Published September, 1979

Genetic Variability Among Glandless Cottons for Resistance to Two Insects[1]

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ABSTRACT

The objective of this study was to determine if genetic resistance to tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois) and tobacco budworm (*Heliothis virescens* F.) could be detected among glandless strains of cotton (*Gossypium hirsutum* L.). We grew 97 glandless strains in the field in two environments. In the first environment, tarnished plant bugs were controlled by five weekly sprayings of an insecticide. In the other environment, tarnished plant bugs were attracted and increased by growing mustard (*Brassica juncea* (L.) Czern. & Coss), in nearby rows. A significant strain × environment interaction for lint yield indicated that there was genetic variability among the glandless strains for resistance to tarnished plant bug. Inspection of the least sensitive strains indicated that many possessed some combination of nectarilessness, hirsuteness, or rapid fruiting ability. These traits and characteristics had been previously found to result in less susceptibility to tarnished plant bugs.

First instar tobacco budworm larvae were established on young plants of 99 glandless strains when the third true leaf was expanding. Significant variability was detected for 7-day average larval weight. Inspection of the 14 strains supporting these smallest larva revealed no readily observable morphological trait that might confer resistance. A second test with the 14 selected strains indicated that the ability of the larvae to develop on these strains was generally lower than on glandless 'Stoneville 7A'. While four strains did not differ significantly from glanded Stoneville 7A, none of the resistant glandless strains equalled glanded Stoneville 7A in suppressing larval weight. Most of the resistant glandless strains came from one cross of the Louisiana breeding program at Bossier City.

These results indicate that significant useful variability for decreased susceptibility to both tarnished plant bug and tobacco budworm is present in glandless cottons.

Additional index words: **Host-plant resistance, *Lygus lineolaris*, (Palisot de Beauvois), *Heliothis virescens* (F.), *Gossypium hirsutum* L.**

THE seed and plant parts of cotton (*Gossypium* spp.) possess small black glands which contain primarily terpenoid aldehydes. Bell and Stipanovic (1) reported that the terpenoid aldehydes in the parts of the plant other than the seeds are mainly gossypol and other gossypol-related compounds which they designated as "heliocides." The terpenoid content of the seed glands is almost entirely gossypol. McMichael (8) discovered, developed, and determined the inheritance of the glandless character in G. *hirsutum* L. He determined that glandless cottons are caused by two recessive alleles, gl_2 and gl_3. Glandless cottons are essentially free of gossypol. Subsequent research by Lee (4) and Wilson and Smith (17) indicated that other dominant alleles at the Gl_3 locus could result in increased terpenoids in the plant parts. Lee (3) also established that there were other modifier genes which result in variability of terpenoid content. Miller (12) summarized the breeding currently used to develop glandless cottons.

The superior nutritive value of glandless relative to that of glanded cottonseed has been summarized by Wilcke (16). In view of the ease of breeding glandless cotton and its greater nutritive value, Martinez (7) strongly encouraged the cotton industry to place a high priority on rapidly using glandless cottons. However, as summarized by Ridgeway and Bailey (13), glandless cottons are more susceptible to attack by many insects. This property of the gossypol glands to give resistance to insects has motivated some researchers (5, 6) to promote and develop cottons with more gossypol. Although the high gossypol cottons are more resistant to most insect pests (5, 6), there is some question that the nutritive value of the seed may be adversely affected.

Regardless of a breeder's viewpoint, whether it is focused on increasing or decreasing the gossypol content of cotton, there is need for breeders to have available as many sources of resistance to pests as possible. Jenkins (2) reviewed the effects of various morphological traits that could give glandless cottons greater insect resistance. However, the identification of other biochemical factors that would result in insect resistance has been limited. Shaver et al. (13) has related part of this difficulty to the presence of gossypol in the insect diet. Their research indicates that the presence of gossypol makes the detection of other biochemical sources of resistance more difficult. One approach breeders might use to detect added resistance, other than that conferred by terpenoids, would be to screen the available glandless cottons for resistance to key pests.

The objective of our research was to screen and evaluate the available glandless germplasm for resistance to two major insect pests: tobacco budworm (*Heliothis virescens* F.) and tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois).

MATERIALS AND METHODS

We requested seed of available glandless strains from public and private breeders in the United States and received 99 strains. Tarnished plant bug resistance was evaluated in the field and tobacco budworm resistance was evaluated in the greenhouse. In all field and greenhouse studies we used 'Stoneville 7A' glanded and a backcross four advanced generation Stoneville 7A glandless strain as standard checks.

Tarnished Plant Bug Screening. In 1977 at Stoneville we divided 97 glandless strains into three approximately equal sets. All entries were grown in two insect environments. One environment consisted of four rows of mustard [*Brassica juncea* (L.) Czern. & Coss] followed by 24 rows of cotton. The middle 16 rows were used for experimentation and the remaining eight rows were used as border. Tarnished plant bugs were attracted and increased in large numbers on the mustard. Plant bugs migrated from the mustard into the cotton, thus providing large numbers of plant bugs on the cotton. This treatment is designated as the "with" tarnished plant bug treatment. The "without" tarnished plant bug treatment was achieved by five

[1] Contribution from AR, SEA, USDA, Delta States Res. Ctr., and in cooperation with the Mississippi Agric. and For. Exp. Stn. Published as Journal Paper No. 4116. Received 9 Feb. 1979.

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Table 1. Effect of tarnished plant bugs on lint yield and average weights of tobacco budworm larvae fed 7 days on Stoneville 7A glanded and glandless cottons.*

Genetic type	Without plant bugs	With plant bugs	Larval wts.
	Lint yield		
	kg/ha		mg
Stoneville 7A glanded	867 a	804 a	3.29 a
Stoneville 7A glandless	863 a	727 b	8.86 c
Glandless strains mean	688 b	609 c	6.58 b

* Means within a column followed by the same letter are not significantly different according to t-test at 0.05 level of probability.

weekly applications of dicrotophos (dimethyl phosphate ester of (*E*)-3-hydroxy-*N*, *N* dimethylcrotonomide), 115 g/ha, beginning about 15 June. These plots were located 55 m from the "with" plots. Mustard was planted 11 April and the cotton was planted 29 April. Four replications of each set were grown in both the "with" and "without" environments. A randomized block design was used. Individual plot size was one row: 1 × 6.9 m. The plots were hand picked for lint yield determinations which were used as an indication of a strains' resistance to plant bugs.

Tobacco Budworm Screening. The 99 glandless strains were divided into three sets of approximately equal size and infested with first instar larvae when the third true leaf was first visible. The level of tolerance of each strain was determined by the average weight of 7-day-old larvae reared on plants grown by two similar methods. In the first method, three plants grown in 25.4-cm diam clay pots were designated as a plot. Ten first instar larvae were placed on the three plants, reared for 7 days, counted, weighed, and average weights per plot were determined. The experimental design was a randomized complete block design with three replications. A plot for the second method consisted of 10 plants (1 plant/pot) grown in 6.4-cm² pots. A 21.6-cm border of flexiglass prevented migration of larvae from one plot to another. Twenty-five larvae were placed in each plot. As with method 1, all larvae from a pot were counted, weighed, and the average weight per larva per plot was determnied. The average number of larvae surviving for 7 days was about 50% of the original number. The experimental design was a randomized complete block with two replications.

On the basis of the smallest average larval weight from these two tests, 14 strains were chosen for the second screening cycle. For the second screening we also included three entries of Stoneville 7A glandless and two entries of Stoneville 7A glanded in each replication. Seven replications of 19 entries were planted as in method two in a randomized complete block design. The average weight per larva per plot was determined.

RESULTS AND DISCUSSION

The average yields of Stoneville 7A glanded, Stoneville 7A glandless, and 97 glandless strains when grown with and without tarnished plant bugs are given in Table 1. There was no difference in yield between glanded and glandless Stoneville 7A when grown in a protected environment. However, when early season insects were promoted by the growing of mustard in nearby rows, Stoneville 7A glanded produced significantly more lint, 77 kg/ha, than Stoneville 7A glandless. These results (See Table 1) indicate that Stoneville 7A glandless cotton is more sensitive than Stoneville 7A glanded cottons to tarnished plant bug. Tingey et al. (15) reported that glandless cottons are more susceptible to tarnished plant bug. In both environments Stoneville 7A glanded and glandless produced higher yields than the other glandless strains.

The mean squares for the glandless strains (Table 2) indicate a highly significant interaction for glandless strains × methods of controlling or promoting early season insects; our previous research suggests that

Table 2. Average mean squares for lint yield and larval weights for combined analyses of three sets of glandless strains.

Source	df	Yield	df	Larval weight
		kg/ha		mg
Methods	3	397,908**	3	849.27**
Replications	18	223,833**	9	143.10**
Strains within groups	94	114,540**	96	8.93**
Strains × Methods	94	14,838**	96	4.27
Error	564	7,969	288	5.35

** Significant at the 0.01 level of probability by use of the F-test.

Table 3. Mean tobacco budworm larval weights after 7 days feeding on selected glandless cottons.

Genetic type	Larval weight
	mg
Stoneville 7A glanded	3.56
Stoneville 7A glandless	5.65
La-g-75-73	3.91
McNair 4-1206	4.18
La-g-73-1	4.28
La-g-75-81	4.46
Bayou 196	4.66
La-g-75-2	4.71
La-g-71-6	4.72
La 74031	5.07
C6	5.11
Pioneer Locket 22	5.30
C8	5.33
Pioneer × 535-2	5.44
NM 838	5.61
TX GN75	7.32

L.S.D. 0.05 = 1.25 for comparison among glandless strains, 1.08 for comparison of any glandless strain with Stoneville 7A glanded, and 1.02 for comparison of any glandless strain with Stoneville 7A glandless.

tarnished plant bugs are the principal injurious insect (10, 11). Inspection of the strains that showed most resistance indicated that several were nectariless, most were hirsute, and many had a rapid fruiting habit. It is well known, as summarized by Meredith (9), that nectariless glanded cottons reduce plant bug numbers and damage. It is also well known that rapid fruiting cottons, which usually mature very early, frequently do not suffer as much damage as average fruiting strains. Research by Meredith and Schuster (11) indicates that hirsute cottons decrease plant bug damage. The recommendation of Jenkins (2) appears to be valid that several known morphological traits should be used to improve resistance to insects in glandless cotton breeding programs.

The 7-day average weights of larvae on Stoneville 7A glanded, Stoneville 7A glandless, and 99 glandless strains appear in Table 1. It is evident that the presence of gossypol glands significantly reduced larval growth. Mean squares for larval weight among glandless strains are given in Table 2. The analysis indicates significant variability among glandless strains but no strains × method of growing young plants interaction was detected.

A second larval feeding study was conducted using the 14 glandless strains which had supported the smallest larvae. As indicated in Table 3, larvae on four strains weighed significantly less than on Stoneville 7A glandless and were not significantly larger than on Stoneville 7A glanded. Seven of the 14 strains tested and three of the four more resistant strains were obtained from the Louisiana breeding program. Most of

the Louisiana strains descended from a complex parentage involving 'Del Cerro', 'Sampson', and 'Stardel'. Stardel glandless was tested in this study and showed no evidence of resistance to either plant bug or tobacco budworm. This result suggests that the Del Cerro or Sampson breeding stocks, or both, contained the genes for resistance detected in this study. We do not know the genetic background of McNair 4-1206.

No easily observable morphological trait, such as nectarilessness, smoothleaf, redplant, or frego bract was observed in any of the resistant strains. Since in these strains there are no gossypol glands, the usual site of gossypol deposition in cotton, and since there is essentially no gossypol in the seeds, we assume that other biochemical compounds besides gossypol inhibited tobacco budworm larval growth. It should be emphasized that although resistance was detected in glandless strains, none of the resistant glandless strains had antibiotic effects equal to glanded Stoneville 7A. Nevertheless, it is important for breeders to have as many alternate sources of resistance as possible.

Three of the Louisiana strains designated as La-g-75-73, La-g-73-1, and La-g-75-2, were somewhat tolerant to plant bugs. No other selections had both plant bug tolerance and tobacco budworm resistance.

It is not evident whether the resistant glandless strains are isoallelic for resistance. Further research is needed to determine whether greater resistance can be obtained in glandless cottons than has been demonstrated in these studies. Since very little conscious selection for resistance to tobacco budworm has been practiced, our data suggest that greater levels of resistance can be obtained. It is also not known from this study how the newly detected resistance will interact with other sources of resistance and what effect it will have on the nutritive value of cottonseed. This study reinforces that of Shaver et al. (14) who concluded that gossypol confounds the analyses and search for sources of resistance other than gossypol.

The results indicate that resistance to tarnished plant bug and tobacco budworm was present in the glandless population studied. For tarnished plant bug, a major portion of the tolerance detected could be attributable to earliness, nectarilessness, and hirsuteness and, thus, apparently is not a newly detected source of tolerance to tarnished plant bugs. For tobacco budworm, the resistance was less than that conferred by gossypol, but was apparently not due to gossypol or any other type of resistance previously detected.

The results from this study should reinforce breeders who want less gossypol and those who want to at least maintain present levels of gossypol and increase the insect resistance of cotton. These results indicate that glandless cottons do not have to be ultrasensitive to major insect pests.

This study also poses several unanswered questions. These are: (i) what is the biochemical or physical nature of the detected resistance and how does it interact with the insects' nutrition and development (ii) what are the genetics and genetic correlationships with other traits such as yield, fiber properties, and seed characteristics (iii) can this resistance be efficiently used with other sources of resistance?

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