May 13	May 22	May 26	May 30	June 2	June 5	June 9	27	81.3
52	May 13	May 23	May 29	May 31	June 4	June 8	June 11	29	81.3
53	May 14	May 23	May 28	May 31	June 3	June 7	June 10	27	81.2
54	May 14	May 23	May 28	May 30	June 3	June 6	June 9	26	81.2
55	May 14	May 23	May 28	May 31	June 4	June 8	June 11	28	81.2
56	May 14	May 23	May 28	May 31	June 3	June 6	June 9	26	81.2
57	May 14	May 23	May 28	May 31	June 3	June 7	June 10	27	81.2
58	May 14	May 23	May 26	May 29	June 2	June 5	June 8	25	81.2
64	May 14	May 24	May 29	May 30	June 3	June 7	June 9	26	81.2
66	May 16	May 24	May 28	May 31	June 3	June 7	June 10	25	81.2
67	May 16	May 24	May 28	June 1	June 3	June 7	June 10	25	81.2
70	May 18	May 27	May 31	June 3	June 6	June 9	June 12	25	81.5
71	May 18	May 27	May 31	June 3	June 5	June 8	June 11	24	81.5
74	May 18	May 27	June 1	June 4	June 7	June 10	June 13	26	81.7
75	May 18	May 27	May 31	June 2	June 6	June 9	June 12	25	81.5
77	May 18	May 27	May 31	June 5	June 8	June 10	June 13	26	81.7
78	May 18	May 27	May 31	June 2	June 5	June 8	June 11	24	81.5
80	May 18	May 27	May 31	June 2	June 5	June 8	June 11	24	81.5
82	May 18	May 27	May 31	June 3	June 5	June 9	June 12	25	81.5
83	May 18	May 29	May 31	June 3	June 7	June 9	June 12	25	81.5
87	May 18	May 28	June 1	June 4	June 8	June 11	June 14	27	82.0
93	May 18	May 28	June 1	June 4	June 7	June 9	June 12	25	81.5
94	May 18	May 28	June 1	June 4	June 7	June 9	June 12	25	81.5
111	May 22	May 30	June 3	June 6	June 9	June 11	June 14	23	82.6
112	May 22	May 30	June 4	June 7	June 9	June 12	June 14	23	82.6
113	May 22	May 30	June 3	June 7	June 9	June 11	June 13	22	82.4
114	May 22	May 30	June 3	June 6	June 9	June 12	June 14	23	82.6
116	May 22	May 30	June 3	June 6	June 9	June 12	June 14	23	82.6
117	May 23	June 2	June 6	June 9	June 12	June 14	June 16	24	83.0
124	May 23	June 2	June 6	June 9	June 11	June 13	June 15	23	82.8
126	May 23	June 2	June 6	June 8	June 10	June 12	June 14	22	82.6
129	May 23	June 2	June 6	June 9	June 10	June 12	June 15	23	82.8
130	May 23	June 2	June 6	June 8	June 11	June 13	June 15	23	82.8
134	May 25	June 2	June 6	June 9	June 11	June 13	June 15	21	82.6
135	May 26	June 2	June 6	June 8	June 11	June 13	June 15	20	83.4
137	May 29	June 8	June 11	June 13	June 14	June 16	June 19	21	85.0
138	May 31	June 8	June 11	June 12	June 14	June 15	June 17	17	85.3
140	May 31	June 9	June 12	June 13	June 14	June 16	June 18	18	85.4
141	June 1	June 9	June 12	June 13	June 14	June 16	June 18	17	85.6
142	June 1	June 9	June 11	June 12	June 14	June 16	June 18	17	85.6
143	June 1	June 9	June 11	June 13	June 14	June 15	June 17	16	85.6
144	June 1	June 9	June 12	June 14	June 15	June 16	June 18	17	85.6
145	May 30	June 9	June 12	June 14	June 15	June 17	June 18	19	85.1
147	May 31	June 9	June 12	June 14	June 15	June 17	June 19	19	85.6
150	June 2	June 9	June 12	June 14	June 15	June 16	June 18	16	85.6
154	June 2	June 10	June 12	June 14	June 15	June 17	June 19	17	85.8
158	June 2	June 10	June 13	June 14	June 16	June 17	June 19	17	85.8
162	June 2	June 11	June 12	June 14	June 15	June 16	June 18	16	85.6
167	June 3	June 12	June 13	June 15	June 16	June 18	June 20	17	85.9
169	June 3	June 12	June 14	June 15	June 16	June 17	June 19	16	85.8
170	June 3	June 12	June 13	June 15	June 16	June 17	June 19	16	85.8
172	June 3	June 12	June 13	June 15	June 16	June 18	June 20	17	85.9

The detailed life history studies were started in May 1925 soon after the nymphs began to hatch from the overwintering eggs and continued until July 1. The studies were resumed during September for the purpose of obtaining comparative data. Records on the life cycle of 60 individuals are given in Table 1. The time required for

complete development varied from 16 to 29 days depending upon prevailing temperatures. From May 6 to June 3, the average period of development was 22.5 days.

Mating and Fertility

Mating does not commonly occur during the daytime, either in the laboratory or in the field. Observations in this connection are limited to one confined pair of insects, which were noted in the act of mating on the morning of May 15, at 11:15 o'clock. The insects were still united at 12 o'clock, but had separated when next observed, one hour later. The maximum time consumed in the process was not determined. During the act of copulation the insects are united at the tips of their abdomens facing in opposite directions.

After transformation to adult, a certain feeding period is necessary to attain sexual maturity. When newly emerged insects of the opposite sex are placed together they remain indifferent to each other and begin feeding immediately, and not until an average period of 3 days has elapsed does oviposition begin, indicating that fertilization has been effected. One successful mating is sufficient to fertilize the average number of eggs laid by the female.

Oviposition

During the spring and summer a feeding period of 3 or 4 days after emergence is required before oviposition begins. It generally occurs between 6 o'clock in the evening and 7 o'clock in the morning.

The eggs are laid singly within the plant tissue by means of a strong sword-like ovipositor. There is very little uniformity of position in which the eggs are placed; most frequently, however, they are situated obliquely to the main axis of the stem with the cap end directed upward and flush with, or slightly protruding from the surface of the stem. Occasionally, the depth to which they are inserted does not exceed the cambium layer, but more often the woody portion of the stem is penetrated by the ovipositor so that the base of the egg is firmly imbedded and when the bark is removed it remains attached to the stem. The female oviposits promiscuously in practically all portions of the plant. As the host plant matures, egg deposition is confined more or less to the growing tips and stems immediately beneath them.

Oviposition begins in April or May soon after the nymphs hatching from the overwintering eggs have reached maturity, and continues throughout the warm season. At College Station the seasonal peak of oviposition in 1925 was reached in August and September. Sageweed or goatweed is preferred for oviposition, although horsemint and *Atriplex* apparently are also very attractive host plants.

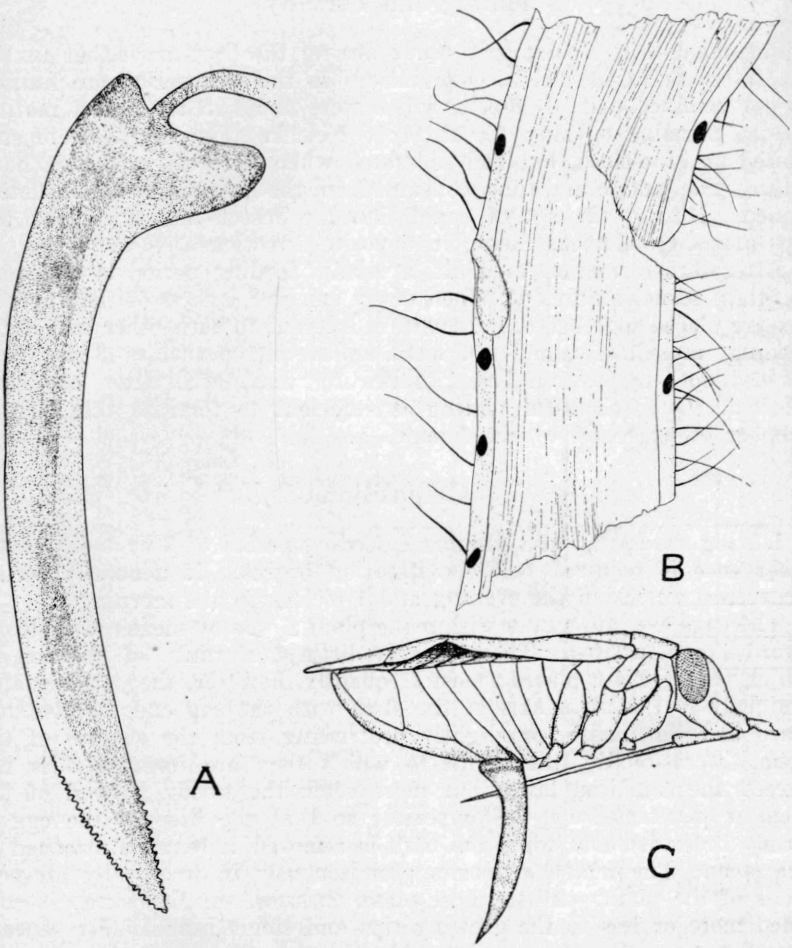

Figure 9. (a) Ovipositor of cotton flea hopper. (b) Section of cotton stalk showing position in which the egg is placed beneath the bark. (c) Sketch of insect in lateral aspect showing relative proportion of ovipositor when extended. Greatly enlarged.

Host Plants

All species of plants in which cotton flea hopper eggs have been found are listed below.

Scientific name.	Common name.
Atriplex sp.	Orach
Croton capitatus	Sageweed or goatweed
Croton Engelmannii	Sageweed or goatweed
Croton Lindheimerianus	Sagewood or goatweed
Croton monanthogynus	Sagewood or goatweed
Croton Texensis	Sageweed or goatweed
Gossypium herbaceum	Cotton
Helianthus Maximilianii	Wild sunflower
Malvaviscus Drummondii	May apple
Monarda fistulosa	Horsemint
Monarda punctata	Horsemint
Solanum elaeagnifolium	Horsenettle

Table 2. Duration of Oviposition Period

Pair	First Egg Laid	Last Egg Laid	Period of Oviposition, Days	Temperature, Mean
1	1925 June 2	1925 June 11	10	84.2
2	June 2	June 10	9	84.6
3	June 13	June 23	11	87.3
4	June 12	June 29	18	87.0
5	June 14	June 25	12	87.5
6*	June 12	June 17	6	89.6
7	June 12	June 27	16	86.8
8	June 17	June 28	12	86.3
9	June 22	June 28	7	86.4
10*	June 22	June 29	8	86.3

*Incomplete record

In the laboratory the period of oviposition during June 1925 varied from 7 to 18 days. The average duration of the period was approximately 11.5 days. Undoubtedly, oviposition continues over a much longer period under natural conditions since the insects may live for 29 days in close confinement during the warm season. The data given in Table 2 were taken over a period of high temperatures and maximum insect activity, and do not approximate spring or fall conditions when the period of oviposition is increased by lower temperatures.

Table 3. Total and Daily Rate of Oviposition

Date, 1925.	Average Mean Temp.	Pair Number									
		1	2	3	4	5	6	7	8	9	10
May 28	77.5	EM	EM	.....	.....	.....	.....	.....	.....	.....	.....
May 29	78.5	0	0	.....	.....	.....	.....	.....	.....	.....	.....
May 30	79.5	0	0	.....	.....	.....	.....	.....	.....	.....	.....
May 31	81.5	0	0	.....	.....	.....	.....	.....	.....	.....	.....
June 1	86.5	0	0	.....	.....	.....	.....	.....	.....	.....	.....
June 2	87.0	4	2	.....	.....	.....	.....	.....	.....	.....	.....
June 3	87.0	6	3	.....	.....	.....	.....	.....	.....	.....	.....
June 4	82.5	4	2	.....	.....	.....	.....	.....	.....	.....	.....
June 5	84.0	2	2	.....	.....	.....	.....	.....	.....	.....	.....
June 6	83.5	1	3	.....	.....	.....	.....	.....	.....	.....	.....
June 7	85.5	2	1	.....	.....	.....	.....	.....	.....	.....	.....
June 8	87.5	1	3	EM	.....	.....	.....	.....	.....	.....	.....
June 9	83.5	3	3	0	EM	.....	.....	.....	.....	.....	.....
June 10	81.0	1	3	0	0	EM	EM	EM	.....	.....	.....
June 11	80.5	1	0	0	0	0	0	0	EM	.....	.....
June 12	88.0	0	0	0	4	0	3	1	0	.....	.....
June 13	89.0	.....	0	3	3	0	5	3	0	.....	.....
June 14	88.0	.....	0	2	3	2	0	5	0	.....	.....
June 15	88.0	.....	0	0	1	2	0	6	0	.....	.....
June 16	88.5	.....	0	1	1	1	1	0	0	.....	.....
June 17	85.5	.....	0	1	1	0	4	2	1	.....	.....
June 18	87.0	.....	.....	1	1	2	0	1	0	EM	EM
June 19	89.5	.....	.....	0	0	0	0	1	0	0	0
June 20	89.0	.....	.....	2	3	0	*	0	0	0	0
June 21	86.0	.....	.....	0	1	1	.....	0	0	0	0
June 22	87.0	.....	.....	2	3	0	.....	1	2	7	6
June 23	86.5	.....	.....	1	2	0	.....	2	2	2	8
June 24	88.5	.....	.....	0	6	0	.....	4	2	0	2
June 25	86.5	.....	.....	0	3	3	.....	5	0	5	1
June 26	83.0	.....	.....	0	0	0	.....	2	0	1	0
June 27	86.5	.....	.....	.....	0	0	.....	1	0	1	1
June 28	87.0	.....	.....	.....	0	0	.....	0	1	3	0
June 29	86.0	.....	.....	.....	2	0	.....	0	0	0	5
June 30	87.5	.....	.....	.....	0	0	.....	0	0	0	0
July 1	85.0	.....	.....	.....	0	.....	.....	0	.....	0	*
July 2	86.0	.....	.....	.....	0	.....	.....	0	.....	0	.....
July 3	85.5	.....	.....	.....	0	.....	.....	.....	.....	0	.....
July 4	87.5	.....	.....	.....	0	.....	.....	.....	.....	0	.....
July 5	83.5	.....	.....	.....	0	.....	.....	.....	.....	.....	.....
July 6	87.5	.....	.....	.....	0	.....	.....	.....	.....	.....	.....
July 7	89.0	.....	.....	.....	0	.....	.....	.....	.....	.....	.....

EM—Emerged, mated
*Incomplete record

The total and rate of oviposition in the laboratory for ten pairs of cotton flea hoppers are given in Table 3. These data are based upon the number of nymphs hatching from the eggs deposited in plants supplied each pair of adults for oviposition. Infertile eggs or those failing to hatch for other reasons are not included, and it should be noted, therefore, that these figures do not represent maximum numbers. After oviposition is begun it usually continues quite regularly until each female's average quota of eggs has been laid. In confinement, from 1 to 3 eggs for a 24-hour period appears to be the average rate of deposition, although as many as 8 were obtained in one day. The maximum number of eggs recorded for a single female is 34.

Dissections of a number of females collected in the field were made to obtain additional information concerning the egg-laying capacity of the insect. It was found that the uterus contained an average of 8 eggs per individual ranging from a minimum of 2 to a maximum of 23 eggs.

Hatching

Some time before hatching, the egg changes from the original glistening white color to a dull yellowish-white. The outline and position of the nymph within the egg are plainly visible under a microscope. The scarlet eyes are conspicuous near the cap or truncate end of the egg through which the nymph emerges as soon as embryonic development is completed. The egg shell is broken by the nymph, which gradually pushes out head first through the opening. During the process of hatching the body is moved backward and forward, which releases the appendages from their original closely appressed position on the ventral surface of the body. The freed appendages are then used by the nymph to complete emergence from the egg. The entire process of hatching requires from 45 minutes to 1 hour.

Table 4. Duration of Egg Stage

Laid		Hatched		Lot Egg Days	Lot Incubation Period, Days	Temperature Mean
Date	Lot Number	Date	Number Nymphs Emerged			
May 13.....	1	May 19–23....	12	103	8.58	80.8
May 14.....	2	May 22–24....	13	115	8.84	81.0
May 15.....	3	May 21–23....	5	38	7.60	80.6
May 16.....	4	May 24.....	2	16	8.00	80.8
May 17.....	5	May 26.....	2	18	9.00	78.8
May 18.....	6	May 27–29....	33	318	9.63	78.3
May 19.....	7	May 28–30....	15	147	9.80	78.3
May 20.....	8	May 29.....	4	36	9.00	78.2
May 21.....	9	May 30.....	3	27	9.00	78.5
May 22.....	10	May 30–June 1	25	226	9.04	79.7
May 23.....	11	June 1– 2....	20	195	9.75	80.0
May 24.....	12	June 2– 3....	2	19	9.50	80.0
May 25.....	13	June 2– 3....	15	130	8.66	79.7
May 26.....	14	June 2– 4....	8	65	8.12	81.4
May 27.....	15	June 3– 6....	18	158	8.77	82.4
May 28.....	16	June 3– 6....	12	93	7.75	82.7
May 29.....	17	June 4– 8....	23	190	8.21	83.9
May 30.....	18	June 6– 9....	11	89	8.09	84.3
May 31.....	19	June 7–11....	5	44	8.80	84.4
June 1.....	20	June 9–10....	5	41	8.20	84.8
June 2.....	21	June 9–12....	30	248	8.20	84.5
June 3.....	22	June 11–14....	30	263	8.76	85.0
June 4.....	23	June 11–14....	25	211	8.44	84.8
June 5.....	24	June 13–14....	7	60	8.57	85.0
June 6.....	25	June 13–15....	10	84	8.40	85.0
June 7.....	26	June 14–16....	9	70	7.77	85.9
June 8.....	27	June 15–16....	11	81	7.36	86.0
June 9.....	28	June 16–17....	4	30	7.50	86.2
June 10.....	29	June 17–18....	5	36	7.20	86.1
June 11.....	30	June 17.....	2	12	6.00	86.0
June 12.....	31	June 19–20....	5	36	7.20	88.0
June 13.....	32	June 19–20....	15	97	6.46	88.0
June 14.....	33	June 20–23....	13	86	6.61	87.5
June 15.....	34	June 21–23....	20	134	6.70	87.4
June 16.....	35	June 22–24....	9	62	6.88	87.5
June 17.....	36	June 23–25....	18	124	6.88	87.2
June 18.....	37	June 24–26....	13	93	7.15	87.0
June 19.....	38	June 26–27....	7	54	7.71	86.9
June 20.....	39	June 27–28....	10	72	7.20	86.6
June 21.....	40	June 27–30....	19	138	7.26	86.4
June 22.....	41	June 28–July 1	38	273	7.18	86.3
June 23.....	42	June 29–July 2	24	176	7.33	86.2
June 24.....	43	June 30–July 3	32	232	7.25	86.1
June 25.....	44	July 1– 5....	39	290	7.43	85.8
June 26.....	45	July 2– 5....	14	100	7.14	86.1
June 27.....	46	July 4– 6....	7	53	7.57	86.2
June 28.....	47	July 5– 6....	11	82	7.45	86.1
June 29.....	48	July 6– 8....	9	68	7.55	86.7
June 30.....	49	July 8.....	1	8	8.00	86.8
July 2.....	50	July 10.....	1	8	8.00	86.5

Records on the incubation period of 50 egg-lots, including a total of 671 eggs, are given in Table 4. Temperature has a positive effect on the duration of the egg stage. The time required for incubation varied according to the prevailing temperatures, from a minimum of 6 days to a maximum of 12 days. The mean temperature for May and June, 1925 was 77 and 86 degrees F., respectively. The effect of this difference in temperature is quite apparent, for it will be noted that the incubation periods as recorded in Table 4 were consistently longer in May. The weighted average duration of the egg stage, for the entire period during which these data were recorded, was approximately 8 days.

Eggs which are laid in the late fall do not hatch until March or April of the following spring. The average mean monthly temperatures from November to March inclusive, at College Station, range from 50 to 60 degrees F. Since the eggs remain dormant during most of this period it may be assumed that an average mean temperature of 50 to 60 degrees F. is effective.

There is a considerable variation in the duration of the instars as will be noted by reference to Table 5. These variations are due to difference in food supply and temperature. When nymphs were fed on *Croton* foliage, 13 to 20 days were required for complete development, while on *Croton* heads, the period of development was much shorter, ranging from 9 to 14 days. During the warm season the average period of nymphal development is approximately 11 days. The effect of temperature on the rate of development is shown in Table 1. There is no discernible difference in the time required for development, between male and female individuals.

Table 6. Summary of Development

	Maximum Period Days	Minimum Period Days	Average Period Days
Egg	12.0	6.0	7.96
First Instar	4.0	2.5	3.02
Second Instar	3.0	1.0	1.60
Third Instar	3.0	1.0	1.78
Fourth Instar	4.5	1.0	2.16
Fifth Instar	5.0	2.0	2.58

In Table 6 is given a summary of the development of the cotton flea hopper. All stages are subject to considerable variation. The duration of the egg stage is affected by the prevailing temperatures and varies from 6 to 12 days. The first instar comprises the most time, ranging from about one-half to one and one-half days more than any of the succeeding instars. The average time required for complete development during the warmest months is 16 or 17 days.

Adult

In 1925 the first adult cotton flea hopper in the field was observed on April 21, about three weeks after hatching of the overwintering eggs was first observed. From this date the number of adults increased rapidly reaching maximum abundance during August and September.

There is no indication of definite broods in the multiplication of the insects, but rather a general overlapping of generations, which results in a more or less uniform increase of numbers until late summer and early fall. With the approach of cold weather the insects die off rapidly, and few, if any, are apparent in the field after the first frost has occurred.

Theoretically, seven or eight complete generations of the cotton flea hopper are possible in one season.

Table 5. Nymphal Development in Summer

Date Hatched	Date of First Molt	Duration of First Instar Days	Date of Second Molt	Duration of Second Instar Days	Date of Third Molt	Duration of Third Instar Days	Date of Fourth Molt	Duration of Fourth Instar Days	Date of Fifth Molt	Duration of Fifth Instar Days	Total Duration of Nymphal Period Days	Average Mean Temp.
Average.....	.....	3.02	.....	1.60	.....	1.78	.....	2.16	.....	2.58	11.05	87.5
June 30, a. m.	July 2, p. m.	2.5	July 4, a. m.	1.5	July 5, a. m.	1.0	July 7, a. m.	2.0	July 9, a. m.	2.0	9.0	86.8
June 30, a. m.	July 2, p. m.	2.5	July 4, a. m.	1.5	July 5, a. m.	1.0	July 6, p. m.	1.5	July 9, a. m.	2.5	9.0	86.8
July 1, a. m.	July 4, a. m.	3.0	July 5, a. m.	1.0	July 6, p. m.	1.5	July 8, a. m.	1.5	July 10, a. m.	2.0	9.0	86.9
July 1, a. m.	July 4, a. m.	3.0	July 5, a. m.	1.0	July 7, a. m.	2.0	July 8, a. m.	1.0	July 10, a. m.	2.0	9.0	86.9
July 1, a. m.	July 4, a. m.	3.0	July 5, a. m.	1.0	July 6, p. m.	1.5	July 8, a. m.	1.5	July 10, a. m.	2.0	9.0	86.9
July 1, a. m.	July 4, a. m.	3.0	July 5, a. m.	1.0	July 6, p. m.	1.5	July 8, a. m.	1.5	July 10, a. m.	2.0	9.0	86.9
Sept. 5, p. m.	Sept. 8, p. m.	3.0	Sept. 10, a. m.	1.5	Sept. 11, p. m.	1.5	Sept. 14, a. m.	2.5	Sept. 17, a. m.	3.0	11.5	87.8
Sept. 5, p. m.	Sept. 9, a. m.	3.5	Sept. 10, p. m.	1.5	Sept. 12, a. m.	1.5	Sept. 14, a. m.	2.0	Sept. 17, a. m.	3.0	11.5	87.8
Sept. 6, a. m.	Sept. 9, p. m.	3.5	Sept. 10, p. m.	1.0	Sept. 12, a. m.	1.5	Sept. 14, a. m.	2.0	Sept. 17, a. m.	3.0	11.0	87.9
Sept. 6, a. m.	Sept. 10, a. m.	4.0	Sept. 11, a. m.	1.0	Sept. 13, a. m.	2.0	Sept. 15, a. m.	2.0	Sept. 17, a. m.	2.0	11.0	87.9
Sept. 6, a. m.	Sept. 9, a. m.	3.0	Sept. 10, a. m.	1.0	Sept. 11, p. m.	1.5	Sept. 13, p. m.	2.0	Sept. 16, a. m.	2.5	10.0	87.9
Sept. 7, p. m.	Sept. 10, a. m.	2.5	Sept. 12, a. m.	2.0	Sept. 14, p. m.	2.5	Sept. 19, a. m.	4.5	Sept. 21, p. m.	2.5	14.0	88.3
Sept. 7, a. m.	Sept. 10, a. m.	3.0	Sept. 12, a. m.	2.0	Sept. 14, a. m.	2.0	Sept. 17, a. m.	3.0	Sept. 19, a. m.	2.0	12.0	88.1
Sept. 7, p. m.	Sept. 10, a. m.	2.5	Sept. 11, p. m.	1.5	Sept. 13, p. m.	2.0	Lost.....	.....	.....	.....	.....	.....
Sept, 7, p. m.	Sept. 10, a. m.	2.5	Sept. 12, a. m.	2.0	Sept. 15, a. m.	3.0	Sept. 17, a. m.	2.0	Sept. 20, a. m.	3.0	12.5	88.3
Sept. 8, p. m.	Sept. 11, a. m.	2.5	Sept. 12, p. m.	1.5	Sept. 14, p. m.	2.0	Sept. 18, a. m.	3.5	Died.....	.....	.....	.....
Sept. 9, p. m.	Sept. 12, a. m.	2.5	Sept. 15, a. m.	3.0	Sept. 16, p. m.	1.5	Sept. 18, a. m.	1.5	Sept. 23, a. m.	5.0	13.5	87.9
Sept. 9, p. m.	Sept. 13, a. m.	3.5	Sept, 15, a. m.	2.0	Sept, 17, a. m.	2.0	Sept. 19, p. m.	2.5	Sept. 22, a. m.	2.5	12.5	87.9
Sept. 9, a. m.	Sept, 13, a. m.	4.0	Sept. 15, a. m.	2.0	Lost.....	.....	.....	.....	.....	.....	.....	.....
Sept. 9, p. m.	Sept. 13, a. m.	3.5	Sept. 16, a. m.	3.0	Sept. 18, p. m.	2.5	Sept. 21, a. m.	2.5	Sept. 24, a. m.	3.0	14.5	87.9

Table 7. Length of Life of Adults

Number	Male			Female		
	Emerged	Died	No. Days	Emerged	Died	No. Days
1	May 27	June 12	16	May 27	June 12	16
2	May 27	June 16	20	May 27	June 17	21
3	June 9	July 8	29	June 8	June 26	18
4	June 9	July 3	24	June 9	July 7	28
5	June 10	July 3	23	June 9	June 30	21
[illegible]	June 11	July 1	20	June 10	July 2	22
[illegible]	June 12	June 29	17	June 12	June 30	18
[illegible]	June 17	July 6	19	June 15	July 6	21
9	June 18	July 2	14	June 18	July 5	17
10	June 18	July 4	16	June 19	July 5	16

The cotton flea hopper does not withstand confinement very satisfactorily, and it may be safely assumed that the normal life-period is greatest under field conditions. In the laboratory the duration of life of twenty adult insects varied from 14 to 29 days during May and June 1925, as is shown in Table 7. The average life-period of both sexes in confinement is about 20 days.

FEEDING HABITS

The adults feed usually upon the most tender portions of the plants, showing a preference for the growing terminal bud cluster. They feed by inserting their beaks into the epidermis of the plant and sucking the juice from the tissue. Usually an individual continues feeding for only a short time in one location, then moves to another, where it again punctures the tissue and resumes feeding. This operation may be repeated many times within a few minutes. The scars resulting from the feeding punctures are very minute. In confinement adults will feed readily on a dilute solution of sugar or honey, sucking it from a sponge. During the course of the life history studies of this insect, several cases were observed where an active individual had thrust its beak into the body of a dead cotton flea hopper in the cage, apparently feeding on the body juices.

The feeding habit of the nymph is very similar to that of the adult insect. Soon after hatching, it begins to feed and moves to the tender growing tip, where it remains usually until after the second or third molt. In cases of severe infestation, 20 to 30 nymphs may be found feeding on a single *Croton* head. When disturbed, the nymphs seek protection by secreting themselves on the under sides of the leaves or by hopping to the ground.

PROTECTIVE HABITS

The cotton flea hopper cannot be classed as a strong flier. However, when disturbed, the insect invariably resorts to flight as a means of protection. It usually flies to a nearby plant and seeks concealment

beneath a leaf or on the opposite side of a stem from the approaching object. There appears to be no difference in the protective habits of male and female cotton flea hoppers; both are active and will resort to flight in eluding enemies.

The nymphs have long legs and are able to run rapidly. On plants they cling closely to the stem or foliage and invariably move to the side opposite from an approaching object. Ordinarily, running is the common protective instinct. However, nymphs are also able to jump or hop and when unduly disturbed they will resort to this means of protection. The greatest distance covered by a single jump or hop rarely, if ever, exceeds 3 or 4 inches horizontally. Individuals of the later instars when disturbed have frequently been observed hopping from plants to the ground and seeking the nearest available shelter.

Aside from the protective habits mentioned above, further protection is afforded by a natural coloration which blends effectively with the plants upon which the insect feeds.

HIBERNATION

In the vicinity of College Station the cotton flea hopper is found in greatest abundance during August and September and rapidly diminishes in number with the approach of lower temperatures. Most of the nymphs and adults are killed by cold weather prior to November 15. The insect passes the winter in the egg stage. Hibernation may begin as early as September 1, although the eggs were observed to hatch during a period of several weeks after this date in the fall of 1925. The latest date of hatching was recorded on November 12. The data obtained on emergence from plants confined in cages show that hibernation is well under way by October 1. The first emergence of nymphs from the overwintering eggs in 1925 was recorded on April 2, and in 1926 first emergence occurred on March 7. During the former year the nymphs continued to emerge irregularly for a period of about six weeks.

At College Station, *Croton capitatus* was found to be the most common host plant in which the eggs are carried through the winter. However, nymphs were also reared from cotton stalks collected from local fields and in Williamson, Hunt, Rusk, and Smith counties. In the black-land sections of the State the indigenous species of *Crotons* very likely will be found serving generally as winter host plants. Aside from *Croton* and cotton, a species of wild sunflower collected in Hunt County, November 1925, was found infested with cotton flea hopper eggs. In the localities where wild sunflower is abundant it may prove to be of some importance in connection with the hibernation of the insect. Further observations on the winter host plants are being made, especially in the black-land regions, where the injury to cotton appears to be most severe. In the Rio Grande Valley, *Atriplex* is an important host plant. Many specimens of this plant collected in Hidalgo County

during the winter season of 1925 were found infested with cotton flea hopper eggs. No other winter host plants have been recorded from this region, but it is likely that cotton also is important in this connection.

NATURAL ENEMIES

Present knowledge indicates that the cotton flea hopper is not held in check effectively by natural enemies. Probably the most important of its natural enemies are the field spiders. A number of different species of these have been observed frequently capturing both the adult insects and partially developed nymphs. While a considerable number of insects may be destroyed by spiders they cannot be considered significant from the standpoint of natural control.

The nymphs of the cotton flea hopper are also frequently attacked by the larva of a small red predacious mite, *Bochartia* sp., of the family Erythraeidae[1]. The mite attaches itself to the host and feeds on the body juices. Nymphs thus attacked remain active for a considerable period of time, and it may be safely assumed that the number destroyed in this manner results in no appreciable reduction of infestation in the field.

During the late summer of 1925 while the occurrence of the cotton flea hopper on *Croton* or goatweed was at its peak, unusually large numbers of ladybird beetles, *Hippodamia convergens* Guer., migrated to the infested plants in several fields. There is some possibility that this species may prove to be a natural enemy of the cotton flea hopper. However, the ladybird beetles in the fields under observation did not multiply sufficiently on the *Croton* plants to produce any apparent reduction of the number of nymphs present.

METHODS OF CONTROL

Cultural Measures

As a result of the study of the life history of the cotton flea hopper it will be noted that there are five important facts which can be utilized in its control:

First, the insect hibernates or passes the winter in the egg stage within the host plants.

Second, at College Station hibernation begins as early as September 1.

Third, the principal winter host plants comprise a number of our common weeds. Wherever *Croton* or sageweed occurs it is the preferred host plant. In the Rio Grande Valley, *Atriplex* is the most important known winter host plant. In the black-land sections of the

[1]Determined by Dr. H. E. Ewing, Bureau of Entomology, U. S. Department of Agriculture

State, eggs of the insect have been found during the winter season in wild sunflower.

Fourth, cotton stalks remaining in the field are a source of infestation to young cotton the following spring.

Fifth, insects, emerging in the spring before cotton is available, feed and subsist upon practically any succulent weeds, and later may migrate to young cotton.

Since the cotton flea hopper hibernates in the egg stage within the host plants, obviously control measures should begin with the destruction of these in the late summer and early fall. At College Station sageweed is the common host plant. If these weeds are cut or pulled up by September 1, practically all the insect eggs which they contain hatch before cold weather begins, and very few remain dormant and hatch in the following spring. A series of experiments in this connection show that cutting or pulling up the plants at later dates is not effective, and if they are allowed to remain in the field they will prove to be a source of infestation to the succeeding crop. In fact, sageweed plants pulled up in November and December of 1925, compared with those which were allowed to remain standing in the field until just before emergence began in March of the following year, yielded as many insects as the latter, in the emergence cages. It is therefore necessary that the destruction of the host plants be complete if they are cut or pulled up after September 1. Plowing under the weeds in the winter, if thoroughly done, will prevent emergence of the insects. However, there is always the possibility of bringing undecayed remnants of infested weeds to the surface while preparing the seed bed. Burning is the most effective means of destroying the infested host plants.

Cotton stalks must be considered as a source of infestation, since the insect has been obtained in the emergence cages from plants collected in various sections of the State. Plowing under cotton stalks during the fall and winter is recommended. This measure is not only effective in combating the cotton flea hopper, but also is a desirable practice in cotton boll weevil control.

The fact that the cotton flea hopper will feed and mature on practically any succulent weeds found in or near cotton fields makes clean culture an important practice in controlling the insect. Furthermore, emergence of the nymphs from the overwintering eggs usually begins before cotton plants are available; hence the practice of clean culture will result in starving out an incipient infestation.

Aside from the fact that the cultural measures recommended here are effective in combating the cotton flea hopper, they are considered to be good farming practices and will increase crop production whether the insect is present or not.

Use of Insecticides

In addition to the cultural measures recommended above, insecticides may be used to a good advantage in controlling the cotton flea hopper. In preliminary experiments a number of different insecticidal materials were used, among which were monohydrated copper sulphate dust, calcium fluosilicate, sodium fluosilicate, calcium cyanide, tobacco dust, hydrated lime, nicotine sulphate dust, sulphur-lime, sulphur, sulphur-nicotine, and sulphur-naphthalene. Early results indicated that sulphur and the materials containing sulphur gave the best promise of control. Consequently the experiments were continued with sulphur and mixtures containing sulphur.

During the progress of these experiments in July and August 1925 at College Station, the insects were not present on cotton in sufficient numbers to obtain reliable data on control. Therefore the efforts were confined to sageweed which was heavily infested. Heavy applications of all insecticides were made with hand and traction dusting machines at 7- and 10-day intervals. A summary of the results obtained is given in Tables 8 and 9.

Table 8. Per Cent of Daily Control After One Application

	First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Sev'th Day	Eighth Day	Ninth Day	Tenth Day
Sulphur.....	71.7	86.9	89.6	90.2	94.1	.....	79.7	79.5	66.7	89.5
Sulphur-naphthalene.....	88.7	91.7	87.5	92.4	92.6	.....	93.9	81.2	83.5	83.9
Number Tests	6	6	5	6	5	.....	4	3	3	2

Table 9. Per Cent of Daily Control After Two Applications

	First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Seventh Day
Sulphur.....	93.8	94.7	89.6	92.7	94.3	.....	67.1
Sulphur-naphthalene.....	97.3	95.4	99.0	98.2	100.0	.....	91.8
Number Tests	2	2	2	2	2	.....	2

It will be noted that both sulphur and sulphur-naphthalene gave excellent control. However, since the sulphur-naphthalene mixture is more expensive and not readily obtainable on the market, sulphur is recommended for use in cotton flea hopper control. Aside from its cheapness sulphur is readily available to all local growers. Commercial sulphur is sold in various grades of fineness under a variety of trade

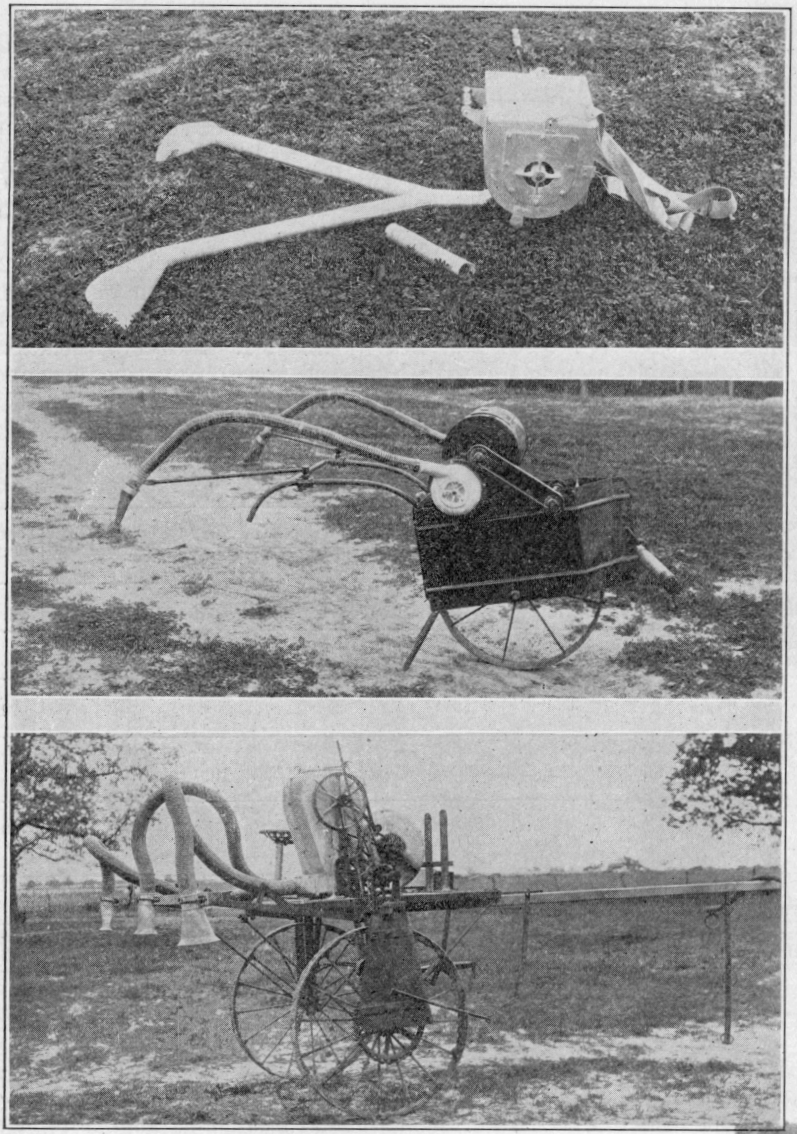

Figure 10. Three good types of dusting machines.

names. It has not been possible, up to the present, to test the effectiveness of all these grades in the control of the cotton flea hopper. In the control experiments at College Station the brand of sulphur known commercially as fine sublimed flowers of sulphur was used and found to be satisfactory for dusting purposes. In Nueces County commercial flour of sulphur was used on cotton in control experiments. This grade of sulphur is also effective in controlling the insect, but is not distributed as uniformly by the dusting machines as are the finer and lighter grades.

The following recommendations for controlling the cotton flea hopper by the use of sulphur are based upon the results of control experiments conducted on sageweed at College Station and field observations on infested cotton in Nueces, Williamson, Hunt, Rusk, and Smith counties:

1. Sulphur applied as a dust is an effective insecticide for controlling the cotton flea hopper.
2. The finer grades of sulphur are best adapted for dusting purposes.
3. The cheapest and most efficient method of applying sulphur to plants is by means of good types of dusting machines.
4. From 12 to 15 pounds of sulphur per acre for each application gives effective control.
5. Early applications of sulphur are the most effective since the young insects or nymphs are more susceptible to the effects of sulphur and adults are not killed generally by the dust.
6. The proper time to begin dusting depends upon local conditions. Every effort should be made to control the infestation from the beginning.
7. Three or four applications at 10- or 12-day intervals in the early part of the season should give protection to the crop in its early stages. If later applications are necessary the interval between dustings should be reduced to 8 days.
8. Applications may be made any time during the day.

SUMMARY

The cotton flea hopper has long been an inhabitant of Texas and is widely distributed within the State. Within the last three or four years the insect has become a major cotton pest, causing severe losses in many localities. The injury to cotton resulting from attack by this insect is manifested by excessive shedding of very small squares and the suppression of fruiting branches.

Croton or sageweed is the preferred food plant of the insect. However, it has been reared on a large number of different species of plants, principally common weeds. Sageweed is also the preferred host plant, but the insect will ovipost in cotton, *Atriplex,* horsemint, wild sunflower, horsenettle, and May apple.

The cotton flea hopper hibernates in the egg stage. The overwintering eggs begin to hatch in March or April of the following spring.

There are no distinct broods or generations of this insect. Reproduction is continuous throughout the warm season. Cold weather in the fall kills all stages of the insect except the egg.

The time required for complete development during the warm season varies from 16 to 29 days, averaging 22.5 days in May and June. Oviposition begins shortly after the insects become mature. During the act of oviposition the plant tissue is punctured by the ovipositor and the eggs are laid singly within the plant. The duration of the egg stage varies from 6 to 12 days, depending upon prevailing temperatures. There are five nymphal stages in the development of the insect. The nymphs are active and feed on the tender portions of the plants by inserting the beak and sucking the plant sap. There is some indication that the insect may transmit a toxic virus.

No natural enemies of importance have been observed. Cultural measures of control are recommended. These consist of the early destruction of host plants and the practice of clean culture. Sulphur and sulphur-naphthalene are effective insecticides in controlling the cotton flea hopper.

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