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Causes of Square Abscission in Cotton in Arizona[1]

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) plantings sometimes abscise large numbers of flower buds (squares). Many environmental and nutritive stresses and insect or disease damage are known to induce this abscission. To determine the specific causes of abscission in Arizona the squares were examined visually under a ×10 stereomicroscope. Symptoms that indicated the cause of the abscission were observed to fall into four categories: 1) dissolution of tissues due to plant bug (primarily *Lygus* spp.) feeding, 2) soft rot due to thrips (*Thysanoptera* spp.) activity, 3) tunnels due to lepidopterous larvae feeding, and 4) desiccation without physical damage indicating physiological stresses. Each week during three seasons (1978 to 1980) the abscised squares were subdivided among these categories. Prior to 15 July the primary cause of abscission was Category 1 with a minor fraction due to Categories 2 and 4. After 15 July Category 3 became more important and Category 2 was seldom observed. In only two sampling periods during the 3 year study did Category 4 exceed half of the abscised squares. Correlation of the Category 1 symptoms with lygus bug population in the field at the beginning of the week of sampling was high ($r = 0.94$ $P < 0.05$). The regression analysis indicated a feeding rate of 1.7 squares insect^{-1} per day^{-1}. Temperature correlation on lygus feeding was not significant. The study showed that visual symptoms of damage can be used to categorize abscised squares by the causal agent and that large variation within and between years occurs.

***Additional index words:* Flower buds, *Gossypium hirsutum* L., *Lygus* spp., *Thysanoptera* spp., Temperature.**

THE COTTON (*Gossypium hirsutum* L.) plant produces a great many more potential fruiting sites than it matures as fruit. In this it is like most other woody, indeterminate trees and shrubs. However, in fruit trees there is little flower bud abscission. Young fruit abscise and decrease the fruit load, but few buds abscise prior to blossoming (Addicott, 1982). In cotton on the other hand, both types of abscission occur. Frequently 25 to 50% of all flower buds (squares) formed by the plant abscise before blossoming (Hall, 1958). Though there is evidence that in some locations square abscission may not affect yield potential of the crop (Gutierrez, et al. 1977) there are other locations where 25% square shedding is considered sufficient to reduce or delay yield (Lewis, 1981, p. 57).

When excessive square abscission occurs it may be difficult to assign reasons for the abscission and thus develop strategies to correct it. Guinn (1982) listed 13 causes of square and boll abscission. These can be subdivided into two categories: 1) internal, physiological stresses brought about by shortages or excesses of moisture, light, or nutrients; and 2) external damage to the organ due to attack by insects or microorganisms. Mauney and Henneberry (1979) described visual symptoms by which squares abscised due to feeding of plant bugs (*Miridae* spp.) could be distinguished from those shed for physiological reasons. This paper describes additional symptoms of external damage which lead to abscission of squares and reports field observations which categorize the abscission according to four causes: 1) plant bug feeding, 2) thrips activity, 3) lepidopterous larvae damage, and 4) physiological stresses.

MATERIALS AND METHODS

Abscised squares were obtained in 1978, 1979, and 1980 from field plots of 'Deltapine 16' (1978) or 'Deltapine 70' (1979 and 1980) at the University of Arizona Cotton Research Center, Phoenix. The plots were 25 × 30 m and were treated according to the accepted agronomic practices for the location. They received 140 Kg N ha^{-1} as urea divided equally into an application prior to planting and a sidedress approximately 70 days after planting. Planting was on 5 to 10 April, depending on year. Irrigation was by furrow flooding with 15 cm each 14 days beginning 50 days after planting. Topical insecticide applications of synthetic pyrethroids were initiated in August for control of bollworm (*Heliothis* spp.) and pink bollworm, *Pectinophora gossypiella* (Saunders), infestations. Eight to 11 applications were necessary.

Squares were collected by examining fruiting branches of all plants in a 1-m-row segment of each of six plots. All squares showing visual evidence of the onset of abscission but still on the branches and those on the soil below were collected and dissected under a stereoscopic microscope. The internal symptoms of damage were used to characterize the reason for abscission. On each sampling date 25 or more squares, drawn from the composite of collections from all plots, were dissected.

Sweep counts of insect populations were made within the plot with a standard 40-cm sweep net over the row of cotton. Generally 50 sweeps (thus sampling 20 m^2 of crop) were made in about 60 m of row. Total numbers of lygus bugs in the field were calculated by multiplying the sweep count by 3.65 (Byerly et al. 1978) to correct for sweep net efficiency and by 500 to convert the area swept to hectares.

Total squares produced and abscised in the plots were estimated by complete weekly counts of the squares, flowers, bolls, and empty flowering sites on six, 1-m plots. The counts were made nondestructively on randomly selected row segments. Square abscission for each week was calculated as shown in Eq. [1].

$$\text{square abscission (week x)} = \text{empty sites (week x)} - \text{empty sites (week x} - 1) - \text{bolls abscised (week x)}. \quad [1]$$

$$\text{bolls abscised (week x)} = \text{flowers (week x)} - \text{bolls set (week x)}. \quad [2]$$

$$\text{bolls set (week x)} = \text{bolls present (week x)} - \text{bolls present (week x} - 1). \quad [3]$$

Single day flower counts were extended to flowers per week by graphing the daily counts and summing the area under the flower curve for each week. The values thus obtained were compared and found to be similar to those taken by others (Guinn and Mauney, 1984) five times each week in adjacent plots.

The experiment to test the involvement of thrips in soft rotting of squares was conducted in the following way. On 1 Aug. 1979, 100 squares near the apex of plants were

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tagged. Half of the plants were in field plots and half were in a nearby greenhouse. Thrips populations were suppressed in the greenhouse by application of aldicarb to the potting soil and by weekly aerosol fogging with dicofol and diazinon. The tagged squares were 1 to 2 mm wide at the base and were visible in the axil of the youngest expanding leaf. The tip of one bract was clipped away with surgical scissors on half the tagged squares in each location. The other half remained untreated. Ten days after tagging and treatment, all squares were removed and examined for symptoms of soft rot.

Temperature was recorded in a weather station maintained by the University of Arizona 0.5 km from the field plots. Degree-day calculations were made using the averaging method (Fry, 1983) with a base temperature of 12°C.

RESULTS AND DISCUSSION

The dissection of large numbers of abscised squares showed that in addition to the symptoms of plant bug damage and physiological stress described by Mauney and Henneberry, (1979), other symptoms were associated with a portion of the abscised squares. One of these symptoms was a 1 to 3 mm hole through the squares just above the pedicel. This damage was presumed to be due to lepidopterous larval feeding. Larval frass was usually present. Most often squares with this damage had been attacked while less than 4 mm in width at positions near the apex of the plant. Both *Heliothis zea* (Boddie) and *Heliothis virescens* (Fabricius) were present in the fields and were presumed responsible for this damage.

Other symptoms that were not obviously associated with either larval or plant bug damage were also observed. The most obvious of these symptoms was soft rot of the antheridium. Though this soft rot was sometimes associated with, and probably a consequence of, larval damage and plant bug feeding, the majority of the instances had none of the visual symptoms of either.

Two additional traits were usually present in these rotted squares: 1) more than half had an abnormal fourth bract as part of the involucre and 2) the interior surface of the fused staminal column was discolored brown. The soft rot seemed to originate in the area of this discoloration and spread throughout the staminal column.

On several occasions during square dissections, thrips nymphs (*Thysanoptera* spp.) were observed feeding on the interior surface of the staminal column. This observation raised the possibility that thrips activity was responsible for the introduction of soft rot organisms into the developing staminal tissue which eventually resulted in the abscission of that square. T. F. Leigh (personal communication) has also observed thrips in the interior of squares and associated their activity with square abscission early in the season in California.

The results of exposing the interior of the flower bud by clipping the tip of the bracts when the squares were 1 to 2 mm in width is shown in Table 1. During the time of this experiment the incidence of soft rot in other portions of the field was low (Table 2). None of the intact tagged squares developed soft rot symptoms, though larval tunnels and symptoms of plant bug feeding were observed (Table 1). Similarly, none of the greenhouse squares, either with trimmed or intact bract, had any soft rot symptoms. In the field group with a bract trimmed, an average of 10 squares had symptoms of soft rot. During dissection, thrips were observed inside the bracts and petals on two of the treated, rotting squares. Since thrips are very actively moving insects, they are likely to be only transient visitors to the interior of squares. The fact that they were observed in a portion of the squares during dissection shows that it was possible for them to enter through the opening created when the bract was clipped.

Table 1. Visual symptoms of damage 10 days after removal of one bract tip (treated) from 25 squares from greenhouse- and field-grown plants.

	Plant bug feeding	Soft rot	Lepidopterous larvae	No damage
	Number of squares			
Field untreated	1	0	4	20
Field treated	0	10**	0	15
Greenhouse untreated	0	0	0	25
Greenhouse treated	0	0	0	25

** Highly significantly different from the untreated ($P < 0.01$) using the chi-squared test.

The thrips that were observed inside the square bracts were seen emerging from the interior of the cylinder of the staminal column. This is the area where the brown discoloration always associated with the soft rot occurs. Though it is possible that the bact trimming in the field exposed the square interior to rot organisms and that the thrips were incidental visitors to the scene of the infection, the presence of thrips provided strong circumstantial evidence that they introduced the organisms that caused the soft rot.

The abscised squares were subdivided into groups according to damage symptoms. The percentages are shown in Table 2 for the 1978, 1979, and 1980 growing seasons. A striking feature of these data is the change in cause of damage which occurred throughout the seasons and from year to year. Some variability may be due to sampling, but because the crop is a dynamic, growing system, the changes from week to week may be very dramatic and real. The lower percentages of total squares abscised from late June to mid-July reflect the rapid increase in total available positions during the first weeks of squaring.

If the seasons were divided at 15 July, the pattern of abscission was very different in the early portion compared with the late. Soft rot and plant bug damage were the major factors inducing abscission prior to 15 July. Lepidopterous larval feeding was a more serious problem thereafter.

Study of the morphological relationships during square development tended to confirm the indications that thrips activity is responsible for introducing the rotting organisms into the interior of the square. Quintanilha et al. (1962) and Mauney (1984) have described the development of a square. Bracts are the first tissues to develop, followed by sepals, petals, stamens, and pistil. Before the bracts are large enough to protect the interior flower parts the developing leaves in the plumule with their large stipules provide protection. At the time when the leaf which subtends

Table 2. Cotton square abscission due to damage by lygus bugs, thrips, lepidopterous larvae or physiological stress.†

Week beginniing		Avg. temp.	Squares abscised‡		Lygus bugs observed	Percent of week's abscissions due to: Lygus	Thrips	Lepidopterous larvae	Physiological stress
		°C	%	no. (× 10⁻³) ha⁻¹ day⁻¹	no. (× 10⁻³) ha⁻¹	%			
1978									
June	5	31	8	2.1	0.9	70	21	0	9
	12	32	7	5.2	1.4	68	22	0	10
	19	34	15	16.3	5.1	70	22	0	8
	26	31	17	28.2	7.3	54	28	1	17
July	3	32	14	5.1	2.8	65	23	0	12
	10	35	16	7.5	0.3	0	21	0	79
	17	35	27	3.0	0.2	30	4	44	22
	24	33	34	10.0	1.2	30	5	42	23
	31	32	34	57.5	2.5	6	3	50	41
Aug.	7	32	43	24.7	2.4	23	2	65	10
1979									
May	24	27	8	–	–	70	30	0	0
June	4	28	3	5.2	4.5	87	5	4	4
	11	32	9	24.2	13.7	87	9	3	1
	18	28	14	10.0	7.9	86	11	0	3
	25	35	13	7.4	3.8	68	11	7	14
July	2	31	10	5.6	1.0	–	–	–	–
	9	33	11	8.4	1.2	29	0	57	14
	16	32	10	16.1	1.2	51	9	30	10
	23	34	11	10.7	6.1	59	7	21	13
Aug.	1	34	12	–	–	18	0	82	0
1980									
June	2	28	16	–	–	80	20	0	0
	9	32	22	9.5	6.1	89	11	0	0
	16	33	11	0	5.3	87	10	0	3
	23	35	12	12.0	5.3	–	–	–	–
	30	33	13	20.6	6.1	68	12	8	12
July	7	35	19	19.4	7.9	52	30	3	15
	14	35	30	46.6	8.8	43	6	47	3
	21	36	52	79.2	20.2	28	0	8	64
	28	35	60	54.3	14.1	60	4	8	28
Aug.	4	36	58	–	–	–	–	–	–

† Missing data (–) are dates when observations were not taken or data could not be calculated due to lack of observation on previous or subsequent weeks.
‡ Percentage (%) of all available square sites found empty in row segments during the reporting week and the number (no.) abscised during the week is calculated by Eq. [1], Materials and Methods.

the square begins to unfold the bracts are 1 mm in width at the base, and the tightly interlocking serrations prevent invasion by casual insects such as thrips. At the time the bracts reach 3 to 5 mm in width the serrations are no longer interlocked tightly enough to prevent thrips from gaining access to the interior of the bud. At that time, however, the petals have enlarged and overlapped so that the staminal column remains protected.

The importance of the abnormal fourth bract as a part of the circumstances leading to soft rot is that the presence of this bract prevents a tight interlock of the bract serrations. This allows thrips to enter the interior of the bud before the petals overlap. The activity of the thrips on the interior of the staminal column may induce the soft rot symptoms. Soft rot was a very minor factor after 15 July. Very few malformed squares develop during this prime flowering period for the plant (data not shown).

Somewhat greater incidence of physiological abscission was observed after 15 July. One week each in 1978 and 1980 this factor was the major cause of square shedding. The physiological abscission occurred directly after an irrigation and can be attributed to the moisture stress prior to the irrigation (Guinn and Mauney, 1984a).

In 1979 the catch from the sweep net was sent to Dr. H. M. Graham, Biological Control of Insects Laboratory, Tucson, AZ for identification. He reported that during June the *Lygus* spp. were identified as primarily *L. hesperus* Knight (70–91%) and *L. desertinus* Knight (12–25%), with a few *L. lineolaris* Beauvois and *L. elisus* Van Duzee. One sample taken 6 August was entirely *L. hesperus*.

Gutierrez et al. (1977) and Mauney and Henneberry (1979) used field and laboratory caging studies respectively to estimate the rate of lygus feeding on cotton squares. The data shown in Table 2 can be used to estimate the rate of feeding of this insect in cotton fields. The squares abscised each week were estimated from plant maps performed on a 1-m row sample. The numbers abscised due to lygus feeding were calculated by multiplying total abscissions by the fraction due to lygus feeding (Table 2). The plot of the number of lygus present at the beginning of each week against the number of abscissions per day during that week are presented in Fig. 1. The linear correlation coefficient for this relationship was r = 0.94 and the slope of the regression line suggested that the rate of square damage was 1.7 squares insect^{-1} day^{-1}. No attempt was made to separate differences in rates of damage by female adults, male adults, and

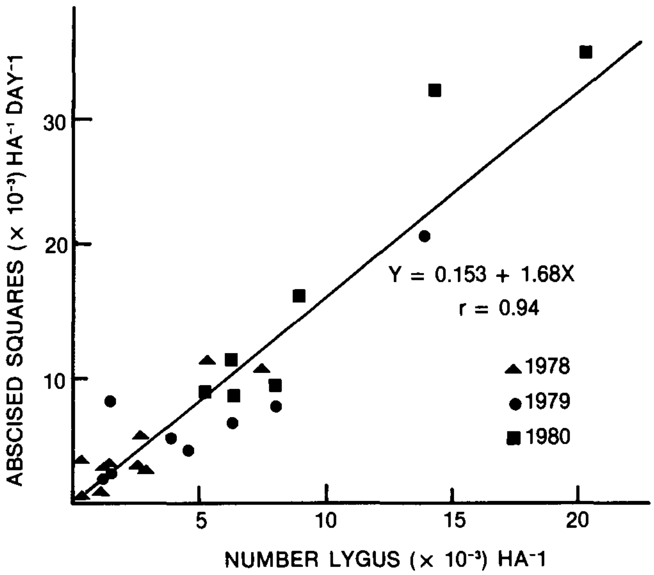

Fig. 1. Relationship of the average number of squares abscised with symptoms of Lygus damage during a week to the number of Lygus observed in the field at the beginning of the week.

nymphs. The rate of damage was intermediate between that reported by Mauney and Henneberry (1979) of 2.8 squares insect^{-1} day^{-1} and that reported by Gutierrez et al. (1977) of 0.8 squares insect^{-1} day^{-1} (average of male and female rate at 33°C.)

The direct correlation of damage rate by lygus and average weekly temperature was poor (r = 0.22). The average temperature for the time period observed in the study during 1978 to 1980 was 33°C. The lowest weekly average (Table 2) was 27°C for the weeks of 24 May 1979 and 2 June 1980. The highest weekly average was 36°C during the weeks of 21 July 1980 and 4 Aug. 1980.

Low correlation of temperature and lygus damage (r = 0.33) was also observed by Mauney and Henneberry (1979) in laboratory experiments. Though the direct correlation of damage and temperature was low in these experiments the correlation of damage with insect-degree-days (12°C base) was high (0.07 squares insect^{-1} day^{-1}, r = 0.94). The difference in the two approaches produced divergent expectations about damage rates at the temperature extremes. The calendar days equation resulted in an expectation of 1.7 squares insect^{-1} day^{-1} at all temperatures. During early season the degree-day ratio above resulted in an expectation of 1.05 squares insect^{-1} day^{-1} at 27°C.

We have observed at least four sets of symptoms which cause square abscission and which are caused by different damage agents. It is apparent that when excessive absission is observed in productive fields it may be difficult to assess the reasons for this abscission. Observations of the insect populations present will, of course, aid in this assessment. However, in view of the different values for feeding rate of lygus observed by Mauney and Henneberry (1979), Gutierrez et al. (1977), and the present study, and the low correlation of lygus damage with temperature, it is apparent that the regression equation relating plant bug numbers to square damage is not yet precise. In addition, thrips activity, worm damage, and physiological stresses are able to add to the total square abscission. The amount of abscission could reach unacceptable levels even though each causative agent was below the population or stress level considered to require action.

Only detailed examination of the abscised squares provides a reliable indication of the agents responsible at a given time. The first two squares on the upper-three fruiting branches and the second squares on the fourth and fifth branches below the terminal have been exposed to damaging agents for less than 10 days (Mauney, 1984). Examination of abscised squares from these sites gives indication of the most recent activity of damaging agents.

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