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LYGUS ELISUS: A PEST OF THE COTTON REGIONS IN ARIZONA AND CALIFORNIA

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The tarnished bug (*Lygus elisus* Van Duzee) is probably a native of western America, and has been found in all cotton districts of the Pacific region. It readily goes to crop plants from its native host plants, of which Chenopodium is one of the commonest. Its activity as a cotton pest was detected very early in an investigation of cotton insects in the Imperial Valley, Calif., conducted in 1916, 1917, and 1918. W. D. Pierce stated in an unpublished report on the cotton insects of the Imperial Valley, based on data gathered on a two-day inspection trip made August 15 and 16, 1913, that "the considerable shedding of squares in cotton fields at that date was principally due to a pale variety of *Lygus pratensis* L." He undoubtedly referred to the species now known as *L. elisus*. During the season of 1916 this insect did not appear as an especially injurious species on cotton, but by midsummer of 1917 it had acquired the status of a real cotton pest. With still greater intensity it launched its 1918 attack at an earlier time of the year.

SEASON OF ACTIVITY

From the experience of the seasons of 1917 and 1918, during which Lygus seriously infested the California cotton fields, it may be said that the activity of the species on cotton is restricted chiefly to the months of July and August. In 1917 the pest became conspicuous on cotton about August 2, whereas in 1918 it was abundant by July 15, or 18 days earlier than in the previous year. As will be explained

[1] At the time the work reported in this bulletin was done, Mr. McGregor was scientific assistant in the division of Southern Field-Crop Insect Investigations, Bureau of Entomology.

later, the activity of the tarnished bug on cotton undergoes a rather sudden cessation toward the beginning of September. It will be seen that the period of attack on cotton was extended from about four weeks in 1917 to about seven weeks in 1918; an expansion which would suggest a process of establishment and adjustment.

EXTENT OF DAMAGE

An idea of the seriousness of the tarnished bug as a pest of cotton in the Imperial Valley may be gained from the fact that from early in July until September 5 the average infestation of all fields examined in 1918 was computed to be in excess of 15 per cent of the squares, blooms, and young bolls present at the time of examination. The pest operates during fully half of the boll-setting [2] season, and attacks the square and boll during the initial fifth of the boll's development. Practically all the forms that are punctured are shed. On the basis of these data it was estimated that about 8 per cent of the 1918 cotton crop of the Imperial Valley (valued at $16,000,000), or cotton valued at $1,280,000, was destroyed through the attack of this insect.

DISTRIBUTION

The tarnished bug of the Southwest appears to be very generally distributed. The writer's investigations of the last few years have established the fact of its presence on cotton in every region visited. At Bakersfield, Fresno, and other San Joaquin Valley points, no trace of the tarnished bug on cotton was seen in the early part of June, 1918, but at the time of a second visit, August 27 and 28, in the same year, the average infestation in the San Joaquin cotton fields was found to be 14.5 per cent. Similarly, an inspection of cotton fields in the Yuma Valley of Arizona on June 26 and 27 failed to reveal a trace of the pest, but on August 3 a 2 per cent infestation was found in one field. Since the latter date is coincident with the height of Lygus occurrence generally in the Southwest, it would appear that in 1918 the species was not much of a menace in western Arizona. In the Palo Verde Valley of California an examination of six fields on July 9 revealed the presence of the tarnished bug in but one of them, which was infested only 1 per cent. Examinations in the Coachella Valley on July 17 and 18 showed the presence of Lygus in three out of four fields, with an average infestation of 1.5 per cent. On August 29 every field examined near Chico, in the Sacramento Valley (800 miles north of the region of the Imperial Valley), was found to be infested, the average infestation being 10 per cent. The development of the pest in the Mexican portion of the Imperial Valley during the season of 1918 was, quite naturally, similar to that in the American part, where, on July 2, the general infestation was computed to be 2 per cent; on July 31 it was 10.5 per cent; by the middle of September it had dropped to 1.5 per cent.

From the foregoing discussion of the distribution it may be seen that the tarnished bug occurs generally in every cotton-growing section of the Pacific region. In addition, the presence of this pest in the Salt River Valley of Arizona in the years from 1913 to 1917 has been noted by A. W. Morrill in his annual reports for 1915, 1916, and

[2] That is, the setting of bolls that have any likelihood of maturing cotton before frost.

1917. He stated:[3] "In one field near Glendale, visited on July 24 [1917], it was estimated that 90 per cent of the cotton squares were destroyed, mostly by these [Lygus] insects * * * Soon afterwards the bugs left the field and a small crop was produced." He stated further that in 1918 the pest suddenly disappeared from the cotton fields between August 6 and 10, a heavy rainfall having occurred in this interval.

In response to instructions from Washington, the writer conducted during 1925 and 1926, incidental to his main project, a preliminary study of the cotton insects in the vicinity of Lindsay, Calif. The following statement concerning *L. elisus* is taken from a recent unpublished report covering this special study:

In the cotton fields of the San Joaquin Valley the tarnished bug lives up to its reputation as a major cotton pest. In September, 1925, a 350-acre field was found to have 50 per cent of its squares and young bolls infested, and the infestation in that field had obtained for a considerable period, as evidenced by the many dried squares showing previous attack. During 1926 a more serious effort was made to follow the progress of Lygus development on a large plantation. The first occurrence of any magnitude was observed July 12, when it was computed that 6 per cent of the squares were infested and being shed. By July 16 the occurrence had increased to an 8 per cent infestation. On July 24 the percentage of infestation by Lygus amounted to 29 per cent of the attached squares, blooms, and nascent bolls and, in addition, the ground was heavily strewn with shed forms. Again on July 29 an inspection of the above field yielded an indicated Lygus occurrence of 25 per cent. By August 2 the infestation was computed to be 11 per cent. However, on the following day (August 3), in a different portion of this 350-acre field, the occurrence of Lygus was found to be 56 per cent of all squares, blooms, and young bolls. On August 24 an infestation of 32 per cent was found to occur, and this in spite of the fact that the field was being permitted to die through the cessation of irrigation. When all the above infestation percentages are averaged, it is found that the average infestation throughout the boll-forming period was 23.9 per cent in our specially observed field. This is incontestable evidence that almost one-quarter of the cotton crop on this particular plantation was taken as toll by the tarnished plant bug.

NATURE OF INJURY

All stages of the tarnished bug attack cotton and suck the plant juices from the cotton squares, blooms, and young bolls. In doing this the bug thrusts the full length of its proboscis into the inner tissue, and from time to time almost withdraws it and again inserts it. Experiments indicate that much of the injury to plant tissue is caused by the injection of some toxic fluid or an organism at the time of this feeding. One bug was seen to keep its beak in the puncture for fully five minutes. When confined in rearing containers tarnished bugs will feed for as long as three days on squares kept fresh by embedding the peduncles in moist sand. Examination of squares after continued feeding operations invariably reveals that the inner floral parts (the pistil and anthers) are badly injured by the perforations. (Fig. 1.) In the case of young bolls the carpels and embryonic seeds are punctured. As has been stated, the work of the insect results usually in the dropping of the squares, blooms, and very young bolls. If bolls have attained a certain size the punctures lead, as a rule, to proliferations. The work of this pest is invariably denoted by the presence on the outer surface of the corolla, calyx, or carpels of small sulphur-yellow daubs or globules, the excrement of the feeding insect.

[3] MORRILL, A. W. REPORT OF THE ENTOMOLOGIST OF THE ARIZONA COMMISSION OF AGRICULTURE AND HORTICULTURE FOR THE YEAR ENDING JUNE 30, 1917. Ariz. Comn. Agr. and Hort. Ann. Rpt. 9: 15-61, illus. 1917.

LIFE HISTORY

Doctor Morrill states in correspondence that in Arizona "Lygus species do not breed to any noticeable extent in cotton fields." Further, regarding generations, he says: "From the fact that there is so little breeding in cotton fields, and considering the length of time that the adults remain, it seems probable that the pests are rather slow breeders."

Owing to extreme difficulty experienced in rearing Lygus under confinement, the data on its life history are disappointingly meager. It is certain, however, that the tarnished bug breeds freely on cotton in the Imperial Valley. Development there begins early in the spring, and Lygus in all stages may be found throughout the growing season on numerous succulent plants. The eggs are deposited most commonly on the squares, being either placed in folds of the floral parts, or at times inserted in ovipositional punctures. Hatching occurs in about four days, and the bugs become adult, under summer conditions, in about 20 days. Since the occurrence of Lygus on cotton continued for 12 weeks in the season of 1918, it is probable that four generations developed on this crop during that time. On alfalfa it is probable that a maximum of seven generations occur between the spring appearance and the cessation of activity early in October. Very little is known about the hibernation of Lygus in the Southwest, but it seems probable that the tarnished bug passe the winter chiefly, if not entirely, in the adult stage.

FIG. 1.—Cotton square, with calyx and corolla dissected to show injury to pistil and anthers by punctures of *Lygus elisus*

DESCRIPTION OF ADULT

Length 5.07 to 6.25 mm., averaging 5.54 mm., or 0.22 inch. A decidedly polychromatic species. The head, chestnut yellow, usually free of the dark longitudinal lines seen in the common eastern form (*L. pratensis*). Eyes deep chocolate, with yellowish posterior border. Proboscis with black tip. Prothorax yellowish green, straw color, or pale fulvous, with two or four small, pitchy, distinct spots in an arched row one-third the distance from the front margin, very variable in size and position, the two on each side sometimes partly coalesced; posterior margin usually much darkened, often with a pair of blackish spots posteriomedially and with a fulvous to blackish spot at each posterior angle. Scutellum in the main pale green, straw colored, or, as usually, lemon yellow, the posterior three-quarters often in shape of a perfect heart, the remaining portion from pale chocolate to black. Wings with ground color deep amber, cuneus and membrane straw colored, clavus smoky to pale reddish brown, paling posteriorly with crimson tips; posterior margin of corium usually with large pale fulvous to cardinal blotch. Antennae chiefly reddish brown; first segment more yellowish, second segment darker at each end, third and fourth segments blackish brown. Legs amber color to reddish yellow, the posterior femora usually (but not always) twice annulated near apices with reddish to deep chestnut; dark forms with coxae and femora blackish olive; tibiae with two reddish to chocolate marks near base and a band of similar color at tip; tibial spines and tips of tarsi brownish to blackish. Venter uniformly yellow-green to lemon yellow; sternum a shade darker; male with subterminal genital blotch of same shade as sternum. (Fig. 2.)

DATE OF APPEARANCE ON COTTON

In 1917 the first observation of Lygus on cotton was made on June 12, and in 1918 the initial appearance was noted on June 11. At this time, in both seasons, the insect was very scarce on this crop but very abundant on alfalfa. In 1917 the tarnished bug did not become very noticeable on cotton until the beginning of August, but in 1918 it had become abundant by the middle of July. The crest of the 1917 infestation (fig. 3) was reached about August 20, and that of the infestation of 1918 about August 12. The infestation of 1917 on cotton was noticeable during a period of only about four weeks, while that of 1918 was general and acute for about five weeks—a remarkably short seasonal period for an insect to operate as a crop pest.

When it is remembered that Lygus had adapted itself to cotton in the Imperial Valley not long before and was in process of establishment it seems natural that its occurrence in 1918 should have been earlier and the infestation more severe than was the case in the preceding year. The factor that prevents infestation on cotton prior to the middle of June is probably not a climatic condition. The mean temperature for the entire period during which Lygus occurred on cotton in the summer of 1918 was 89.4° F., and for the three weeks just prior to the appearance on cotton it was 86° F. The difference between these temperatures is seemingly too slight to account for the nonoccurrence of the pest during the earlier period. The failure of the tarnished bug to establish itself on cotton before the middle of June can be accounted for by the fact that the formation of squares does not normally occur until this date. In the Imperial Valley Lygus evidently does not feed on the cotton foliage, however tender, but appears to feed entirely on the squares, blooms, and nascent bolls. This explanation is further substantiated by the fact that the insect is very abundant on alfalfa for some time prior to its appearance on cotton but fails to migrate to the latter until the budding season arrives.

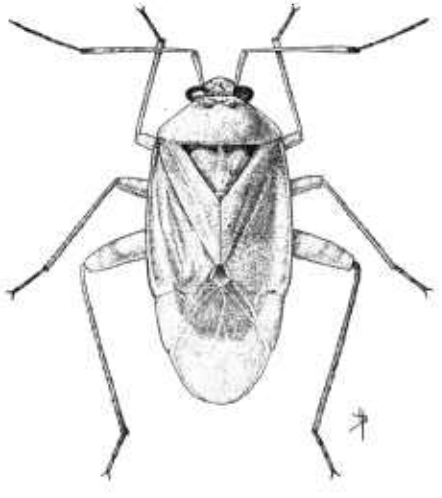

FIG. 2.—Adult of *Lygus elisus*, dorsal view

SEASONAL DECIMATION

The last few days of August, both in 1917 and in 1918, witnessed an abrupt reduction in the numbers of Lygus on cotton. This decimation occurred also on alfalfa, but not to the extent that it did on

cotton. By September 10, in those two seasons, the tarnished bug had practically disappeared from cotton. The explanation of this abrupt disappearance of the pest is not easily found. The mean temperature for the 10-day period coincident with the reduction of the pest in 1918 was 87° F., which was slightly lower than the mean temperature of the period immediately preceding, but the difference in temperature hardly accounts for the decimation. Several predatory insects were rather abundant in the fields at about this time, but it is doubtful whether they alone were responsible for the sudden reduction in numbers. The reason for the abrupt decimation in the latter part of August is unknown.

RÔLE OF ALFALFA

During the three seasons that the tarnished bug was under observation in the Imperial Valley the importance of alfalfa as a supporting host became increasingly evident. Through a great number of field observations it has been well established that in the Imperial Valley alfalfa is the preferred host plant of Lygus. In Table 1 are presented the results of collections from many full sweeps of the insect net in growing alfalfa and cotton in 1918. The average capture of

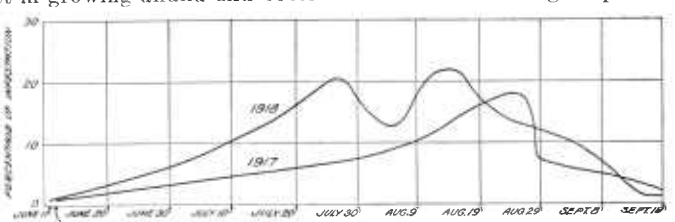

FIG. 3.—Seasonal occurrence of *Lygus elisus* on cotton in the Imperial Valley, summers of 1917 and 1918

Lygus prior to October 1 on alfalfa was 70.8 individuals, and on cotton 5.6 individuals, per 100 sweeps of the net. It will be seen that during the active season the tarnished bug exhibits a very marked preference for alfalfa. Under ordinary conditions there appear to be fully eleven times as many tarnished bugs per given area on alfalfa as on cotton.

TABLE 1.—*Relative abundance of Lygus elisus on alfalfa and cotton*

Date	Number of sweeps of net	Lygus individuals captured	
		On alfalfa	On cotton
1918			
July 27	400	402	----
Aug. 1	100	----	29
Aug. 7	200	----	2
Aug. 10	100	----	6
Aug. 12	400	----	13
Aug. 15	200	40	----
Sept. 8	100	44	----
Do	200	----	6
Sept. 11	80	95	----
Sept. 13	100	208	----
Sept. 17	200	82	----
Sept. 20	200	35	----
Oct. 1	[illegible]	----	----
Do	100	8	----
Oct. 5	100	6	----
Oct. 9	200	3	----
Oct. 11	200	2	----

[a] Number of sweep made on cotton; no captures.

That alfalfa constitutes an ideal host plant for the tarnished bug is a fact that plays an important part in the seasonal activity of tho pest on cotton. Between the middle and end of August, 1918, an infestation of Lygus, affecting 35 per cent of tho squares and blooms, was studied in a large cotton field adjacent to an alfalfa field. It was established that the alfalfa had died to the ground about July 10, because of the general shortage of water throughout the valley—for several years an annual occurrence at about this date. In order to save the cotton crop the entire water allotment of the ranch was applied to it. The alfalfa at the time of drying was undoubtedly heavily infested with Lygus, an exodus of which took place from the dry alfalfa, resulting in the just-mentioned heavy infestation of the adjoining cotton. Several other cases of an exactly similar nature were brought to the writer's attention in the course of the season.

The cutting of alfalfa presents almost the same phenomenon as that of drying from water deficiency, and for each field it is repeated at about monthly intervals.

Figure 4 graphically presents the relation of alfalfa cutting to Lygus infestation on adjoining cotton. In this case a 10-acre field of Pima cotton

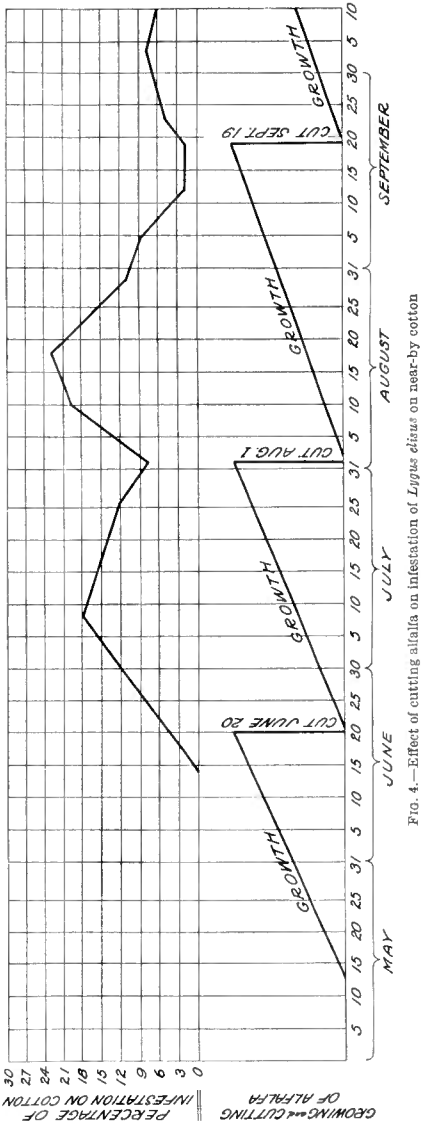

FIG. 4.—Effect of cutting alfalfa on infestation of *Lygus elisus* on near-by cotton

grew immediately adjoining 3 acres of well-cared-for alfalfa. The data from which this drawing was prepared were of a retrospective nature, and would have been ampler and better planned had the idea of the vital relation between hay cutting and pest dispersion occurred earlier to the writer. The observations on which the infestation curve is based were made independently, on the dates indicated for the beginning and the inflections of the curve, and the graphical representation of the growth and cutting of the alfalfa was based on data obtained later from records. It thus happens that the cuttings of June 20 and September 19 were made between consecutive dates of observations for infestation. However, the diagram shows clearly that immediately after the cutting of the alfalfa the tarnished bugs migrated and became established on the neighboring cotton, augmenting suddenly the infestation on the latter. Such migrations were noticeable after the cuttings of June 20, August 1, and September 19, and are no doubt a regular phenomenon when alfalfa and cotton grow near each other.

The statements that alfalfa is far more heavily infested by the tarnished bug than is cotton and that alfalfa nevertheless suffers little damage as compared with cotton appear at first incongruous. But this condition is easily appreciated when it is understood that on alfalfa the activity of the pest is directed against all the succulent foliage, while on cotton only the buds, young blooms, and bolls, the sole productive part of the crop, are attacked.

NATURAL CONTROL

Investigations of the Bureau of Biological Survey of the United States Department of Agriculture have revealed bugs of the genus Lygus in the stomachs of 26 species of birds, of which swifts and nighthawks appear to take these insects in largest numbers. Birds which may visit cotton fields in California, and which are known to prey upon Lygus, include the nighthawk, Say phoebe, Brewer and red-winged blackbirds, vesper and chipping sparrows, and the bank swallow. Probably all swallows, swifts, and flycatchers, birds taking their prey indiscriminately from the air, consume large numbers of Lygus, insects which fly freely.

The writer has observed no material control by insect enemies, although reduviids have occasionally been seen attacking Lygus. Spiders also destroy considerable numbers of these bugs.

ARTIFICIAL CONTROL MEASURES

CONTROL ON ALFALFA

The foregoing observations on alfalfa in its relation to Lygus infestation on cotton lead to a discussion of possible control measures as applied to alfalfa. The severest tarnished-bug infestations in cotton fields have always been in those adjacent to alfalfa. At first thought, therefore, one would consider it very questionable to grow cotton in such a location. Doctor Morrill[4] states that "The tarnished plant bugs appear to breed upon alfalfa for the most part, and if it were practicable it would be a wise precaution to avoid planting

[4] MORRILL, A. W. Op. cit. p. 59.

cotton in a field adjoining alfalfa." On the other hand, if it develops that a simple means of eradication of the pest on alfalfa can be devised, such a procedure might help to reduce the subsequent infestation in adjacent cotton. At the season when Lygus becomes threatening to cotton, the plants are often of such a height as to preclude the safe employment of a large vehicle for distributing insecticide. Such an apparatus, however, could be used at any time in alfalfa fields.

Experiments on a limited scale were conducted during the season of 1918 by way of testing the efficacy of resublimed sulphur against the tarnished bugs on alfalfa. This chemical was applied with a knapsack duster to one-third of an acre of knee-high alfalfa at the rate of 6 pounds per acre. Immediately before treatment the infestation was such as to yield an average of 120 Lygus individuals per 100 sweeps of the net. One and one-half hours after the application of sulphur the infestation had dropped to 30 per 100 sweeps, indicating a reduction in this brief time of 75 per cent of the original infestation. Moreover, comparative counts indicated that about 65 per cent of the superabundant alfalfa thrips were also missing at the end of the same interval. Subsequent tests of a similar nature further encouraged the writer to believe that satisfactory measures can be devised for the control of Lygus on alfalfa. If this proves to be the case, alfalfa can be made to serve the function of a trap crop for neighboring cotton, especially in view of the fact that alfalfa becomes infested considerably earlier than does cotton.

FIG. 5.—Applying sulphur dust with knapsack duster to experimental cotton plot

CONTROL ON COTTON

The possibility of controlling Lygus on cotton is as interesting as the possibility of controlling it on alfalfa. On July 27, 1918, when the general infestation in the field was found to be 12 per cent, a half acre of the Pima cotton at the Meloland Experiment Farm was thoroughly dusted with resublimed sulphur, the application being made with a knapsack duster such as is represented in Figure 5. The results of this test are presented graphically in Figure 6.

From Figure 6 it is seen that in five days (July 27 to August 1) the infestation in the sulphured plot dropped from 12 per cent to nothing and in the untreated plot the pest's occurrence dropped (through

natural agencies) to 8 per cent. On August 10 the infestation was only 4 per cent in the sulphured plot, but it had increased to 20 per cent in the untreated one. On August 18 the infestation was 2 per cent in the sulphured and 23 per cent in the untreated plot. No further observations were made until September 5, when the annual autumn decimation had taken place, and the occurrences in the treated and untreated plots were 3 and 4 per cent, respectively. It should be kept in mind that only one treatment, that of July 27, was given.

On August 12, at the height of the Lygus occurrence, a large cotton field on the Timkens ranch was found to be infested to the average extent of 35 per cent of the squares. The ranch management undertook a test on a large scale of the efficiency of sulphur dusting On August 15 to 18 resublimed sulphur was applied by the pole-and-bag method, at the rate of about 10 pounds per acre, to about 80 acres of the cotton most severely infested. On August 19, 100 squares were taken for examination from various parts of the field, representing the areas which had been dusted on each of the four days of treatment, and 100 squares were taken from untreated cotton. The percentage of infestation was found to be 38 for the untreated cotton and 21 for the sulphured cotton. While the surrounding untreated cotton was becoming more severely infested, the reduction in Lygus infestation of the sulphured cotton was 44.7 per cent, or nearly half, and 17 per cent of the squares in the treated field were saved from infestation by the dusting.

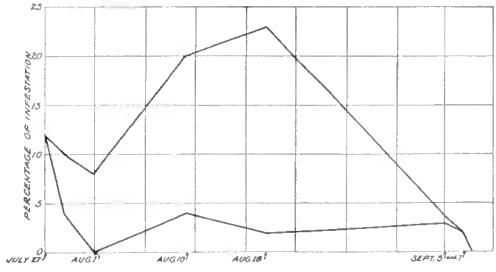

Fig. 6.—Effect of sulphur dust against *Lygus elisus* on cotton. The upper curve represents the progress of infestation in the untreated check; the lower curve represents the infestation of the sulphured plot at the same time

Because of inefficent help the application of sulphur to this field was far from ideal. Fifteen or twenty pounds per acre should have been applied instead of 10, and, as was shown by the trial at the Meloland farm, the insecticide would have been much more effective if it had been blown on by a machine duster instead of being applied by the cruder pole-and-bag method.

Including material and labor, the cost of sulphuring at the Timkens ranch was found to be about 70 cents per acre. In fields with good crop prospects the saving of 17 per cent of the squares setting on August 19 would, in the value of increased lint, be equivalent under 1919 prices to about $13 per acre. This indicates that dusting, even in the inefficient way practiced in the experiment at the Timkens ranch, represents a very good investment.

In connection with the incidental study of cotton insects at Lindsay, previously mentioned, the effect of sulphur dust against Lygus was again tested. About an acre of cotton on the 350-acre Skinner plantation was treated in the early morning of August 3, 1926. The application was made with a rotary hand duster when the tempera-

ture was 70° F. (the temperature was 104° later in the same day), and when the air was still. At the time of dusting, the Lygus infestation in the treated cotton amounted to 56 per cent of all the squares, blooms, and nascent bolls. On the following day an examination of the treated area showed that the infestation had dropped to 21 per cent. On this basis the control is computed to have been 62.5 per cent from the one application of sulphur. It was clear that there had been rather marked control, and this supports the results obtained in 1918 in the Imperial Valley.

When the results to date of the control tests on cotton and of those on alfalfa adjacent to cotton are considered it is believed that both operations give promise. If, however, later trials with modern cotton-dusting equipment should demonstrate the economy of this practice in tall cotton, the idea of the alfalfa trap crop might well be eliminated from further consideration.

ACTION OF SULPHUR DUST AGAINST LYGUS ELISUS AND OTHER INSECTS

Experiments were conducted to determine the specific action of sulphur dust against Lygus and other insects. On several occasions sweepings were made over alfalfa, and the resulting catches were exposed to sulphur under various conditions. For these tests two cube-shaped containers of 16-mesh fly screen were constructed, about 5 by 5 by 5 inches in size. The captured tarnished bugs, or other insects, were introduced into the cages and securely inclosed. In every case a small sheet of cardboard was placed over each cage, so that the insects and a small patch of ground were shaded from the direct sunlight. The insects were prevented from coming in actual contact with the sulphur. Table 2 presents the results of three of these tests.

TABLE 2.—*Tests of the action of sulphur dust on Lygus elisus and other insects*

Exposure	Height of cage above ground	Temperature at cage level	Insects alive	Insects dead
	Inches	°*F.*		
Center of Inkweed bush against east side of house for 30 minutes, about 11 a. m.; dust applied to bush and ground.	24	102	None	10 Lygus, 29 Ceresa, 3 large green jassids, 4 dipterons, 1 reduviid.
Directly over sulphured ground for 10 minutes; west side of house, about 3 p. m.	12	112	do	51 Ceresa, 7 small yellow jassids, 5 Lygus, 5 big green jassids, 3 brown jassids, 1 reduviid, 3 striped beetles.
Over dense mat of weeds; west side of house, for 30 minutes, about 2 p. m.; sulphur applied generously to weed foliage and surrounding ground.	15	116	1 grasshopper, 1 Eurymus larva.	261 Ceresa, 5 dipterons, 4 Lygus, 4 striped beetles, 4 small yellow jassids, 2 syrphid adults, 2 large reduviids, 2 big green jassids, 1 big brown jassid, 1 Geocoris adult, 1 Diabrotica adult.

The results with the check cages are not included in Table 2. They may be summarized in the single statement that those cages, under exactly identical conditions, except for the absence of sulphur, occasioned absolutely no mortality.

These results speak for themselves. The tests demonstrate that the 12 or more species named, including Lygus, when confined at a height of from 12 to 24 inches above the ground, over a liberal application of sulphur dust applied to the surface of the soil and the surrounding foliage, with an accompanying temperature at the cage level of 102° to 116° F., and under other conditions obtaining in southern California, are killed in 30 minutes or less.

Obviously, when the sulphur is applied in a field crop the insects, if winged, are relatively free to escape, but the immature stages (much more frail than adults) would be quickly killed under conditions similar to those of the experiments here detailed when the crops are not too high above the radiating surface of the ground.

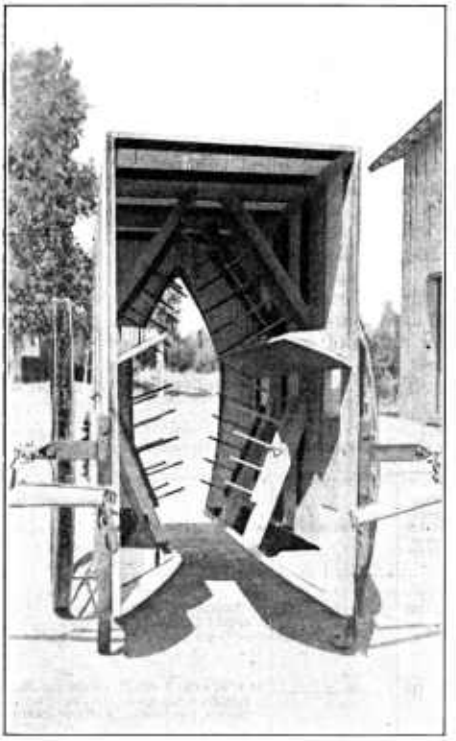

FIG. 7.—Lygus dozer, especially constructed for work against *Lygus elisus* on cotton

FATAL TEMPERATURE FOR LYGUS ELISUS

It was found by several tests that when exposed to a soil temperature of from 125° to 128° F. (in the absence of sulphur), adults and nymphs were killed in from three to five minutes.

LYGUSDOZER

The idea was conceived of constructing a portable device to be drawn along the cotton row, subjecting the foliage to an agitation which would cause the tarnished bugs to fly or hop off and be captured within the inclosing chamber. Figure 7 illustrates the Lygusdozer designed along those lines. The important features of the device are that it is built so as to "straddle" the cotton row. It measures 42 inches between the outside ends of the hubs of the wheels and has a vertical clearance of about 4 feet 8 inches and a chamber length of 6 feet. The chamber has eight diagonal braces, each carrying a hinged comb of long wooden tines and bearing at the sides two upper and two basal galvanized troughs; the rear end is largely inclosed with a wire-margined canvas, and the apparatus is drawn by two draft animals. As the dozer passes along the cotton row the foliage is taken into the front end and brushes against the combs, which

spring backward and rake through the plants. The troughs are kept about half full of crude oil; not so much oil as to flow too readily with the movement of the dozer. The idea was that the bugs, disturbed by the combs, would fly, hop, or fall into the oil containers and perish there. The implement was not completed for trial until toward the end of the Lygus season, and the rapid disappearance of the pest thereafter prevented a thorough testing of the efficiency of the device. The results obtained, however, show that the principle is worthy of additional investigation.

Insects in considerable variety were captured in the oil pan, including many Lygus in all stages. Many Euschistus and other pentatomid bugs, so harmful to the cotton bolls, were also ensnared. Other insects captured were a species of Oecanthus, *Hippodamia convergens* Guér., a species of Seymnus, and a species of Chrysopa. Obviously a device of this nature will capture alike pests and predators.

LIGHT TRAPS

The management of the Timkens ranch conceived the idea of testing the effectiveness of lights in attracting the tarnished bugs at night. Kerosene lanterns were placed on small platforms built on 5-foot posts and distributed along the borders between "lands" at intervals of about 150 feet. About 35 of the lights were operated, which were considered enough to treat about 8 acres per night. On two occasions examinations of the oil-coated pans under the lights revealed the fact that Lygus adults were being attracted rather freely. It was regrettable, however, that several predatory species, particularly a large reduviid, were also being captured in large numbers. In relative numbers, the tarnished bugs were most largely represented. Considering the very inadequate nature of the lights used, this test gives some promise that light traps may be used to advantage as a contributing measure in the control of Lygus.

SUMMARY

The tarnished bug, *Lygus elisus* Van Duzee, has been known for some time as a pest of various plants, but it remained for the present investigation to develop the fact that it is perhaps the most serious pest of cotton on the Pacific coast. In the Imperial Valley, where it was chiefly studied, growing alfalfa is more extensively attacked, even, than cotton. Injury to alfalfa is less serious than to cotton, owing to the fact that on the former crop the pest distributes its attack to all parts of the foliage, while on cotton the insects concentrate on the buds, blooms, and bolls, the sole productive portion of the plant.

Injury to cotton by the tarnished bug is caused by the feeding punctures made in the square, bloom, and boll by the piercing mouth parts. Practically all stung squares, blooms, and very young bolls are very soon shed. Since the actual mechanical injury associated with the feeding of Lygus is slight, compared with the resulting damage, it seems reasonable to suspect that either a toxic material or an organism may be introduced into the plant tissue at the time of feeding. Other evidence supports this supposition.

The work of this pest is denoted by the presence near the scene of its attack of characteristic yellow daubs. This feature caused A. W. Morrill to suggest the name "cotton dauber."

Development begins early in the spring in the Imperial Valley. Under summer conditions hatching requires about 4 days, and the bugs become adult in about 20 days. The tarnished bug attacks alfalfa during the greater portion of its growing season, while the attack on cotton is limited to the period from early in June to early in September. As a result, there are about seven generations per year on alfalfa and about four generations on cotton.

Infested alfalfa, growing in the neighborhood of cotton, is a common source of the acute attacks on the latter crop. These may arise in two ways—either from the drying of the alfalfa because of water shortage or from cutting the alfalfa for hay. In either case an exodus of the tarnished bugs to the cotton is almost sure to occur, provided, of course, that the cotton is kept growing.

An abrupt reduction in the numbers of the tarnished bug occurs annually about the end of August. An explanation of this decimation is not known, as the climate in the hotter portions of the Southwest continues much the same until about the end of September.

Finely divided sulphur dust has been found effective against the tarnished bug. Applied to growing alfalfa at the rate of 6 pounds per acre, a single application of this material brought about a reduction of Lygus individuals amounting to 75 per cent of the original infestation. A similar application to infested cotton practically eliminated the pest and kept the infestation down to a minimum for more than three weeks. In another case, where 80 acres of cotton were treated with sulphur dust by the cruder pole-and-bag method, the number of Lygus individuals was reduced in an average interval of two days to the extent of 44.7 per cent of the initial infestation. Although it seems to have been demonstrated that severe migrations of the tarnished bug to cotton may be prevented by dusting near-by alfalfa, these tests have shown that direct control may also be secured by the sulphuring of cotton. The latter operation is dependent on the availability of adequate cotton-dusting machinery.

When, in the Imperial Valley, under laboratory conditions, tarnished bugs were confined in screen cages from 12 to 24 inches above the ground, over sulphur dust liberally applied to the surface of the soil, and at temperatures of from 102° to 116°F., death followed in not more than 30 minutes. Individuals similarly confined over areas free from sulphur suffered no mortality.

The adults and nymphs of Lygus were killed in from three to five minutes when exposed to a soil temperature of 125° to 128° F., in the absence of sulphur.

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