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LYGUS BUG INJURY TO PRESQUARING COTTON

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Lygus Bug Injury To Presquaring Cotton

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Lygus bugs, of which *Lygus hesperus* Knight is the dominant local species, are major pests of Arizona cotton during the fruiting stage. Previous research has not established whether lygus bugs can cause significant injury to presquaring cotton nor have later effects of such injury been described.

Despite this absence of information a number of Arizona growers have regularly applied insecticides to presquaring cotton for lygus control, because of a belief that the plants grew better when these pests were controlled during this growth stage.

The following work was stimulated by the difficulty in explaining abnormal plant growth symptoms found extensively in central Arizona during the early part of the 1962 season. Affected plants had "blank," or "flat" squares, were abnormally shaped, and were without the usual number of normal squares. Affected fields were usually found next to desert areas from which lygus bugs had been observed migrating from drying vegetation.

This is a report of a study in 1963 to determine whether lygus bugs are, in fact, capable of damaging cotton plants by feeding during the presquaring period, and whether such damage may later be manifested by such symptoms as abnormal plant growth or blank squares.

Literature Review

Most of the known information on lygus bug injury to cotton in Arizona was summarized by Telford et al. (1962), who state that lygus bugs feed on squares, blooms and small bolls. It is also implied that lygus bugs are found on cotton only after squaring begins. Ewing (1929), however, showed that lygus bug feeding in Texas by a related species, *L. pratensis* (now called *L. lineolaris*), caused abnormal branching and swelling of internodes and petioles. He demonstrated that lygus bug feeding was not limited to the fruiting portion of the plant. Crosby and Leonard (1914) showed that *Lygus lineolaris* (P. de B.) caused multiple branching and stunting of peach seedlings. Leigh (1963) was unsuccessful in

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rearing lygus bugs on cotton, indicating that cotton may be one of the less desirable sources of food.

The "blank square" problem in Arizona was first reported by Shields and Gries (1962) as follows: "In Arizona this past season some of the cotton flower buds failed to form, so that the bracts were empty or blank. As the bracts continued to grow in the absence of flower parts, they often became elongated and flat, with two bracts usually much larger than the third. These two bracts became tightly pressed together, giving rise to the descriptive term 'flat squares'." These authors were not able to associte insects with the blank or flat square problem, due to the absence of feeding punctures.

In June and July 1962 the writers also observed that a number of central Arizona cotton fields, particularly near desert areas, failed to set normal loads of squares. Although no records were taken, it was noted that many plants contained variable numbers of blank, or flat squares. In these fields plants were also observed with branched stems (Figure 7), enlarged thickened leathery leaves, or with elongated basal internodes and petioles.

Report of 1963 Experiments

The variety Deltapine Smooth Leaf was used in all experiments except where Pima S-2, a long staple variety, was used as noted. All work was done at the University of Arizona Cotton Research Center, near Phoenix.

Lygus bugs, both nymphs and adults, were collected from nearby alfalfa fields and introduced into cages within an hour after collection, usually in the morning.

Cotton plants were grown in six-inch flower pots, usually four plants per pot. These pots were placed in an open area, exposed to the natural environmental factors, such as sunlight and wind, in order that the plants might approximate the hardiness of field grown seedlings.

Three types of cages were used. The first were "sleeve cages" made from copper wire cylinders having a diameter of five inches. These were placed over each flower pot in such a manner that the lower end was pressed approximately 0.5 inch in the soil. After the insects had been introduced, the upper end of the cage was covered with a piece of white muslin held in place with a rubber band. These cages were then kept in an insectary for various lengths of time. For each caged pot which included lygus bugs there was usually a check pot with an equal number of seedling plants, enclosed by the "wire sleeve cage" but without lygus bugs, for use in evaluating injury.

The second type of cage was used in the open. These cages were made of fine screen wire and were two feet wide, two feet long, and two feet in height. Usually four six-inch flower pots were placed in each of two cages. One cage had lygus bugs introduced in it, while the other had none. After the exposure period a few of the treated and untreated plants were transplanted to the field.

The third type of cage, called the "field cage," was 2.5 feet wide, 4.5 feet long, and 3.5 feet high. These cages were covered with fine screen wire that could either retain or exclude insects. These cages were used in evaluating lygus damage on field-grown seedling cotton as well as fruiting (mid-season) cotton. Since cotton grows taller under screen cages, both the "lygus infested plants" and the "lygus free plants" were caged for the same period of time. After the period of exposure to lygus

Figure 1. Recently emerged seedlings killed by lygus bugs.

bugs, the caged plants were dusted with malathion to kill the insects. Thus the plants continued growing for the remainder of the season without late insect injury to complicate the results. Additional insecticide treatments were required.

Lygus bugs were not able to survive long on cotton plants after the cotyledons hardened. The mortality was so extreme that sometimes as high as 50 per cent of the lygus bugs died within three days. It was therefore necessary to restock the cages every seven days. The dates the cages were restocked are shown in the footnotes of the tables.

The lygus bugs were collected from alfalfa, a favorite food source. When caged over hardened seelings, many of the bugs merely rested on the sides of the cages and probably died of starvation because the growing point of the cotton was not sufficiently attractive as a source of food. Although lygus bugs were caged for as long as 30 days in some of the tests, no nymphs were observed. This agrees with Leigh's (1963) work in which he was unable to rear lygus bugs on cotton.

Since the objective of this work was to determine if lygus bugs could injure presquaring cotton, high populations per plant were used. This may account for the high mortality of caged lygus bugs.

DISCUSSION OF RESULTS

Newly Emerged Cotton

Newly emerged cotton is quite tender and the cotyledons are very succulent. At this stage of growth, lygus bug adults feed readily on the succulent cotyledons. If the population of bugs is high, such as five per plant, they will suck a majority of the cotyledons dry and then start sucking the stems dry. The data in Table 1, from a test conducted in the insectary, show that five lygus bugs per plant can kill outright at least 75 per cent of recently emerged seedlings in but three days. One lygus bug per plant killed approximately 50 per cent of Deltapine Smooth Leaf seedlings in a week's time. Figure 1 shows the damage that two adult lygus bugs per plant can do in a three-day period.

An experiment was conducted on Pima S-2 (long staple) cotton during August 1963. At this season the plants grew more rapidly than those planted in May. As a result, the plants probably were slightly more vigorous.

Furthermore, at the end of the seven-day exposure period, the uninfested plants had one or two true leaves. Data in Table 2 shows that lygus bugs killed a number of these plants and injured a high percentage of those remaining. Furthermore, many of the cotyledons had been sucked dry. In this case, however, injury meant a suppression of the growing point, usually by lygus bug feeding, thereby preventing the development of the true leaves, which did develop on all of the uninfested plants. These data show that long staple cotton can be injured by lygus bugs.

Table 1. Effect of Lygus Bug Feeding on 2 to 3 Day Old Cotton (Sleeve Cages).

Pot No.	*No. plants per pot*	*No. lygus bugs per plant*	*Pct. plant mortality after feeding*			
			1 day	*3 days*	*5 days*	*7 days*
			Experiment 1			
1	6	5	100			
2	4	0	0			
			Experiment 2			
1	4	5	100	100		
2	4	5	50	75		
3	4	1	25	75		
4	4	1	0	25		
5	0	0	0	0		
6	0	0	0	0		
			Experiment 3			
1	3	5		100		100
2	3	5		100		100
3	3	5		100		100
4	3	1		0		67
5	3	1		0		67
6	3	1		0		30
7	3	0		0		0
8	3	0		0		0
9	3	0		0		0
			Experiment 4			
1	4	2			25	
2	4	2			100	
3	4	2			100	
4	4	2			0	
5	4	1			25	
6	4	1			50	
7	4	1			0	
8	4	1			0	
9	4	0			0	
10	4	0			0	
11	4	0			0	
12	4	0			0	

Table 2. Injury Resulting From Caging Various Populations of Lygus Bugs on 3 Day Old Long Staple Cotton (Sleeve Cages).

	Lygus Bug Injury on	
	Aug. 2	*Aug. 9*
1 Lygus Bug per Plant		
No. Plants	12	12
Ave. Height per Plant, Inches	4.6	4.8
% Plants Killed	0	33
% Remaining Plants Injured	0	75
2 Lygus Bugs per Plant		
No. Plants	12	12
Ave. Height per Plant, Inches	4.5	4.8
% Plants Killed	0	0
% Remaining Plants Injured	0	100
3 Lygus Bugs per Plant		
No. Plants	12	8
Ave. Height per Plant, Inches	4.0	3.8
% Plants Killed	0	33
% Remaining Plants Injured	0	100
5 Lygus Bugs per Plant		
No. Plants	12	5
Ave. Height per Plant, Inches	4.1	4.5
% Plants Killed	0	58
% Remaining Plants Injured	0	80
Untreated		
No. Plants	8	8
Ave. Height per Plant, Inches	3.7	4.3
% Plants Killed	0	0
% Remaining Plants Injured	0	0

Figure 2. Plants on the right show retardation of plant growth resulting from lygus bug feeding.

Injury Prior to Emergence of First Leaves

In this experiment the lygus bugs were caged over hardened seedlings with visible growing points. This was a day or two before the first leaves were due to appear. Lygus bugs at this stage feed primarily on the growing point, although at very high population levels they will also feed on the cotyledons, as shown in Test 3 of Table 3.

Table 3 summarizes results of caging various lygus bug populations on seedling cotton for various time intervals. The data show that lygus bugs retarded the plant growth as much as 40 per cent. The greatest retardation was during the cool part of the growing season, when the plants were growing slowly. The least retardation was in July, when cotton was growing rapidly. In Arizona practically all the growth during the presquaring period is made during cool weather. Figure 2 illustrates retardation of growth as a result of lygus bug feeding.

Lygus bug feeding on cotton at this stage of growth deforms the plants. The most obvious deformity, which occurred on approximately 25 per cent of the plants, was a suppression of the growing point, delaying development of the true leaves. In other plants the growing point was forked, resulting in a plant with two, and sometimes more, stems. The remainder of the plants developed a number of growing points with small leaves, so that the plants had a witch's broom appearance. Test No. 4 in Table 3 shows that lygus bug feeding resulted in more leaves per plant than found on uninjured plants, although such leaves were less than half the size of those on the normal plants. This last test was made during July, when seedling cotton grew very vigorously. Therefore the injury was different from that caused by lygus bugs feeding on seedlings grown in cool weather, as illustrated by the data in Tests 1 and 2 of Table 3.

The percentage of deformed plants was greater during the cooler part of the growing season, when an infestation as short as nine days resulted in deformed plants. Heavy populations of six lygus bugs per plant caged for eight days killed 40 per cent of the seedlings and injured the growing point of 42 per cent of the remaining plants.

Prior to the appearance of the first leaf, a number of plants had the growing tips removed with a razor blade. The subsequent growth showed that the plants developed normally, with one stem and normal sized leaves. These data indicate that lygus bug injury is not actually a quick killing of the growing tip, but the result of a cumulative effect of feeding injury over a prolonged period.

Another series of plants was exposed to an average of three lygus bugs per plant for 31 days. This experiment was started on July 22. Because of high temperatures, the plants grew rapidly. Furthermore, the lygus bug mortality was also very high. Yet, at the end of the exposure period, all the insect-exposed plants were shorter, had fewer leaves and forked stems (Table 4). These potted plants were then placed in the open and ensuing growth observed. The data in Table 4 show that early lygus bug injury retarded the development of squares, blooms and bolls. For a while the injured plants were shorter than the normal plants, but by September 9 the injured plants were taller. The lygus bug-injured plants had developed forked stems, whereas the normal plants had single stems. These data indicate that early lygus bug injury is reflected in the later growth of the cotton plant.

Observations of Injury During One to Two Leaf Stage of Growth

Various lygus bug populations were caged on plotted plants that were in the one to two leaf stage of growth. Table 5 shows the effect of exposure of plants to lygus bugs for nine days when the first leaf appeared. One lygus bug per plant injured the growing tip of 55 per cent of the plants. Three lygus bugs per plant injured the growing tip of 88 per cent of the plants. Increasing the population of lygus bugs to five per plant resulted in 33 per cent of the plants being killed and 82 per cent of the remaining plants being injured. A population of one bug per plant did not affect leaf development, but populations of three and five lygus bugs per plant retarded development of leaves, as shown in Table 5.

In another experiment, reported in Table 6, lygus bugs were caged on plants in the one and two leaf stage of growth. As shown also in Table 5, one lygus bug per plant injured slightly more than 50 per cent of the seedling plants. In this experiment three lygus bugs per plant killed 33 per cent of the plants. The plant mortality was greater when five lygus bugs per plant were caged. Half-grown or larger nymphs were also caged on seedling plants. Data in Table 6 show that nymphs are slightly less injurious than adults. This is contrary to a commonly accepted belief that one nymph is as destructive as two adults. In this experiment lygus bugs retarded the growth of cotton significantly, as indicated by data in Table 6.

Table 7 compares the amount of injury caused by lygus bugs on short and long staple cotton. These data show that lygus bugs retard growth and suppress leaf development in both varieties of cotton. Furthermore, 75 per cent of the growing tips were injured on the short staple variety and 89 per cent of the long staple variety. This suggests that long staple cotton in the seedling stage is even more susceptible to lygus bug injury than short staple.

Table 3. Lygus Injury to Cotton Seedlings in Outdoor Cages; Insects Introduced Immediately Prior to Appearance of First True Leaves.

	Unexposed Plants	*Plants Exposed to Lygus Bugs*
Test No. 1		
Ave. No. Lygus Bugs per Plant	0	2[1]
Ave. Height per Plant, Inches	4.9	2.9
Ave. No. Leaves per Plant	3.1	2.0
Total No. Plants	12	12
% Plants Deformed	0	100
Test No. 2		
Ave. No. Lygus Bugs per Plant	0	2[2]
Ave. Height per Plant, Inches	3.5	2.7
Ave. No. Leaves per Plant	2.4	1.1
Total No. Plants	17	17
% Plants Deformed	0	100
Test No. 3		
Ave. No. Lygus Bugs per Plant	0	6[3]
Ave. Height per Plant, Inches	3.5	2.4
Ave. No. Leaves per Plant	1.4	0.2
Total No. Plants	20	20
% Plants Killed	0	40
% Surviving Plants Deformed	0	42
Test No. 4		
Ave. No. Lygus Bugs per Plant	0	2[4]
Ave. Height per Plant, Inches	5.1	4.8
Ave. No. Leaves per Plant	3.8	4.3
Total No. Plants	15	15
% Plants Killed	0	7
% Surviving Plants Deformed	0	57

[1] Exposure period April 23 to May 22. Two lygus bugs per plant introduced in cages April 22 and May 6.

[2] Exposure period June 14 to June 23. Two lygus bugs per plant introduced in cages June 14 and 17.

[3] Exposure period from June 28 to July 5. Six lygus bugs per plant introduced in cages on June 28 and July 1.

[4] Exposure period from July 5 to July 22. Two lygus bugs per plant introduced in cages on July 5, 12 and 15.

Injury to Cotton in Four to Five Leaf Stage of Growth

Both adults and nymphal lygus bugs were caged on cotton in the 4- and 5- leaf stage of growth. In the first test five lygus bug adults per plant fed for 18 days. The data in Table 8, Test 1, showed that this high population retarded growth of the plants. Furthermore, lygus bugs on the small immature leaves killed them so that at the end of the exposure period the average number of leaves per plant was actually less than when the experiment was started. This high population injured the growing point on all the plants. Exposing the plants to the same

number of lygus bugs per plant, but for only seven days, showed that even in so brief a time lygus bugs retarded the growth of cotton and injured 79 per cent of the growing tips (Test 3 of Table 8).

In the second test of this experiment, a population of five lygus bug nymphs, half grown or larger, was allowed to feed 18 days on seedling cotton in the 4- to 5-leaf stage of growth. This nymphal population did not retard the growth of the plants as the adults did, nor did it affect the number of leaves. As these nymphs fed on the plants, approximately half of the growing points were injured or destroyed. These data indicate that the nymphs were not as destructive as adults to presquaring cotton.

Table 4. Effect of Lygus Bug Feeding for 31 Days on Seedling Cotton (Outdoor Cages).

	Untreated	*Lygus Bug Exposed Plants*
Data on August 23		
Ave. No. Leaves per Plant	10.2	9.8[1]
Total No. Plants	12	12
Number of Plants Deformed	0	12
Ave. Height per Plant, Inches	12	8.7
Data on August 29		
Ave. No. Leaves per Plant	14.2	12.9
Ave. No. Squares per Plant	1.8	0
Ave. Height per Plant, Inches	12.4	11.1
Data on September 9		
Ave. No. Squares per Plant	3.3	3.8
Ave. No. Blooms per Plant	0.2	0.0
Ave. No. Bolls per Plant	0.4	0.0
Ave. Height per Plant, Inches	14.1	15.5

[1] Lygus bugs were caged over plants from July 22 to August 23. Three lygus bugs per plant were introduced in cage on July 22, 26 and 31.

Table 5. Injury Resulting From Various Lygus Bug Populations Caged for 9 Days on Cotton in the 1-Leaf Stage of Growth (Outdoor Cages).

	Effect of Lygus Bugs on Small Cotton Plants
1 Lygus Bug per Plant	
No. Plants	9
Ave. Height, Inches	3.5
Ave. No. Leaves per Plant	1.1
% Living Plants Injured	55
% Plants Killed	0
3 Lygus Bugs per Plant	
No. Plants	9
Ave. Height, Inches	3.2
Ave. No. Leaves per Plant	0.6
% Living Plants Injured	88
% Plants Killed	0
5 Lygus Bugs per Plant	
No. Plants	9
Ave. Height, Inches	3.9
Ave. No. Leaves per Plant	0.9
% Living Plants Injured	82
% Plants Killed	33
Untreated	
No. Plants	9
Ave. Height, Inches	3.6
Ave. No. Leaves per Plant	1.3
% Living Plants Injured	0
% Plants Killed	0

Table 6. Injury Resulting From Various Lygus Bug Populations Caged for 9 Days on Long Staple Cotton in the 1 to 2 Leaf Stage of Growth (Sleeve Cages).

	Date of Examination	
	August 14	*August 23*
1 Lygus Bug per Plant		
No. Live Plants	12	12
Ave. Height per Plant	3.5	4.2
Ave. No. Leaves per Plant	1.8	
% Plants Injured	0	58
% Plants Killed	0	0
3 Lygus Bugs per Plant		
No. Live Plants	12	8
Ave. Height per Plant	3.5	3.6
Ave. No. Leaves per Plant	1.5	
% Plants Injured	0	75
% Plants Killed	0	33
5 Lygus Bugs per Plant		
No. Live Plants	12	5
Ave. Height per Plant	3.7	3.9
Ave. No. Leaves per Plant	1.8	
% Plants Injured	0	100
% Plants Killed	0	58
5 Lygus Bug Nymphs per Plant		
No. Live Plants	12	6
Ave. Height per Plant	3.2	3.3
Ave. No. Leaves per Plant	1.8	
% Plants Injured	0	66
% Plants Killed	0	50
Untreated		
No. Live Plants	12	12
Ave. Height per Plant	3.2	5.1
Ave. No. Leaves per Plant	1.6	
% Plants Injured	0	0
% Plants Killed	0	0

Table 7. Comparison of Lygus Bug Damage to the Seedling Stage of Long and Short Staple Cotton (Outdoor Cages).

Average of 20 plants	*Staple*	*Treatment*[1]	*Observations*[2] *First*	*Final*
Height, Inches	Short	Lygus bugs	2.3	4.9
		Control	2.3	5.8
	Long	Lygus bugs	1.8	5.1
		Control	1.9	6.5
No. True Leaves	Short	Lygus bugs	0.0	3.6
		Control	0.0	4.8
	Long	Lygus bugs	0.0	3.3
		Control	0.0	5.1
% Plants Deformed	Short	Lygus bugs	0.0	75.0
		Control	0.0	0.0
	Long	Lygus bugs	0.0	89.0
		Control	0.0	0.0

[1] Started on June 17 and ended on July 10.

[2] An average of six lygus bugs per plant was introduced in the treatment cage on June 17, 21, 24, 28, July 1 and 5.

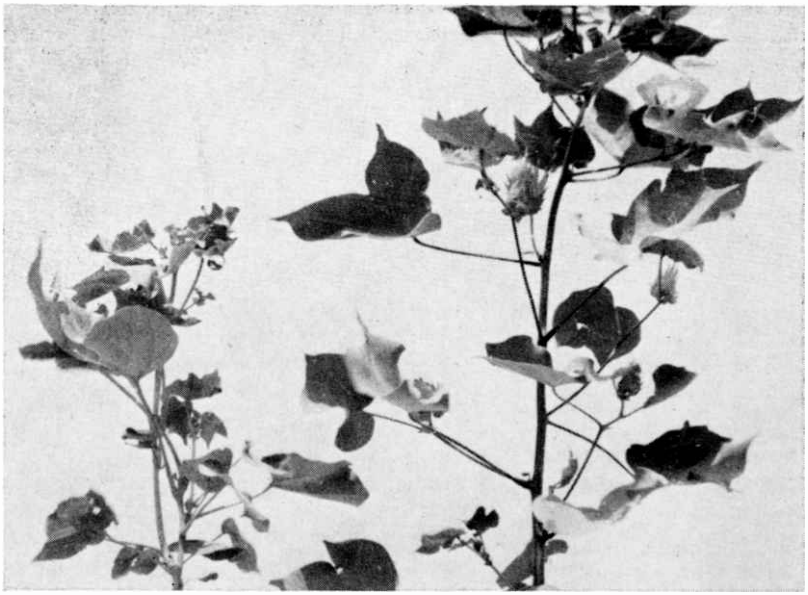

Figure 3. Plant on left shows retarded growth as result of lygus bug injury to the plant in the seedling stage of growth.

Table 8. Injury Resulting from Caging 5 Lygus Bugs per Plant on Cotton in the 4 to 5 Leaf Stage of Growth.

	Time of Observation	
	Start	*After Exposure*
Test No. 1		
5 Lygus Bugs per Plant for 18 Days		
No. Plants	9	9
Ave. Height, Inches	4.6	4.2
Ave. No. Leaves per Plant	4.7	4.0
% Living Plants Injured	0	100
% Plants Killed	0	0
Untreated		
No. Plants	9	9
Ave. Height, Inches	4.5	5.7
Ave. No. Leaves per Plant	4.3	5.7
% Living Plants Injured	0	0
% Plants Killed	0	0
Test No. 2		
5 Lygus Bug Nymphs per Plant for 18 Days		
No. Plants		9
Ave. Height, Inches		5.5
Ave. No. Leaves per Plant		4.1
% Plants Injured		55
Untreated		
No. Plants		6
Ave. Height, Inches		5.6
Ave. No. Leaves per Plant		4.1
% Plants Injured		0
Test No. 3		
5 Lygus Bugs per Plant for 7 Days		
No. Plants	9	9
Ave. Height, Inches	5.5	5.6
% Plants Injured	0	78.6
Untreated		
No. Plants	9	9
Ave. Height, Inches	5.8	6.4
% Plants Injured	0	0

Lygus Bug Injury on Field Planted Cotton

A field of cotton was planted late in rows six inches apart, the seed being spaced three inches apart in the row. Each of six screen cages (2.5 by 4.5 by 3.5 feet) was placed over four rows of cotton. Each cage enclosed approximately 50 seedling plants. On June 14, an average of three lygus bugs per plant was introduced in three of the cages. Because the entire field was sprayed twice with Toxaphene - DDT during the exposure period, it was necessary to restock the cages on June 21, June 28 and July 5. The other three cages were kept insect-free for comparison. On July 9, all lygus bugs were killed with malathion. The cages then were removed and plant growth observed during the remainder of the season.

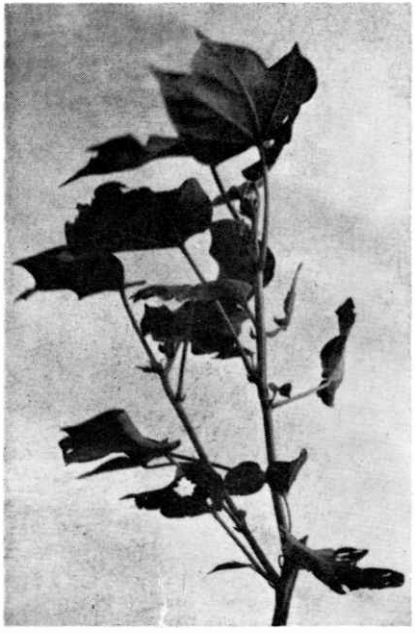

Figure 4. Split stem resulting from lygus bug injury to seedling cotton.

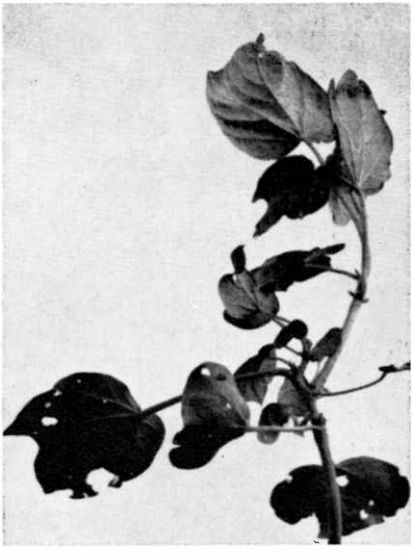

Figure 5. Cotton plant shaped abnormally, resulting from lygus bug damage in seedling stage.

Data taken July 9 show that lygus bug injury retarded plant growth (Table 9). Figure 3 shows the initial retardation of growth resulting from lygus bug injury to the original growing point. However, in approximately 10 weeks of growth these injured plants became equal in height to the normal plants (Table 9). At the end of September, many of the plants injured earlier were taller than the uninjured plants.

On July 8, some 87 per cent of the lygus bug-infested plants had abnormal shapes, compared to 12 per cent for the insect-free plants (Table 9). Basically these misshapen plants resulted from lygus bugs feeding on the original growing point. Most of the plants were like those shown in Figure 4. These plants had a split or forked stem starting from the original growing point which originated between the cotyledons.

Figure 5 shows another type of injury. Here the original growing point was so severely injured that a new growing point started at the base of the cotyledon node, producing a normal growing branch. However, the original growing point produced a mass of leaves with a witch's broom appearance. Figure 6 illustrates another type of early lygus injury, characterized by development of extra large, thick and leathery leaves on elongated petioles. These leaves originate at the point of injury and, because of their size, tend to mask the growing points, of which there may be more than one per plant that develop normal leaves.

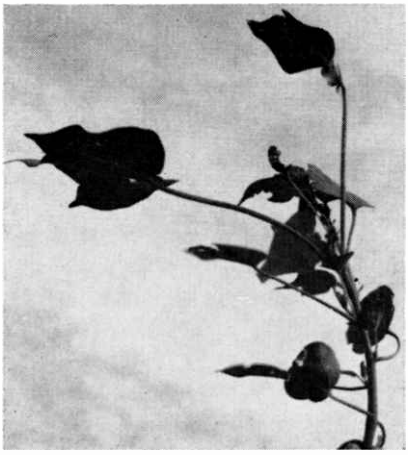

Figure 6. Large leaves on elongated petioles are the result of lygus injury at the seedling stage of growth.

A second experiment was conducted in the fall with the insects caged on cotton in the 1-leaf stage from September 16 to November 15. This long period was necessary because of the prevailing cool weather that slowed growth and limited lygus bug activity. It took two months for the cotton to arrive at the same stage of growth that June cotton developed in 22 days. The same type of injury developed in the fall experiment, but fewer plants were affected, as shown in Table 10. However, data indicate that more than one lygus bug per plant is required to produce abnormal plants.

In another fall experiment, also conducted in the field, lygus bugs were caged on cotton in the 4 and 5 leaf stage of growth. Abnormal plants were also produced (Table 11). These fall experiments again emphasize that lygus bug feeding causes abnormal plants.

Lygus bug injury to cotton in the seedling stage of growth prevented the development of squares, as shown in Tables 9, 10 and 11. Data in Table 10 show that even as low a population as one lygus bug per plant can inhibit development of squares. Because of the high mortality of caged lygus bugs, the damage was probably done with a plant population which averaged less than 0.5 lygus bug per plant. These data again emphasize the damage that lygus bugs can do to presquaring cotton by inhibiting the development of squares.

Effect of Early Season Injury on Mid- and Late Season Cotton Growth

Field cage plots were allowed to mature under insect-free conditions. About a month after the lygus bugs had been removed from the cotton plants, the lygus bug injury to cotton plants was more pronounced, especially for those plants which were severely injured. Plants with slight injury resulting in a simple forking of the stem had only one noticeable abnormality: the stem was forked near the base of the plant and squares were missing on the lower part of the plant. Plants which were more severely injured had a witch's broom type of growth, and grew three to eight stems or branches from the growing point, as shown in Figure 7.

Also on such plants there were a few of the large, thick leathery leaves typical of symptoms described by Shields and Gries (1962). Fig-

Table 9. Growth and Fruiting of Cotton Plants After Being Exposed for 22 Days to Heavy Lygus Bug Populations in Large Field Cages (Lygus Bugs Removed on July 9th).

Average per Plant	*Treatment*	*Date of Examination*					
		July 9	*July 26*	*Aug. 9*	*Aug. 22*	*Aug. 29*	*Sept. 9*
Height, Inches	Lygus bug	12	12	22	30	32	—
	Control	21	24	28	32	32	—
No. Squares per Plant	Lygus bug	0.1	0.3	4.8	8.6	10.2	10.8
	Control	2.0	2.3	11.6	6.8	6.6	4.5
No. Blank Squares per Plant	Lygus bug	0.0	0.1	0.2	0.2	0.2	0.1
	Control	0.0	0.0	0.0	0.0	0.0	0.0
No. Blooms per Plant	Lygus bug	0.0	0.0	0.1	0.5	0.6	1.5
	Control	0.0	0.4	0.2	0.8	0.8	0.5
No. Bolls per Plant	Lygus bug	0.0	0.0	0.1	1.4	1.1	8.4
	Control	0.0	0.4	1.6	6.9	5.9	9.9
% Abnormal Plants	Lygus bug	87					
	Control	12					

Bales cotton on Oct. 21:	*Lygus bug plots*	3.9
	Control	4.3

ure 8 shows those large leaves on elongated petioles. Also shown are the enlarged nodes caused by lygus bug feeding. Also noticeable are the long internodes with few leaves on the lower half of the multiple stems. However, as the season advanced the new growth, which was normal, finally masked most of the early injury. Figure 9 also shows a plant with multiple stems resulting from severe lygus bug injury in the seedling stage of growth.

Table 10. Effect of Lygus Bugs Feeding for Two Months Starting on Cotton in the First True-Leaf Stage of Growth. Fall Experiment (Field Cages).

	Plants	
	Lygus Bug Injury	*Uninjured*
Experiment 1		
No. Lygus Bugs per Plant, Introduced 6 Times[1]	1	0
Total No. Plants	49	47
Ave. Height per Plant, Inches	10	16
Ave. No. Squares per Plant	0.3	2.4
% Abnormal Plants	30	6
No. Plants with Blank Squares	5 (10%)	0
Total No. Blank Squares	5	0
Experiment 2		
No. Lygus Bugs per Plant, Introduced Once[2]	1	0
Total No. Plants	47	47
Ave. Height per Plant, Inches	15	16
Ave. No. Squares per Plant	2.4	2.4
% Abnormal Plants	16	6
No. Plants with Blank Squares	0 (0%)	0
Total No. Blank Squares	0	0
Experiment 3		
No. Lygus Bugs per Plant, Introduced 6 Times[1]	2	0
Total No. Plants	47	52
Ave. Height per Plant, Inches	14	17
Ave. No. Squares per Plant	0.2	3.0
% Abnormal Plants	55	10
No. Plants with Blank Squares	3 (6%)	0
Total No. Blank Squares	3	0
Experiment 4		
No. Lygus Bugs per Plant, Introduced 6 Times[1]	3	0
Total No. Plants	40	44
Ave. Height per Plant, Inches	13	16
Ave. No. Squares per Plant	0.1	2.8
% Abnormal Plants	43	0
No. Plants with Blank Squares	7 (18%)	0
Total No. Blank Squares	8	0

[1] Introduced September 16, 24, October 1, 8, 15 and 24.
[2] Introduced on September 16.

Table 11. Effect of Lygus Bugs Feeding for 45 Days Starting on Cotton in the 5-Leaf Stage of Growth. Fall Experiment (Field Cages).

	Lygus Bug Injured	*Uninjured*
No. Lygus Bugs per Plant, Introduced 4 Times[1]	5	0
Total No. Plants	23	30
Ave. Height per Plant, Inches	14	16
Ave. No. Squares per Plant	0	1.6
% Abnormal Plants	34	8
No. Plants with Blank Squares	5 (20%)	0
Total No. Blank Squares	10	0

[1] Introduced October 1, 8, 15 and 24.

[2] Five of the smaller plants were killed by lygus bugs.

Figure 7. Multiple branching of stem resulting from severe lygus bug injury on seedling cotton.

Figure 8. Swellings on the stems of seedling cotton are the result of severe lygus bug injury.

The early lygus bug injury delayed squaring for approximately one month. As a result, heavy boll populations were delayed for about three weeks. When the plants matured, the lygus bug-injured plants yielded 0.4 bale less cotton per acre (Table 9).

Both lygus bug-injured plants and uninjured plants from Tests 1 and 3 of experiment 3 (Table 3) were transplanted to a regular cotton field. Transplanting shocked the plants, but when they started growing the uninjured plants were more vigorous. The lygus bug-injured plants set their squares later and in lesser number (Tables 12 and 13). Consequently, the number of bolls finally set was less, as shown in Figure 10.

These data show that lygus injury to seedling cotton delays early squaring, thereby prolonging the growing period required for yields comparable to uninjured plants. An extra two or three treatments in September would be required in order to prevent injury from bollworms to the late maturing bolls. Lygus bug injury also causes multiple branching of the main stem of cotton plants, making such cotton more difficult to harvest. It must also be emphasized that a variety such as Deltapine Smooth Leaf, even in a long growing season, cannot produce a sufficiently heavy late or "top" crop to compensate for the losses caused by lygus injury earlier in the season.

Injury to Mid-Season Cotton

Table 14 shows the effect of caging five lygus bugs, either adult or nymph, per fruiting form on three plants. This was to simulate conditions of cotton grown next to a maturing safflower field where adult lygus bugs were migrating in large numbers into cotton fields over a period of three to four weeks.

The data show that both the adult and nymphal lygus bugs caused loss of squares. The number of bolls set was therefore reduced even after the cages were removed and the insects killed. The yield of the plants exposed for approximately one month to both adults and nymphs was reduced greatly. As there were only two cages used in each treat-

Figure 9. Multiple stems resulting from lygus injury to seedling cotton.

ment, no conclusions can be drawn from the yield differences between the plants exposed to adult and to nymphal lygus bugs.

In determining the need for chemical control treatments, some field entomologists consider one nymph equal to two adult lygus bugs in destructiveness.

The final yields reported in Table 14 indicate that nymphs should be considered about equal to adults in their ability to injure mid-season cotton, even though in the test field the nymphal cages were in an area of poor production.

These data definitely show that adult lygus bugs can cause a considerable amount of damage to mid-season cotton, especially if the numbers are large. This damage results in the shedding of injured squares, the production of fewer matured bolls, and lowered yields. The reduction in fruiting structures is accompanied by increased vegetative growth. Plants injured by lygus bugs tend, therefore, to be taller than uninjured plants.

Table 12. Subsequent Growth of Cotton Plants Transplanted in the Field After Being Injured by Lygus Bugs for 29 Days in the Seedling Stage.

Portion of Plant[1]	*Lygus Bug Injured*[2]	*Average Per Plant On*							
		June 3	*June 17*	*July 8*	*July 26*	*Aug. 9*	*Aug. 22*	*Aug. 29*	*Sept. 6*
Squares	Yes	0.0	0.8	5.9	10.0	14.0	5.5	14.5	16.0
per Plant	No	0.0	3.0	12.9	13.0	18.0	3.5	14.0	9.5
Blooms per	Yes		0.0	0.0	2.0	1.0	0.5	0.0	1.0
Plant	No		0.0	0.0	4.0	1.0	1.0	0.0	1.0
Bolls per	Yes		0.0	0.0	4.0	7.0	7.0	9.5	6.5
Plant	No		0.0	0.0	8.0	17.0	20.0	19.5	20.0
Height	Yes	2.9	6.3			15.0	16.0	17.5	19.5
(Inches)	No	4.9	8.5			20.0	20.5	21.0	23.5

[1] Plants were transferred from pots to open field on June 3.
[2] Two lygus bugs per plant.

Figure 10. Plant on the right shows how lygus bug injury to seedling cotton reduced the number of bolls eventually set by the cotton plant.

Blank Squares and Lygus Bugs

In Experiment 4, reported in Table 4, the plants were allowed to continue growing in the pots after being injured in the seedling stage by lygus bugs. When squares were later produced, they were found to be normal. Tables 12 and 13 also show the growth of transplanted plants that had been injured by lygus bugs in the seedling stage. The plants produced normal squares and no blank squares were found.

A few blank squares were found on field-planted cotton injured by lygus bugs in the seedling stage. Table 9 shows that an average of 0.1 blank square per plant was found at the last examination on plants injured by lygus bugs during the early growth stages. This is significant, because 33 per cent of the early squares produced on these plants were blank. In the fall experiments, lygus bugs were caged for a period extending from the one-leaf stage until the appearance of squares.

In the four tests summarized in Table 10 the percentage of plants with blank squares were 10, zero, 6, and 18, respectively, although in no case did an affected plant have more than a single blank square. When plants were not given an initial exposure to lygus bugs until the 5-leaf stage, with exposure continued for 45 days, 20 per cent of the plants developed blank squares at the rate of two per plant.

Table 13. Subsequent Growth of Transplanted Cotton Plants After Being Injured for 7 Days by Lygus Bugs in the Seedling Stage.

Portion of Plant[1]	*Lygus Bug Injured*[2]	*Average Per Plant On* Aug. 9	Aug. 16	Aug. 29	Sept. 6
Squares	Yes		2.3	6.0	6.2
	No		4.3	7.3	14.0
Blooms	Yes			0.3	1.0
	No			0.8	1.0
Bolls	Yes			0.0	1.0
	No			0.3	2.5
Height (Inches)	Yes	9.5	11.9	15.0	18.3
	No	8.3	14.8	19.0	23.5

[1] Transplanted from pots to open field on July 7.
[2] Six lygus bugs per plant.

Caging both adult and nymphal lygus bugs on fruiting cotton (Table 14) produced an average of two or more blank squares per plant, with every plant affected. In 1962 it has been observed that lygus bugs migrating from safflower to fruiting cotton caused shedding of all the top squares and that an average of one to two blank squares developed on each of the plants in the field. Unfortunately for our purposes, the grower applied insecticides at this point and the plants later produced a good crop of normal squares.

These experiments with caged cotton plants demonstrated that feeding by lygus bugs is capable of producing small but significant numbers of blank squares on affected plants. A more common result of lygus injury is the dropping, or shedding, of the affected squares. Blank squares appear to be the result of injury by lygus bugs, and possibly other agents, to the meristematic areas of young but slightly older fruiting buds which remain on the plant. In either case the true nature and extent of these forms of lygus bug damage are not usually recognized until two to three weeks after the removal or disappearance of the insects responsible.

Table 14. Effect of Large Populations of Lygus Bug Adults and Nymphs Feeding on Mid-Season Cotton (Field Cages).

Stage of Lygus Bug	*Portion of Plant*	*Lygus Bug Injury*	*Pre-Treatment Average*	*Ave. Growth, After Treatment on* Aug. 5	Aug. 16	Aug. 22	Aug. 29	Oct. 22
Adult[1]	Height (Inches)	Yes	22.9	32.1		38.6	42.4	
		No	22.7	32.7		34.1	34.5	
	Squares	Yes	17.9	1.7		11.8	21.0	
		No	18.9	6.8		7.7	19.0	
	Blank Squares	Yes	0	0		2.5	2.0	
		No	0	0		0	0	
	Blooms	Yes	1.6	0		0	0.6	
		No	1.7	0.5		0.2	0.6	
	Bolls	Yes	5.0	5.4		5.2	5.3	
		No	7.4	15.3		14.5	15.9	
	Bales/Acre	Yes						1.8
		No						2.6
Nymphs[2]	Height (Inches)	Yes	24.9			38.6	40.6	
		No	27.0			30.7	31.0	
	Squares	Yes	11.3		1.5	4.0	10.8	
		No	12.4		4.4	4.9	8.9	
	Blank Squares	Yes	0		0.4	1.8	2.7	
		No	0		0	0	0	
	Blooms	Yes	1.8		0	0.3	0.3	
		No	2.0		0.3	0.2	1.1	
	Bolls	Yes	10.4		4.2	4.2	5.3	
		No	7.9		9.1	10.1	10.5	
	Bales/Acre	Yes						1.2
		No						2.4

[1] Lygus bugs were caged on plants from July 9 to August 5. 250 adult lygus bugs were introduced in each treatment cage on July 10, July 19 and July 31.

[2] Lygus bug nymphs were caged on plants from July 22 to August 16. 200 nymphs were introduced in each treatment cage on July 23, July 31 and August 9.

SUMMARY

The following conclusions may be drawn from these experiments:

Lygus bugs can kill cotton seedlings within two or three days after the seedlings emerge from the ground. At this stage of growth, lygus bugs feed on the cotyledons.

After the cotyledons have hardened, lygus bugs feed only on the growing points of the seedling plants. Such feeding results in deformed plants and retards squaring for a period of two to four weeks. Lygus bugs may injure both Deltapine Smooth Leaf and Pima S-2 varieties in the seedling stage.

Lygus bug injury to cotton plants in the seedling stage may be reflected in lower yields during a normal growing season. Conditions favoring the maturity of a large late-season crop of bolls may offset most of this early loss.

Blank squares may result from feeding by lygus bugs on meristematic tissues of presquaring cotton.

Presquaring cotton plants grown in fields adjacent to preferred host crops, such as alfalfa or safflower, or near areas of native desert vegetation, can be seriously injured by heavy, inward-migrating infestations of lygus bugs. Under the conditions of irrigated agriculture found in central Arizona, such migrations may result when preferred host plants are no longer available or are not in a condition to support the existing populations of lygus bugs.

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