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THE COTTON FLEA HOPPER,

Psallus seriatus (Reut.)

IN OKLAHOMA

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Flea Hoppers Seldom Cause Loss, But Other Cotton Pests Cannot Be Slighted

Cotton flea hoppers seldom reduce cotton yields in Oklahoma, the research reported in this bulletin shows. Therefore efforts to control this insect are generally needless, *except when it is unusually numerous in areas where boll weevil is also a pest.*

This does not mean that efforts to control other cotton insects can be relaxed. Boll weevils, grasshoppers, leaf worms and numerous other pests are potential destroyers. When conditions favor their increase, they exact heavy toll from growers who do not fight them.

New chemicals, now being tested, promise more effective control of the weevil and other damaging insects in the future. Results of the tests will be made known as soon as possible. Meanwhile, the use of well established materials, such as calcium arsenate dust for controlling leaf worm and boll weevil, may often mean the difference between a good crop and none at all. Methods of controlling insects which damage cotton are described in Okla. Agri. Exp. Sta. Circular C-96.

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THE COTTON FLEA HOPPER,

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CHARLES H. BRETT, R. R. WALTON, AND E. E. IVY[1]

INTRODUCTION

The cotton flea hopper, *Psallus seriatus* (Reut.) is about ⅛ inch long. Its body has an obovate outline and a pale green, variable color pattern. The dorsum is more or less covered with small brown spots. Eyes are reddish to brown. Antennae are four-jointed and covered with a pale pubescence. An adult is shown in Fig. 1. The complete life cycle of the cotton flea hopper is pictured in Figures 2, 3, and 4, which show, respectively, an egg, a nymph, and an adult. Both the adults and wingless nymphs are very active. When first hatched, the nymphs are translucent white but soon change to pale green. Their eyes are prominent and scarlet in color. Reinhard (13)[2] gives excellent descriptions and illustrations of the various stages.

Apparently this insect is indigenous to the United States where it has been known since 1876 when it was described by Reuter (15) from specimens collected in Texas. Since then, it has been taken in nearly every state.

In 1898, Mr. J. D. Mitchell of Victoria, Texas, reported to Howard (8) that the insect was locally known in Texas cotton fields as the "cotton flea." It was supposedly injuring embryo buds, casing them to discolor and drop off.

Hunter (9) reported severe injury in southern Texas during 1923 and 1924. He considered the loss in 1923 due to "cotton fleas" as exceeding that caused by boll weevils. Hundreds of fields were a total loss. Dusting experiments in Calhoun County, Texas, showed that sulfur gave good control.

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[1] Considerable help was received from a number of persons during the period of this research. Dr. F. A. Fenton has been a constant and invaluable source of advice in planning and carrying out the various phases. Others whose contributions were of great importance and most of whom are mentioned in this report are Prof. Robert Stratton, Messrs. Charles F. Stiles, James S. Echols, and Larry F. Bewick. Field work on this subject was conducted under the supervision of Ephriam Hixson in the years 1937-1942. His name as one of the authors was omitted at his request. The engravings for Figures 2, 3, and 4 were made from photographs taken by Dr. H. A. Waters, of the Sherwin-Williams Paint Company.

[2] Numbers in parenthesis refer to Literature Cited, page 31.

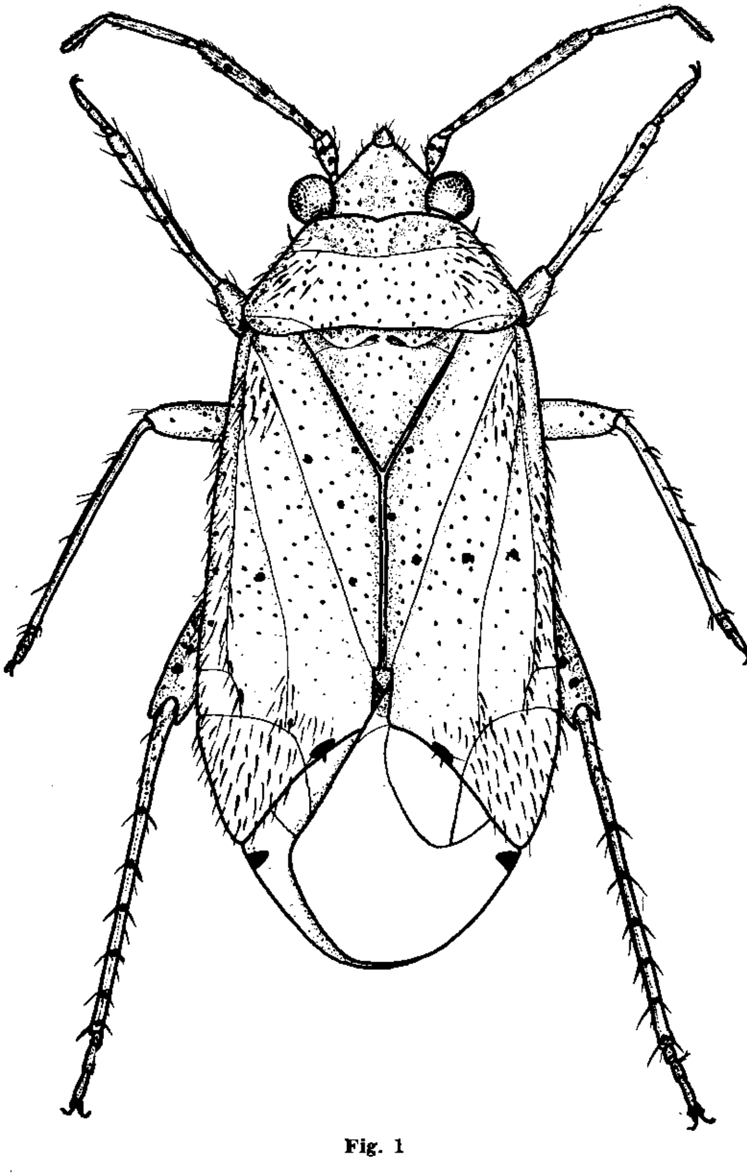


Fig. 1

Hunter suggested the possibility of virus transmission and also that the term "cotton hopper" would be a more appropriate name than "cotton flea." Reinhard (13) combined these into "cotton flea hopper" which has since become the accepted common name.

Reinhard (14) reported widespread injury to the cotton crop in Texas and other states in 1926 which could have been caused by the cotton flea hopper. Plants failed to fruit normally during the early part of the season. Insecticidal tests were made on the high infestation which was present on goatweed. From a number of materials, superfine sulfur was found to give most satisfactory control. The destruction of winter host plants was suggested as a means of reducing spring emergence.

One of the factors involved with the increased spread and threat of this insect was the expansion in cotton farming. Prior to the reported outbreaks of the early and middle twenties, cotton acreages in Oklahoma had increased by over 200 percent in ten years. Fields became much larger in size, a situation which Thomas and Owen (16) have pointed out is favorable for greater flea hopper injury. Disturbance of new soil and overgrazing of pastures aided the increase of host plants which would support overwintering. Surveys showed the flea hopper to be on the increase, and the possibility that it might do great damage to the cotton crop of this state stimulated a research program concerning it. The present paper is a compilation and report of work done in Oklahoma during the years 1936 to 1945 inclusive.

VARIATION OF INFESTATION LEVELS UNDER OKLAHOMA CONDITIONS.

During 1943 and 1944, extensive surveys were made under the direction of Stiles and Hixson. Considerable information was obtained through cooperation with 4-H Club members in the various counties. Weekly reports were compiled and distributed concerning the current level of infestation of the flea hopper and boll weevil. This work was continued during 1945, but few reports were received on the flea hopper for that year due to the generally low infestation. Figure 5 shows counties in which records were made and gives a general picture of the degree of infestation in the different areas based on the average maximum recorded for the two years.

Valley regions, especially in the southwestern part of the State, showed the highest level. Tillman County, with an average maximum above 20 percent (20 flea hoppers per 100 terminals), was the most heavily infested area. Fields in sandy spots of the North Fork of the Red River Valley averaged the highest in that county. Infestations of the lowest levels occurred in the North and Northeastern counties.

Fig. 2.—Flea hopper egg inserted in the stem of a Croton plant, exposed by peeling back the epidermis.

General infestation varies greatly from year to year. In the 1932-34 Biennial Report of the Oklahoma Agricultural Experiment Station, Hixson stated that flea hoppers had been scarce during the past two years. Following this period, there was an increase trend. On June 29, 1936, it reached a peak of 13.2 flea hoppers per 100 terminals in Bryan County. Dur-

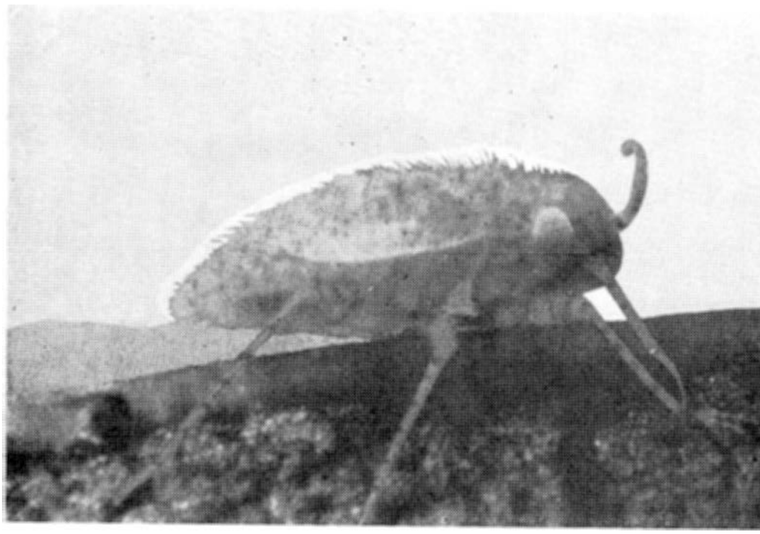


Fig. 3

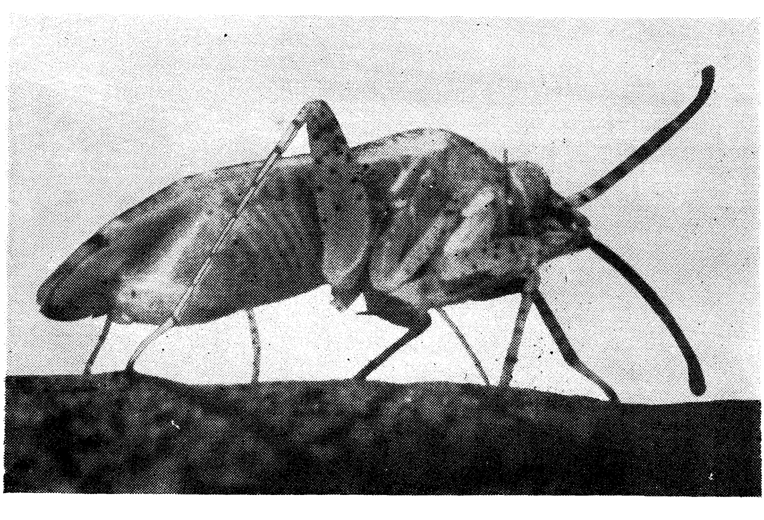


Fig. 4

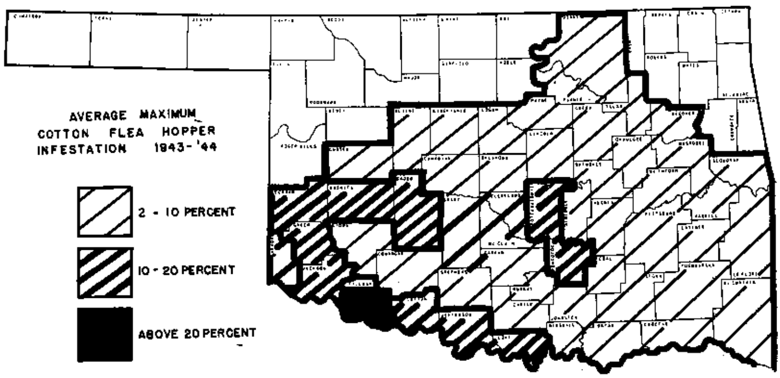


Fig. 5

ing 1937, thirteen closely watched fields near Idabel, Oklahoma, had an average infestation of 13.92 flea hoppers per 100 terminals. In 1938, it ranged somewhat higher. During 1939 and 1940, it dropped back to a very low level.

In 1941, tests were set up in Tillman County because of the higher levels of infestation in the southwest region. During August of that year, one check plot reached a peak of 240 flea hoppers per 100 terminals. In 1942, it dropped back, averaging about 23 flea hoppers per 100 terminals in check plots set up near Tipton, Oklahoma. Severe drouth in 1943 reduced the insect population greatly. It increased somewhat in 1944 and dropped to another low point in 1945.

There is tremendous variation in the level of population throughout the State which does not follow a cyclic pattern but is determined principally by climatic factors, the prevalence of weed hosts and the condition of cotton plants, which may be vastly different between localities. Even in the same locality it has been found that the level may range from below 10 to over 100 flea hoppers per 100 terminals in different fields and that it is by no means uniform within a given field. This is a point of much importance when considering the flea hopper problem in Oklahoma.

HOST PLANT RELATIONSHIPS

In reviewing literature from various states, a list of 147 different species of plants reported as hosts of the cotton flea hopper has been compiled. Hixson (7) reports 87 species of host plants belonging to 24 families, in Oklahoma. He states that the genera *Oenothera, Monarda, Solanum,* and *Croton* are the most important. Small flowered crowfoot *(Ranunculus parviflorus* L.) is the most common host plant. His study of host sequence showed the principal early spring plants upon which nymphs develop are cut-leaved evening primrose [*Oenothera laciniata* (Hill)], which is common throughout the state, and *R. parviflorus,* which is common in the eastern part. Late spring and early summer host plants on which the first generation develops are the various *Monardas,* horsenettle (*Solanum elaeagnifolium* Cav.), *O. laciniata* L., mayweed *(Anthemis cotula* L.), and goatweed *(Croton* spp.). The most important late summer host plants in Oklahoma (July until frost) are *Croton capitatus* Michx. in the eastern part of the state; *C. texensis* in the sandy areas of the western part; *C. Lindheimeranus* Scheele, in the central prairie area, mostly in stubble fields; *S. elaegnifolium;* and horsemint *(Monarda punctata* L.).

During November, 1943, Brett and Walton observed adults and nymphs swarming in *Cladothrix lanuginosa* Nutt. These were growing abundantly in sandy soils west of Tipton, Oklahoma. Exposed areas along the bank of the North Fork of the Red River were covered with this species. *Croton* plants were comparatively scarce that year, but those which could be found were not sustaining as high a population as the *Cladothrix* plants. When these areas were again examined during the first week of May, 1944, young *Cladothrix* plants were prevalent and a few nymphal flea hoppers were found on nearly everyone. *O. laciniata* was unusually abundant in nearby pastures but few flea hoppers could be collected from it.

Collections and observations made during 1944 and 1945 by Brett and Echols showed the most important host plants in the Tipton area during those years belonged to the genera *Cladothrix, Croton,* and *Solanum.*

Important factors contributing to an abundance of host plants are overgrazing, lack of clean cultivation, unattended fence rows, and waste areas. In 1941 at Tipton, Hixson and Bewick demonstrated that mowing weeds in pastures would result in an increase in the growth of grasses with a subsequent reduction of many weeds. They also observed that flea hoppers were most numerous in fields near to or surrounded by weeds.

OTHER MIRIDS RESEMBLING THE FLEA HOPPER[1]

In July, 1937, Ivy collected specimens of *Reuteroscopus ornatus* (Reut.) from pigweed and cotton. This mirid resembles *P. seriatus* but is somewhat larger, darker green, and with a distinct color pattern. In 1938, he found *Reuteroscopus sulphureus* (Reut.) in cotton near Idabel, Oklahoma. This species was almost always present in cotton in that area and at times became more numerous than *P. seriatus.* It was easily confused with *P. seriatus* especially in the immature stages. Adults have a somewhat distinguishing dull yellow cast.

Fourth and fifth instars of the three species, *P. seriatus, R. sulphureus,* and *R. ornatus* were placed in voile cages on the tips of *Croton* and *Ambrosia* plants. Such cages are shown in Figure 6. Upon reaching the adult stage, they were paired both with the same species and with all combinations of the other species. No crossing occurred.

Pairs of the same species mated upon reaching the adult stage. For 15 pairs of *P. seriatus* the preoviposition period averaged 5.3 days and the oviposition period 9.5 days. Females averaged 21.12 eggs each and lived for 14.44 days; males lived 10.6 days. Nymphs developed to maturity in 17.43 days.

Preoviposition for eight pairs of *R. sulphureous* lasted 4.6 days. The females lived 7 days and averaged 6.75 eggs apiece. Males lived 6 days. Nymphs developed in 22.22 days.

The preoviposition period for one pair of *R. ornatus* was 4 days. Thirty-four eggs were laid over a period of 18 days.

NATURE OF FLEA HOPPER INJURY TO YOUNG FRUITING BUDS OR "SQUARES"

It has long been known that the flea hopper causes injury to the fruiting bud which results in its being shed. The exact nature of this injury however, has been controversial. At times it has appeared impossible that so few insects present could cause such extensive damage. In other instances, comparatively high infestations have produced slight, if any, damage to the crop. Hunter (9) suggested that virus transmission might be the cause for such phenomena.

Painter (12) inoculated various parts of cotton plants with suspensions of cotton buds on which flea hoppers had been caged, crushed flea hoppers, diastase, pepsin, trypsin, invert sugar syrup solution, water, and centrifuged croton juice. No effects were shown on any plants except those

[1] Identified by Dr. H. H. Knight and Dr. H. M. Harris of Iowa State College.

Fig. 6

treated with crushed flea hoppers and suspensions of injured cotton buds. The latter produced split lesions. There was also a difference in the average rate of growth which paralleled that of plants in cages where hoppers had been introduced. Growth decreased at first and this was followed by a slight increase.

King (10) concluded from experimental and histological study that there was no indication a virus was involved. Ten different species of plant-sucking insects were used in his tests. Some of these do not normally feed on cotton. He says,

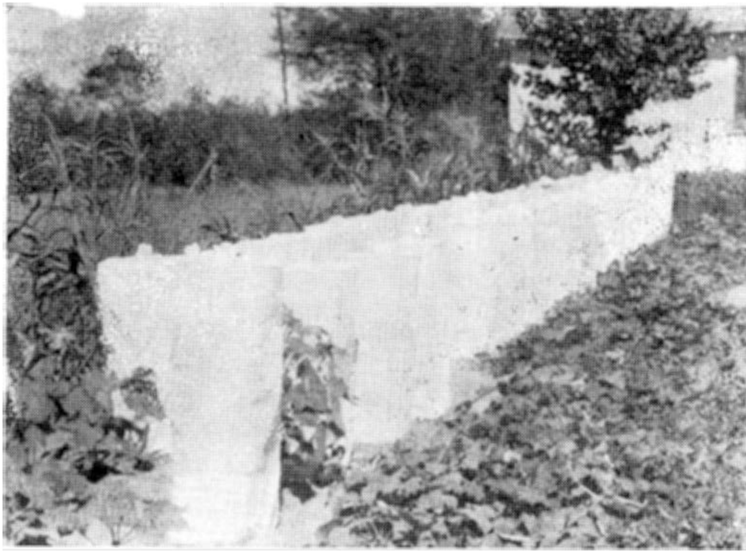


Fig. 7

" . . . . nearly all individuals caused a reaction in the tissues of cotton stems and leaf petioles similar to that produced by the cotton flea hopper, *Psallus seriatus*. This is taken to indicate that hopper damage is due to injected substances normally present in the insects and toxic to the plant, rather than to a transmissible disease." No shedding occurred except where feeding was near the squares. Considerable variation was found in the toxicity between individual insects of the same species.

During 1938 at Idabel, Oklahoma, Ivy confined ten flea hoppers in a cage on the tip of a plant and then caged the entire plant, checking carefully to see that all other insects were removed. Cages used in this test appear in Figure 7.

His results (Table I) show that injury did not spread to the entire plant. Loss of squares was greatest in the area where insects were confined.

It is probable that flea hopper populations of the same level may attack varying percentages of the squares. These insects can feed on nearly all parts of the plant and their selection of squares would be determined by a number of factors, including the relative succulence of different tissues, density of vegetation, and climatic relationships.

TABLE I.—Effect of caging P. seriatus *on a portion of the plant only; Idabel, Okla., 1938.*

Duration of test	Number of replicates	Av. percentage of squares retained by entire plant	Snedecor's T-value
Aug. 2 to Aug. 25	4	61.4	1.12
Check	11	68.1	Not significant
Sept. 23 to Oct. 15	4	70	3.5
Check	10	88.5	Not significant

EXTENT OF INJURY CAUSED TO SQUARES BY *P. seriatus* AND CERTAIN OTHER INSECTS

In 1938, Ivy made a series of cage tests at Idabel, Oklahoma, in which he measured the retention of squares of infested plants as compared with non-infested plants. Table II shows the markedly high percentage of shed caused by *P. seriatus* during most of the growing season.

Cages were of the same type as was used in studying the effect of flea hoppers confined to small areas (Fig. 7). The upper part of the cage was voile and the lower part muslin. The base of the muslin was buried in a trench. Entrance into the wire frame cages was made by means of a nine-inch zipper near the top. Cages were examined every two or three days at which times dead insects and shed squares were removed and pinned.

TABLE II.—Effect of caging P. seriatus *on cotton plants; Idabel, Okla., 1938.*

Duration of test	Stage of insect	No. of replicates	Av. percentage of retained squares	Snedecor's T-value
June 15 to July 5	Adults, Nymphs	4	22.76	10.64
Check	Adults, Nymphs	9	66.06	Highly significant
Aug. 2 to Aug. 25	Adults, Nymphs	7	28.2	6.13
Check	Adults, Nymphs	11	68.16	Highly significant
Sept. 24 to Oct. 15	Adults	8	16.25	19.74
Check	Adults	10	88.51	Highly significant

Seven replicates were made in cage tests with *R. sulphureus*. The square retention averaged 55.5 percent in the treats as compared with 74.2 percent in the checks. This was less injury than caused by *P. seriatus*. *R. ornatus* caused a shedding of 61 percent in the treats as compared with 74.2 percent in the checks. This is very little effect and not comparable to that of *P. seriatus*.

The rapid plant bug, *Adelphocoris rapidus* (Say), caused considerable shedding of squares. Only 12.8 percent were retained in the test cages as compared to 89 percent retention in the checks. This insect was even more abundant in cotton than *P. seriatus* in the vicinity of Idabel, Oklahoma, during July and August of 1938. Ordinarily, it is considered to be of minor importance.

All of the insects mentioned above belong to the family Miridae. Other tests were conducted in which 26 different species of insects commonly found in cotton were caged together in large numbers. These belonged variously in the families Cicadellidae, Membracidae, Lygaeidae, and Fulgoridae. They caused little, if any, injury from the standpoint of shedding squares.

Severe attacks by flea hoppers on cotton during the early part of its squaring period is known to result in an abnormal development of some plants. There may be fewer fruiting branches with a tall whip-like growth of the main stem. Sometimes there is an increase in the number of vegetative branches. Such peculiar growth of the plant cannot, however, always be attributed to flea hoppers. In 1938, Hixson observed a variety of cotton (Acala 8) shedding squares during the early part of the season in much the same manner as from flea hopper injury, although none of the insects were present at that time. Blank stalks commonly appeared in 1940 whether flea hoppers were present or not. In 1941, blank stalks appeared both in surfur treated plots and check plots.

Counts taken in test plots during 1942 showed that plants reared from first-year seed produced 3.6 percent blank stalks. The rest were good. Plants reared from four-year-old seed produced 21.2 percent blank stalks. The cause for this was not known; however, it was observed that there was some mixture in the four-year-old seed while the year-old seed had been carefully selected. Blank stalks appeared both in the sulfur treated and check plots.

EFFECT OF SQUARE REMOVAL ON BOLL PRODUCTION

Hixson [Dunlavy *et al.* (2)] observed in the results of his 1941 tests that a loss of squares might stimulate the plant to produce more blooms and bolls rather than less and that if the number of bolls was decreased their size would normally increase; however, there was a loss of boll size in some varieties.

Hamner (6) in 1943 gave strong support to these findings by his experiments in Mississippi. Squares were artificially removed from plants (Cleveland 54 variety) in small protected plots. He obtained the highest yield during 1939 in plots where 10 percent of the squares were picked off the first week, 20 percent the second week, 30 percent the third week, 40 percent the fourth week, and 50 percent the fifth week. In 1940, the highest yield was obtained in plots where up to 40 percent of the squares were removed by the fourth week and in 1941 where up to 30 percent were removed by the third week. At the end of these periods, mechanical removal was stopped. Hamner states that, "the percent of blooms set on and the number of bolls required to make a pound of seed cotton on the treated plots show that the plant compensates to a large extent for the loss of squares." He concludes that a plant reacts to a partial loss of blooms by setting a higher percent of those remaining.

Eaton (4), experimenting with Acala variety in Arizona, found a 24 percent increase in yield where all bolls, flowers, and large squares were removed on the eighth day of the flowering period. Flowers were produced 14 days later. There was also a decided increase in yield where all flowers and floral buds were removed during the first 25 days of the flowering period. He observed that strains which ordinarily abort large numbers of early bolls and buds yielded more than determinate strains.

McNamara *et al.* (11) found that only 38 to 45 percent of the flowers produced by Half and Half variety developed into mature bolls. Terminal abortion at the first node was greater in Delfos and Half and Half than in the varieties having larger bolls. The greatest number of bolls were set on branches which showed the greatest number of terminal abortions. It was observed that a good rain would delay shedding while dry hot weather would cause the shedding of small bolls; however, seasonal effects were not as great as might be expected.

Dunlap (1) found light to have a greater effect on fruiting and shedding than drought or high temperature. Periods of cloudy weather were followed by increased rates in shedding of fruiting forms. Variations in light affected the number of bolls borne to maturity more than it did the formation of flower buds. Certain varieties were less sensitive to unfavorable light conditions than others. These included Half and Half which is a variety commonly grown in southwestern Oklahoma and one used in many of the studies reported in this bulletin.

It is apparent that nutritional dominance over vegetative growth inhibits boll setting and terminal development and the number of bolls developed is relative to the area of leaf surface (excluding environmental influences). Experimental evidence has shown that a sacrifice of the first bolls will result in a larger plant with a more extensive root system and that this plant will support more fruit. Although there is undoubted evidence, as has been shown by Ewing and McGarr (5), that flea hoppers can damage cotton, and rather severely under certain conditions, it is also conceivable, from data at hand, that under many circumstances comparatively high infestations may cause little if any loss. One might even suggest that at times flea hoppers could be responsible for a greater setting on of fruit during a period when it would be carried and thus increase the yield.

RELATION OF FLEA HOPPER TO DIFFERENT VARIETIES OF COTTON

During 1937, Hixson made regular infestation counts on eight varieties of cotton in order to determine any host preference which might exist. The range extended from 10.4 flea hoppers on 100 terminals on Acala 8 to 15 flea hoppers per 100 terminals on Stoneville 5.

In 1941, Hixson [Dunlavy *et al.* (2)], in cotton variety tests at Lawton and Tipton, Oklahoma, found the Acala 8 varieties to be more susceptible to flea hopper attack than other types. Something in the physiology of the plant appeared to be affected, and boll size as well as yield was decreased under flea hopper influence. This was also found to be true of some Mebane varieties. He considers as a possible reason why such varieties have not done well in the southwestern part of the state the fact that they were developed under ideal growing conditions without the shock of flea hopper attack. Dunlavy *et al.* (3) reported in 1945 that Acala 8 was a low producer on both sides of the State and that the production of this variety has little place in Oklahoma.

In 1942, Hixson made variety tests near Tipton, Oklahoma. Twenty-six varieties were set out in two-row plots. Rows were 70 feet long and 40 inches apart. Six replicates were used. Half of each plot was dusted five times with sulfur and half was left as a check. The average yield for all undusted plots was 1,388 pounds of seed cotton per acre. The flea hopper infestation averaged 22 insects per 100 terminals. In all dusted plots, the average yield was 1,488 pounds per acre with an average infestation of 11.2 insects per 100 terminals. In four cases, varieties showed lower yields in dusted plots than in checks. Some varieties with more flea hoppers yielded more cotton, others with fewer flea hoppers yielded less cotton per acre.

FLEA HOPPER CONTROL EXPERIMENTS IN OKLAHOMA

1936—In 1936, tests made by Fenton in Bryan County, using sulfur at the rate of 11.2 pounds per acre, showed a decrease of 37 percent in the flea hopper infestation of treated plots as compared with an increase of 8 percent in the checks. Dust was applied June 29. Three weeks later there were 14 percent more blooms in the treated plots than in the checks. The peak infestation of 13.2 flea hoppers per 100 terminals was not, however, sufficiently high to show a gain in yields.

1941—During 1941, in Tillman County, Hixson dusted three fields twice with sulfur to control flea hopper. The infestation was reduced below 20 flea hoppers per 100 terminals. Yields in the treated plots averaged 45 pounds seed cotton per acre less than the checks. None of the treated plots gained over the checks. No relation between yield and flea hopper infestation was shown.

1942—During 1942, Hixson made tests in a large field of Half and Half variety. The plots were 6 to 8 acres in area. Yield was based on three 1/20 acre samples per plot. Dusting was done with 325-mesh sulfur. Table III shows the effectiveness of the treatments on flea hopper control and the relation to yield. Some of the dusting applications made during a rather high wind brought out the conclusion that sulfur controls flea hoppers whether dusted in wind or calm. There was no significant gain in yield as a result of controlling the flea hoppers.

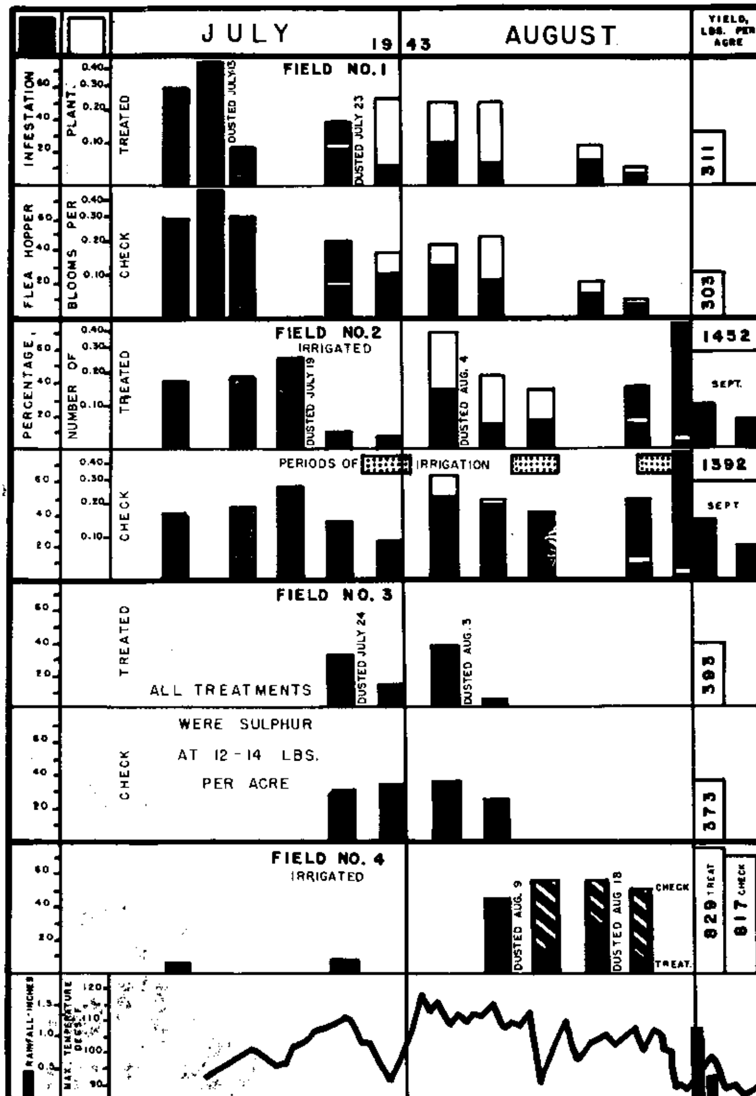
1943—In 1943, Walton conducted tests in four different fields near Tipton, Oklahoma. Two of these were irrigated during the latter part of July and the middle and latter part of August. The season was exceptionally hot and dry. Figure 8 shows a maximum temperature of 120° F. during the first

TABLE III—Relation between flea hopper control and yield; Tipton, Okla., 1942.

Material	Pounds per acre	No. of applications	Av. No. of flea hoppers per 100 terminals	Yield, Pounds per acre
Test 1				
Sulfur	10	3	10.27	1670.6
Sulfur	15	3	13.37	1823.2
Sulfur	15	2	18.15	1766.0
Sulfur and calcium arsenate	12	3	15.78	1742.0
Sulfur and calcium arsenate	18	3	13.95	1860.0
Check	--	--	19.7	1748.0
Test 2				
Sulfur	15	2	18.15	1941.2
Sulfur	15	1	26.22	2032.0
Sulfur	15	5	14.05	2031.0
Check		--	30.66	1842.0

part of August with no rainfall throughout July and August. Cotton fruited well during July and the first half of August; however, there was considerable shedding with little growth in the plants. Flea hopper infestations varied greatly over the area, being heavier in the sandy soils near the river than in the loam soils of the central region. Fields with high infestations were selected for tests. They were dusted full length in plots 48 rows wide. Two hundred terminals were examined in each plot for estimating infestation. Daily bloom counts were made in fields 1 and 2. Each field was dusted twice at times when the infestation appeared to have reached a peak. Using 325-mesh sulfur at the rate of 12 to 14 pounds per acre, flea hoppers were successfully controlled. Figure 8 shows the bloom counts in the treated plots of fields 1 and 2 to be considerably higher than in the check for about three weeks after dusting. There was a continual leveling off of this difference.

One of the most interesting results which appeared in Walton's 1943 test was the relation of water and climate to yield per acre and the population level of the flea hopper. In fields 1 and 3, which was not irrigated, the flea hopper population, after gaining its initial peak, continually decreased as the hot dry season progressed. In irrigated fields, the flea hopper population would increase for a period following each irrigation and later drop off as plants became less succulent. Yields were very low in unirrigated fields. In field 1, the dusted plots averaged 311 pounds of seed cotton per acre as compared



JULY
19 43
AUGUST
YIELD, LBS. PER ACRE
INFESTATION
PLANT
TREATED
FIELD NO. 1
DUSTED JULY 13
DUSTED JULY 23
311
FLEA HOPPER
BLOOMS PER
CHECK
303
PERCENTAGE,
NUMBER OF
FIELD NO. 2
IRRIGATED
DUSTED JULY 19
DUSTED AUG. 4
1452
SEPT.
PERIODS OF IRRIGATION
1392
SEPT.
FIELD NO. 3
DUSTED JULY 24
DUSTED AUG. 3
ALL TREATMENTS
WERE SULPHUR
AT 12 - 14 LBS.
PER ACRE
395
373
FIELD NO. 4
IRRIGATED
DUSTED AUG. 9
DUSTED AUG 18
CHECK
TREAT.
829 TREAT
817 CHECK
RAINFALL-INCHES
MAX. TEMPERATURE DEGS. F.

Fig. 8

Fig. 9

with 303 in the checks. In field 3, the dusted plots averaged 393 pounds as compared with 373 in the checks. Irrigation of fields 2 and 4 greatly increased the plant's ability to hold fruit. Field 2 produced 1452 pounds of cotton per acre in the dusted plots as compared with 1392 in the checks, while field 4 produced 829 pounds in the dusted plots and 817 in the checks.

The slight difference in yield between treated and untreated plots shows nothing beyond normal experimental variation. However, the gain in yield in irrigated fields as compared with non-irrigated ones demonstrated the plant's ability to increase greatly the amount of fruit which could be borne to maturity when conditions were made more favorable to it. This increase was very much the same whether flea hoppers had been controlled or not.

1944—In 1944, both caging and field tests were conducted by Brett.

In the caging tests, cotton plants were confined in muslin cages of adequate size to allow for freedom of growth. On July 1, 20 adult *P. seriatus* were placed in each of 10 cages. The plants at this time averaged about 12 inches high. On August 24, these plants were examined. An average of 14 shed squares was collected from each infested plant. This same number

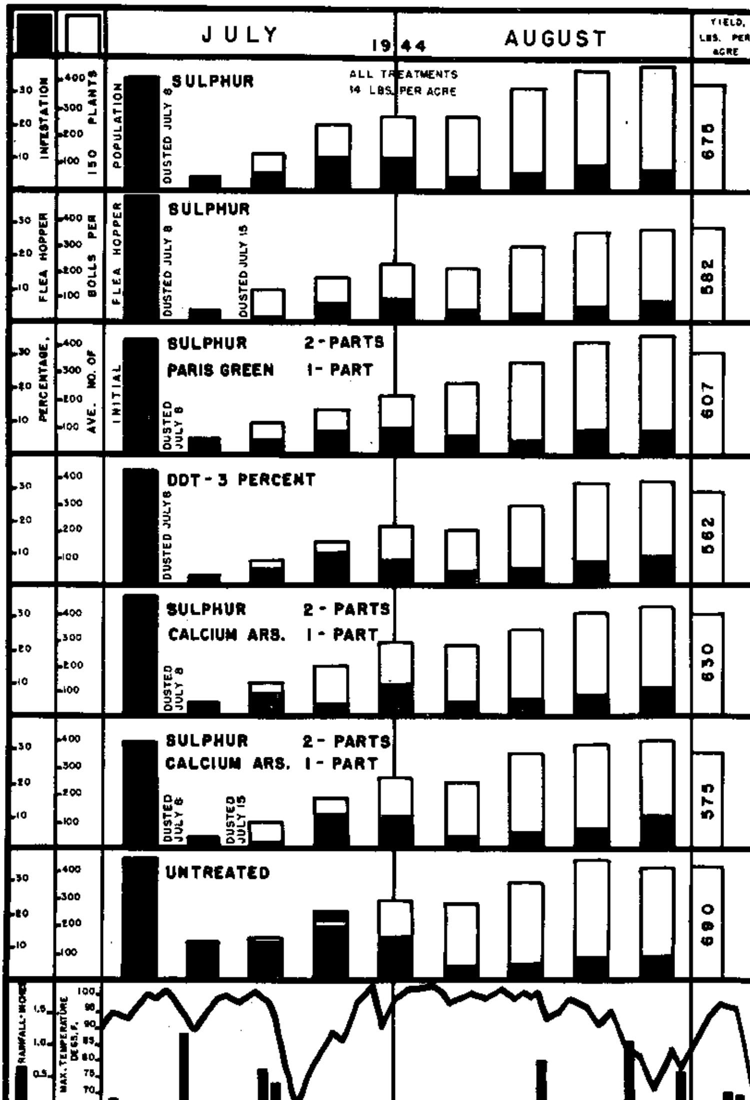

JULY
1944
AUGUST
YIELD, LBS. PER ACRE
PERCENTAGE, FLEA HOPPER INFESTATION
AVE. NO. OF BOLLS PER 150 PLANTS
INITIAL FLEA HOPPER POPULATION
ALL TREATMENTS 14 LBS. PER ACRE
SULPHUR
DUSTED JULY 8
675
SULPHUR
DUSTED JULY 8
DUSTED JULY 15
582
SULPHUR 2-PARTS
PARIS GREEN 1-PART
DUSTED JULY 8
607
DDT-3 PERCENT
DUSTED JULY 8
562
SULPHUR 2-PARTS
CALCIUM ARS. 1-PART
DUSTED JULY 8
630
SULPHUR 2-PARTS
CALCIUM ARS. 1-PART
DUSTED JULY 8
DUSTED JULY 15
575
UNTREATED
690
RAINFALL-INCHES
MAX. TEMPERATURE DEGS. F.

Fig. 10

TABLE IV—Effect of different insecticide dusts, applied at 14 pounds per acre, on cotton flea hopper and the effect of control on yield; Tipton, Oklahoma, 1944 and 1945.

Insecticide	Form	Number of flea hoppers				Percentage of reduction		Yield, pounds per acre as compared with check
		Before dusting		After dusting				
		Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	
1944								
Sulphur	352-mesh	33	173	17	9	49	95	15 lbs. less
Paris green	1 part							
Sulphur	2 parts	41	163	8	18	81	90	83 lbs. less
DDT	3 percent	32	183	17	2	47	98.9	128 lbs. less
Calcium Ars.	1 part							
Sulphur	2 parts	50	178	11	15	78	92	60 lbs. less
Untreated	----	41	179	24	42	62	76	----
1945								
DDT	5 percent	79	205	36	9	55	96	Same as check
DDT	10 percent	118	231	15	4	92	99	130 lbs. gain
Sulphur	325-mesh	101	260	35	20	66	92	5 lbs. gain
Sabadilla	10 percent	139	256	63	80	51	69	105 lbs. less
Lethane, B-71	Rhom & Haas	88	330	69	134	30	60	75 lbs. less
Untreated	----	86	273	101	144	+18	64	----

of squares was also collected from each of 10 uninfested caged plants. The infested plants at this time bore an average of five bolls each. The uninfested plants averaged six bolls per plant. Ten plants which had not been caged averaged 12 bolls per plant and were decidedly smaller than the caged plants. Very few shed squares could be found under them.

These results show an increase shedding, a reduction in the number of bolls developing, and an increase in plant size as the result of caging. No flea hopper influence, however, was evidenced. Caging effects were principally due to a decrease in the amount of light available to the plant and are entirely in agreement with records obtained by Dunlap (1).

Field tests during 1944 consisted of seven different types of treatment, each replicated four times in the same field (Half and Half variety) using latin square arrangement. Plots were 300 feet long and 18 rows wide. All dusts were applied with the six-row, one-horse, Root model Y-2 duster shown in Figure 9, at the rate of about 14 pounds per acre. Types of treatments, trend in flea hopper infestation, boll development, and yields are shown in Figure 10. Table IV shows the comparative effect of the different dusts on adults and nymphs and their percentage of reduction. It will be noted here that the addition of Paris green or calcium arsenate to sulphur, at the rate of one part in two, greatly increased control of adult flea hoppers. Sulphur gave good control for nymphs but apparently none at all (when compared with the checks) for adults without the arsenicals added. Three percent DDT dust did not control adults but was the most effective of all dusts used in reducing nymphs. All treatments reduced the nymphs 90 percent or above. They were, however, reduced 76 percent in the checks due to dry weather. Figure 10 shows the same correlation between moisture and flea hopper population as has been previously discussed, i. e., following rainfall plants became more succulent and the insect population increased, with this relationship reversed during hot dry weather.

High temperature and drouth conditions accompanied by strong winds during the first part of August caused a heavy shedding of bolls. This is undoubtedly one of the several factors overshadowing any damaging influence which might have been caused by flea hoppers.

Yields, averaged from 1/20 acre samples in each of the plots, showed a loss with all treatments as compared to the checks regardless of flea hopper control. This loss, ranging from 15 pounds per acre in the sulphur treated plots to 128 in the DDT treated plots, was experimental variation due to differences in soil or other factors and shows nothing pertaining to insect control.

1944 Tests With Potato Leaf Hoppers

Heavy damage was observed in two cotton fields in the spring of 1944 near Glencoe, Oklahoma, due to an infestation of potato leaf hopper, *Empoasca fabae* (Harris). The young plants were over 50 percent burned. Following a heavy rain, the leaf hoppers disappeared and cotton plants recovered without retaining injurious effects.

On July 15, about 30 adult potato leaf hoppers were placed on caged plants. These insects propagated on the cotton. Plants were burned severely and their development greatly impaired. On August 24, an examination of six infested plants showed an average of 2.8 bolls per plant. Six uninfested plants averaged 5.3 bolls each.[1]

1945—The 1945 tests at Tipton, Oklahoma, followed the same procedure as was used in 1944. Half and Half variety was used during both years. The most heavily infested fields were located in the sandy soil region near the North Fork of the Red River. The 1945 season was unusually late and it was necessary to keep a close watch on the flea hopper situation in order to set up a test. Infestations over the State were low. As can be seen in Figure 11, the population in the field used for experimental work started building up in July. Good rainfall during the middle of July boosted it rapidly. Plots were dusted July 26.

The treatments compared were 5 percent DDT, 10 percent DDT, 325-mesh sulphur, 10 percent sabadilla, and B-71 Lethane as prepared by Rohm and Haas Company.

Ten percent DDT gave the most effective control of all treatments. All concentrations of DDT gave good control of nymphs but high percentages were necessary to control adults. Three percent DDT in the 1944 tests reduced the adult population 47 percent. In the 1945 tests, 5 percent DDT reduced numbers of adults 55 percent while 10 percent DDT caused 92 percent reduction.

About the same control was obtained with 5 percent DDT as with 325-mesh sulphur. Since DDT is considerably more expensive than sulphur, it would not replace it in the event flea hopper control became necessary. Ten percent sabadilla reduced adults 51 percent and nymphs 69 percent compared

[1] Photographs of injury are shown on page 71 of the 1942-44 Biennial Report of the Oklahoma Agricultural Experiment Station.

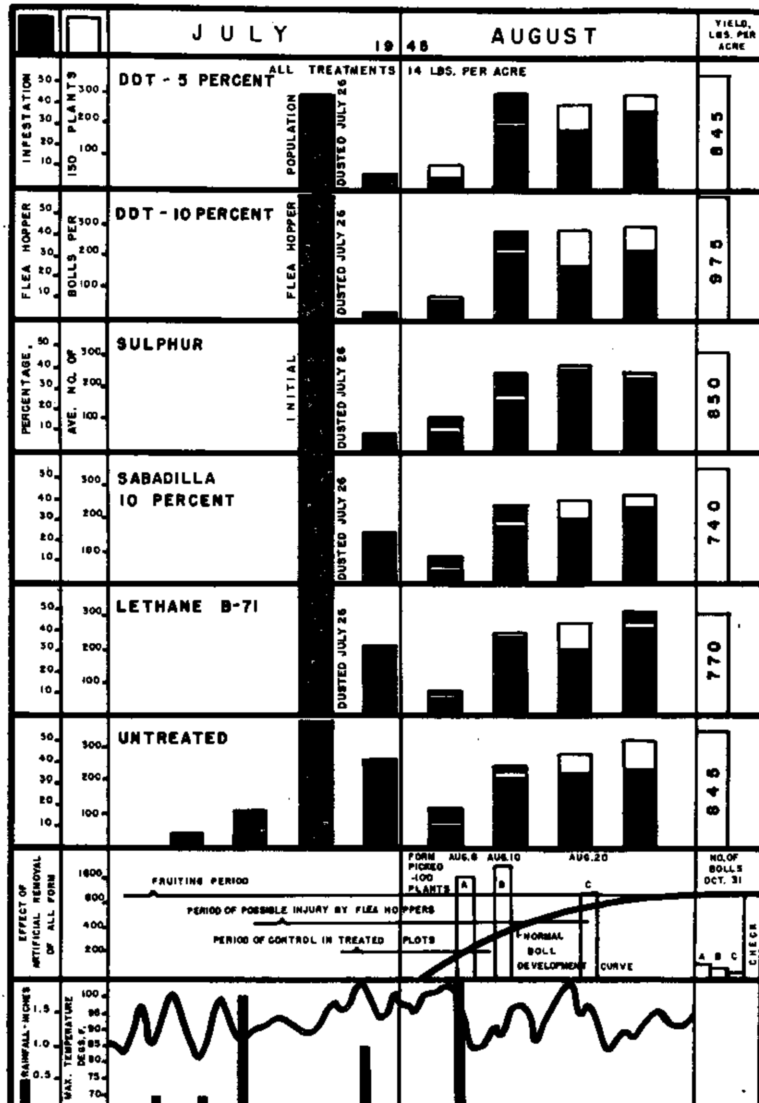

JULY
1948
AUGUST
YIELD, LBS. PER ACRE
ALL TREATMENTS 14 LBS. PER ACRE
INFESTATION
150 PLANTS
FLEA HOPPER
BOLLS PER
PERCENTAGE,
AVE. NO. OF
DDT - 5 PERCENT
DDT - 10 PERCENT
SULPHUR
SABADILLA 10 PERCENT
LETHANE B-71
UNTREATED
INITIAL FLEA HOPPER POPULATION
DUSTED JULY 26
845
975
850
740
770
845
EFFECT OF ARTIFICIAL REMOVAL OF ALL FORM
FRUITING PERIOD
PERIOD OF POSSIBLE INJURY BY FLEA HOPPERS
PERIOD OF CONTROL IN TREATED PLOTS
FORM PICKED -100 PLANTS
AUG.8
AUG.10
AUG.20
NORMAL BOLL DEVELOPMENT CURVE
NO. OF BOLLS OCT. 31
CHECK
RAINFALL-INCHES
MAX. TEMPERATURE DEGS. F.

Fig. 11

with 66 percent for adudts and 92 for nymphs in the sulphur plots. B-71 Lethane reduced adults 30 percent and nymphs 60 percent. A comparison of these materials in their control on adult and nymphal flea hoppers and the relation to yield is shown in Table IV.

Variation in yield ranged from a loss of 105 pounds per acre in the sabadilla treated plots to a gain of 130 pounds per acre where 10 percent DDT was used. The season was such that cotton was extremely irregular in its development. Some fields had been replanted three times, and during the early part of the season it was not uncommon to see a field which ranged from newly planted cotton to plants which were producing squares. The field used for testing was above average in uniformity, but even here plants in areas where water stood during the early part of the season were retarded at that time and later became the most vigorous.

An attempt was made to determine the effects of heavy loss of fruit by hand picking all of the forms from some plants. Figure 11 shows graphic results of this test. On August 8, 1,625 forms were removed from 100 plants. These plants produced 89 bolls by October 31. On August 10, 1,716 forms were removed from another 100 plants which produced 78 bolls October 31. On August 20, 1,287 forms were picked from 100 plants which produced but 37 bolls by October 31. One hundred plants from which forms were not removed produced 1,041 bolls by October 31. These results indicate that the earlier in the season forms are removed, the greater is the recovery. Such low recovery at the time pickings were made indicates the crop was on the plants by August. Flea hopper damage could have been measureable only before that time. Since these insects were controlled in the treated plots July 26, at the peak of their infestation, their influence should have been in evidence in the final yields if they were doing damage to the crop.

DISCUSSION

Plants from which forms were picked grew more vigorously than the others. They were taller, greener, more leafy and stood out in marked contrast against those supporting fruit. This is the normal reaction when nutritional requirements of the fruit have been removed. Such reaction was previously discussed in this bulletin and supports the interpretation that flea hopper influence was not evident, due to limitations of weather and other environmental factors. The plant balances its development with all external and internal energies, including soil, temperature, and moisture. Although flea hoppers may cause considerable shedding, other factors produce the same effect. Such shedding may even benefit the plant during its early growth. Eventually it produces as many bolls as it is able to nourish and carry to maturity. Its limitations under the conditions of southwestern Oklahoma appear to be set by forces other than flea hopper influence. The development of varieties suitable to the growing conditions of this region with improvements in methods of cultivation and harvesting constitute the most important problem. Such studies are being carried on by the Agronomy Department of the Oklahoma Agricultural Experiment Station. A cotton substation is located at Tipton, Oklahoma, for this specific purpose.

SUMMARY

Since 1936, the Department of Entomology of the Oklahoma Agricultural Experiment Station has conducted research concerning the cotton flea hopper. This insect has been found most prevalent in the southwestern part of the State, which is also the most important cotton growing area. There is tremendous variation and fluctuation of the infestation level throughout the State and even within a single field during a season. This variation correlates rather closely with rainfall, plant succulence, and the prevalence of hosts, being greatest in the presence of these factors and least in their absence.

Plants belonging to the genera *Oenothera, Monarda, Solanum, Croton, Ranunculus,* and *Cladothrix* are the most favored hosts. They are generally abundant due to overgrazing of pastures, lack of clean cultivation, unattended fence rows, and waste areas.

Reuteroscopus ornatus (Reut.) and *R. sulphureus* (Reut.) have been found in cotton. These insects also belong to the family Miridae and are so similar in appearance to the cotton flea hopper that they are easily confused with it. They also damage squares and cause shedding. Biological studies were made concerning them.

Tests conducted in Oklahoma support the conclusions of others that injury to the fruiting buds or "squares" results from toxicity and not disease such as virus transmission, and that damage is local rather than systemic.

Tests in which the cotton flea hopper and several other insects were confined on caged plants showed them to be responsible for the shedding of quite a high percentage of squares. The appearance of abnormally developed plants or blank

stalks in the field, however, was not found to be generally caused by flea hoppers. The normal reaction of infested plants was to increase in size and vigor and retain a higher percentage of blooms and bolls which were set on. If fewer bolls were borne, these tended to grow larger and heavier.

Some varieties of cotton were found to be more susceptible to flea hopper attack than others, but none of the susceptible varieties are among those currently recommended for production in Oklahoma.

During a period of five years, tests were made to determine the most satisfactory dusts, their rate of application, and the economic value of control. During this period a total of 25 tests were made, each replicated three or four times. There was a difference of only 8.4 pounds of seed cotton per acre between the treated and non-treated plots. Good control of the flea hopper was obtained, but its advantage did not appear in yields. This is believed due to the plant's ability to compensate in various ways for any loss of squares caused by flea hoppers. Under the growing conditions of southwestern Oklahoma, considerable shedding is caused by variation in light intensity, high temperatures, and drouth. Flea hopper influence is a factor which would not normally add to this usual climate effect. Plants balance their development and reach a point wherein they are supporting all of the bolls they are able to mature. This usually is reached in August. When forms were removed from plants during August, they responded with a greatly increased vegetative development and vigor, but were unable to recover their fruit in time for boll maturity.

DDT was found to give excellent control, but was not effective against adult flea hoppers except at the higher concentrations. Three percent DDT reduced the adults 47 percent, 5 percent DDT reduced them 55 percent, and 10 percent DDT reduced them 92 percent.

Because of the comparatively high price of DDT, it would not replace sulphur in the event control were deemed advisable. The addition of Paris green or calcium arsenate to sulphur at the rate of 1 part in 2 parts greatly increased control of adult insects. Other insecticides tested were less effective than DDT or sulphur.

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