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Tolerance of Glabrous and Pubescent Cottons to Tarnished Plant Bug[1]

W. R. Meredith, Jr. and M. F. Schuster[2]

ABSTRACT

Lint yields of glabrous cottons (*Gossypium hirsutum* L.) are frequently lower than those of pubescent cottons. Since glabrous cottons might be more sensitive to tarnished plant bugs [*Lygus lineolaris* (Palisot de Beauvois)] than are pubescent cottons, we investigated the association between plant bugs and reproductive development of glabrous and pubescent cottons. Greenhouse evaluations were conducted in 1975 and 1977 with two plant bug nymphs per five plants. In the first test, reduction of flower buds by the plant bugs was 74% for four glabrous cottons, but was only 15% for two pubescent cottons. Similarly, in the second test, these reductions were 78 and 33% for five glabrous and two pubescent cottons, respectively.

We also needed to develop a method for detecting tolerance that was not associated with pubescence. Thirty hybrids were produced by crossing the cultivar 'Carolina Queen' and its glabrous (Sm_2Sm_2) isoline to 15 tester parents. Each tester parent and its two hybrids were grown in the field in two insect regimes. In one, plant bug infestations were minimized with early-season use of insecticides, while in the other infestations were encouraged by growing mustard (*Brassica juncea* L. Czern. & Coss.) nearby. Yields were decreased by the plant bug enhancement; yields of glabrous hybrids were reduced by 239 kg/ha while those of pubescent hybrids were reduced by only 163 kg/ha. Tolerance to plant bugs was observed in eight of the parental lines, but only in two of the Sm_2sm_2 hybrids. One of these hybrids, with 'Timok 811' as a parent, was itself hirsute; the other had a high terpenoid nectariless strain, HG-BR-8N, as a parent.

These data demonstrate that glabrous cottons are more sensitive to plant bugs than are pubescent cottons. They also indicate that possibly detection of germplasm tolerance to plant bugs can be facilitated through field evaluations of Sm_2sm_2 hybrids.

Additional index words: Host-plant resistance, *Gossypium hirsutum* L., Screening method.

GLABROUSNESS is a trait desired by breeders since glabrous cottons (*Gossypium hirsutum* L.) possess resistance to at least four insect pests (10) and also produce cleaner lint (1, 9) than do pubescent cottons. Lukefahr (10) reviewed the pest resistance properties of the glabrous trait and concluded that glabrous cottons conferred resistance to bollworm [(*Heliothis zea* (Boddie)], tobacco budworm [*H. virescens* (Fabricius)], pink bollworm [*Pectinophora gossypiella* (Saunders)], and cotton fleahopper [*Pseudatomoscelis seriatus* (Reuter)]. He also reported that glabrous cottons result in an increase in cabbage loopers [*Trichoplusia ni* (Hübner)] and leafhoppers (principally *Empoasca* spp.). Ewing et al. (1) and Lee and Rayburn (9) reported that lint from glabrous cottons generally has a higher grade and less trash than that from pubescent cottons.

The botanical description and genetics of glabrous (smooth leaf) cottons were summarized by Lee (7), who reported that there are three known loci involved in conditioning glabrousness. The alleles Sm_1^{sl} and Sm_2 confer the highest level of smoothness and also reduce pest populations more than the other alleles. Since glabrosity is conditioned by any one of three dominant genes at different loci, one would expect that many of the commonly used cultivars would be glabrous. However, only two cultivars, 'Deltapine 16' and 'Rex Smoothleaf', containing the sm_3 allele, have been used to any extent. Despite thousands of selections, there has been very limited use of the more glabrous alleles, Sm_1^{sl} and Sm_2. Two cultivars, 'Coker 417' and 'Coker 413', each with Sm_1^{sl}, have had limited use by growers.

The reason for the limited use of glabrous cotton is their poor yield and delayed maturity. Jones et al. (4, 5) reported that glabrous isolines were frequently later in maturity and lower in yield than their pubescent isolines. In their opinion, glabrous cottons were more sensitive to tarnished plant bug [*Lygus lineolaris* (Palisot de Beauvois)]. Lukefahr (10) in his review, however, does not mention sensitivity of glabrous cottons to plant bugs. Smith (14) reported that D_2 smooth leaf (Sm_1^{sl}) was deleterious to yield. He observed that glabrous cottons were later in fruiting,

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[2] Research geneticist, USDA, SEA, AR, Cotton Physiology and Genetics Laboratory, Stoneville and professor of Entomology, Entomology Dep., Mississippi State Univ. (Present address: Texas A & M Ext. Ctr., 17560 Coit Rd., Richardson, TX 75080).

Table 1. Number of flower buds on glabrous and pubescent plants infested with tarnished plant bug nymphs and on uninfested plants.

Strain	Level of pubescence†	Glabrous gene	No. of flower buds/plant		Bud reduction
			Infested	Uninfested	
					%
		1975 (1 Mar. to 1 May) greenhouse studies			
Bayou Smooth-1	2	Sm_2	3.3	18.3**	82
Bayou 11860 D_2	2	Sm_1^{sl}	2.8	10.8**	74
Carolina Queen	2	Sm_2	6.5	22.5**	71
Carolina Queen	1	Sm_2Sm_3	4.3	13.3**	68
Carolina Queen	4	–	12.0	15.2	21
Pilose	5	H_2	12.5	13.7	9
		1977 (1 May to 1 July) greenhouse studies			
Bayou 11860 D_2	2	Sm_1^{sl}	10.0	61.5**	84
Coker 310	2	Sm_2	3.0	42.0**	93
Carolina Queen	1	Sm_2Sm_3	24.5	56.5**	57
Carolina Queen	3	Sm_2	5.3	47.3**	89
Stoneville 213	3	sm_3	13.3	38.8**	66
Carolina Queen	4	–	25.0	60.0**	58
Pilose	5	H_2	53.2	58.0	8

** Significantly more flower buds as indicated by an L.S.D. at the 0.01 level of probability.
† Levels of pubescence: 1 = completely glabrous; 4 = normal pubescence.

possessed longer internodes, and had larger leaves; in general they were more vegetative than were normally pubescent cottons.

The above characteristics closely resemble those described by several researchers (2, 13) that were attributable to plant bugs. Hanny et al. (2) demonstrated that plant bug infestations in presquaring cotton could delay maturity and induce vegetative growth. These researchers found no differences in susceptibility between pubescent 'Stoneville 213' and 'Coker 310' and sm_3 glabrous Deltapine 16. Schuster's review (13) indicated that plant bugs can delay crop maturity of pubescent cottons and, under certain severe conditions, can cause decreased yields.

One objective of our studies was to evaluate the influence of plant bug nymphs on the fruiting of several glabrous and pubescent cottons. A second objective was to develop an insect-genetic screening technique to identify genetic sources of tolerance that are unrelated to the degree of pubescence.

MATERIALS AND METHODS

We contrasted glabrous and pubescent cottons with a constant plant bug infestation in two greenhouse studies and with enhanced and with reduced infestations in the field. In our greenhouse studies we used four glabrous and two pubescent strains in 1975 and five glabrous and two pubescent strains in 1977. These strains are listed in Table 1. Seed were planted in 19-liter pots containing a mixture of Leeper Fine Sandy loam, perlite, and peat on 1 Mar. 1975 and 1 May 1977. Plants were thinned to five plants per pot 1 week after emergence. When plants reached the seven-leaf stage, with small flower buds (pin head squares), two third instar plant bug nymphs were placed on the five plants in a pot in half (four) of the pots; the other four pots were not infested. Infested pots were checked each day and new nymphs were placed on plants where none were found. The infestation period was 21 days. Previous unpublished studies suggested that this infestation rate, 40% (two nymphs per five plants), was the threshold level for 'Stoneville 7A'. Squares on the five plants were counted at the end of the infestation period. The experimental design was a split plot design with four replications. Cultivars represented whole plots and levels of nymphs represented subplots; one pot per subplot. 'Carolina Queen' (Sm_2), (Sm_3), and (Sm_2Sm_3) and Coker 310 (Sm_2), BC_4 strains were obtained from Dr. J. A. Lee. Stoneville 213 (sm_3) was developed by the senior author by backcrossing (BC_4) sm_3 into Stoneville 213 from Deltapine 16.

For our field test, planted in 1976, pubescent and glabrous, (Sm_2) Carolina Queen, were crossed to 15 cultivars and strains to produce 30 hybrid combinations. Carolina Queen is a pubescent cultivar that was commonly used in the 1960's in the southeastern U. S. It is very sensitive to plant bugs in the Mississippi Delta. Glabrous Carolina Queen was developed by backcrossing Sm_2 from *G. barbadense* L. into Carolina Queen (8).

Stoneville 213 and Deltapine 16 are commonly used commercial cultivars. The remaining 13 cultivars were chosen because of their broad genetic background and because previous unpublished studies and observations suggested these entries had tolerance to plant bugs. The two hybrids between Carolina Queen pubescent or glabrous and a particular entry would be isogenic to the same degree as were the Carolina Queen isolines. Since Sm_2 generally conditions glabrousness in the heterozygous state, we produced 15 pubescent and 15 glabrous hybrids. The 15 cultivars and strains will be referred to as the 15 tester parents.

We grew the 30 hybrids, their 15 parents and three Carolina Queen isolines under two insect control regimes. In one regime, we assured a high population of insects by applying the method developed by Laster and Meredith (6). Cotton and 'Florida Broadleaf' mustard (*Brassica juncea* (L.) Czern & Coss.) were planted in a 20- × 4-row planting pattern. The middle 12 rows of the 20-row cotton plots were used for this test with four rows on each side used as a border. Mustard was planted 5 April and the cotton was planted 18 May 1976. Insects were attracted to and increased in large numbers on mustard, then migrated from the mustard into the cotton. This regime is designated as the "with" plant bug regime. The "without" regime was achieved by applying dicrotophos (dimethyl phosphate ester with (E)-3-hydroxy-*N,N* dimethylcrononomide), 115 g/ha a.i., five times beginning 5 June and ending 26 July. The "without" plots were located 40 m from the "with" plots. The mustard was cut 5 July.

Five replications of the 48 populations were grown in the "with" and "without" plots. Within the "with" and "without" regimes, the experimental design was a split-plot with 16 whole plots and three subplots. A whole plot consisted of one of the 15 tester parents and the two hybrids made with that parent. In addition to these 15 whole plots, one whole plot consisted of pubescent, glabrous, and pubescent × glabrous Carolina Queen isolines. Individual plot size was one row 1 × 6.9 m. Each plot was sampled twice with a De-Vac[3] sampler beginning on 7 July and ending 26 July. Yield data were obtained by hand picking seedcotton during the last 2 weeks of October. Yield components

[3] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

Table 2. Pertinent mean squares for yield and yield components.

Source	df	Lint yield†	Lint percent	Boll size	Seed index	Lint index	Seed/boll	Bolls/plot
Plant bugs = B	1	24,594**	94.5**	0.08	78.5**	73.4**	1,365.9**	5,568**
Cultivars = C	14	491**	194.5**	5.81**	15.7**	17.1**	25.7**	20,009**
BXC	14	284**	6.0*	0.22	4.3	0.8**	9.8	1,889**
Error a	112	98	3.0	0.35	3.0	0.3	7.8	383
(Parent = P) vs H	1	4,765**	35.8**	26.92**	31.7**	11.4**	23.1**	6,209**
Hybrids = H	1	5,117**	101.7**	4.49**	3.8	7.1**	6.4	23,056**
BX(P vs H)	1	1,303**	3.8*	0.45**	0.1	0.0	5.4	5,585**
BXH	1	1,089**	0.3	0.14	0.1	0.3*	1.6	19,715**
CS (P vs H)	14	510**	38.0**	1.06**	2.7	1.2**	21.0**	2,753**
CXH	14	60*	2.7	0.16	3.4	0.2	6.4	784
BXCX (P vs H)	14	93**	3.8*	0.19	1.7	0.1	4.8	2,361**
BXCXH	14	64**	1.2	0.11	3.8	0.1	2.1	1,235**
Error b	240	31	2.1	0.13	2.3	0.1	7.6	552

*,** Indicates significant F tests at 0.05 and 0.01 probability levels, respectively. † Mean square × 10^{-3}.

were determined on a 35-boll sample taken from each plot immediately before harvest.

The combined analysis of variance (Table 2) was computed using only the 15 whole plots for tester parents and their 30 hybrids. The two degrees of freedom for subplots were orthogonally partitioned into tester parents (P) vs. hybrid means and the variation between glabrous and pubescent hybrids (H). This latter comparison provided a statistical comparison between glabrous and pubescent hybrids and their various interactions.

RESULTS AND DISCUSSION

Plants with two plant bug nymphs per pot had fewer flower buds than those plants that were uninfested (Table 1). However, greater reductions occurred on glabrous than on pubescent cottons. The average reduction in flower bud numbers was 74% for the glabrous but only 15% for the pubescent cottons in 1975. In 1977, reductions were 78 and 33% for the five glabrous and two pubescent cottons, respectively. Although the Carolina Queen entries might be considered near isogenic, the other entries in these tests did not have near-isogenic counterparts. In our view, the data suggest, however, that the glabrous cottons that were tested were more sensitive to plant bugs than the pubescent cottons. These results suggest that at least part of the poor performance of glabrous cottons in the Mississippi Delta is caused by the increased sensitivity of these cottons to plant bugs.

The field study conducted in 1976 reinforces these conclusions. De-Vac sampling of the field plots showed marked differences in insect numbers on the "with" and "without" plots. The average numbers/ha of plant bugs, leafhoppers, and fleahoppers on the "with" plots obtained by De-Vac sampling were 9,553, 6,444, and 9,627 for plant bugs, leafhoppers, and fleahoppers, respectively. The respectively averages on the "without" plots were 2,390, 2,913, and 902. The only genetic differences detected were that glabrous hybrids averaged 5,147 fleahoppers, significantly more than pubescent hybrids and tester parents (averages of 4,111 and 4.480 /ha, respectively). Since other researchers (4, 5, 10) have discussed the influence of leafhoppers and fleahoppers in their environments, we only briefly report these pest numbers in this study. In the Mississippi Delta, entomologists have rarely been able to detect any major damage on pubescent or sm_3 cultivars due to fleahoppers or leafhoppers. However, the direct effect of these two pests on Sm_1^{sl} and Sm_2 cottons has not received major attention. In Louisiana studies, Jones et al. (4, 5) attributed the delay in maturity and decreased yield more to plant bugs than to leafhoppers. Also, Lukefahr (10) has reported that glabrous cotton confer resistance to fleahoppers.

While the use of mustard to encourage plant bugs and other insects has been discussed elsewhere (6), a brief discussion of its usefulness and limitations is given. The limitations of the technique are: (i) Numerous insect species besides plant bugs are forced upon the plots; (ii) by the very nature of the procedure and small plot size, migration of adult insects from mustard to the plots and among plots is great. This results in similar numbers of adult insects on all plots; (iii) we measure primarily one type of tolerance; that is the ability of a genotype to produce lint under high early season insect infestations. Types of antibiosis such as reduced insect reproduction and growth would have little chance to be expressed under this regime.

The chief advantages are: (i) Method is simple and inexpensive; (ii) method results in large numbers of a major Delta pest (plant bugs) being present at a critical plant growth stage; presquaring and earlysquaring. No other recognized major Delta insect pest has been appreciably influenced by this method; (iii) method results in relatively uniform numbers of plant bugs being on all plots; (iv) method results in increased numbers of plant bug nymphs (6), plant damage, delayed maturity, and decreased yield, symptoms and signs often attributed to plant bugs; (v) genetic differences can easily be detected.

Since our collective studies over several years and locations, (6, 11) have consistently been best explained as the result of plant bug activity, we are assuming in this study also that plant bugs are the major cause of the differences detected.

Mean squares given in Table 2 indicate that the "with" and "without" plant bug enhancement treatments (B) had major influences on yield and yield components. Highly significant interactions of plant bugs with cultivars and glabrous vs. pubescent hybrids were detected for yield, lint index, and number of bolls per plot. Performance of Carolina Queen isolines, parents, glabrous, and pubescent hybrids is presented in Table 3. Yields of pubescent, glabrous, and heterozygous Carolina Queen isolines were reduced 267, 341, and 329 kg/ha, respectively, in the "with" plant bug plots when compared to the adjacent protected plots. The average yield reduction of the 15 tester parents was not as great as that of the Carolina

Table 3. Effect of small (OPB) and large (+PB) numbers of tarnished plant bugs on lint yield and yield components of three Carolina Queen isolines and their hybrids.

	Lint yield		Lint		Boll size		Seed index		Lint index		Seed/boll		Bolls/plot	
Isoline genotype	OPB	+PB	OPB	+PB	OPB	+PB	OPB	+PB	OPB	+PB	OPB	+PB	OPB	+PB
	kg/ha		%		g						no.			
Carolina Queen														
sm_2sm_2	511	244	39.2	37.7	4.97	4.97	9.8	11.1	6.3	6.8	30.8	27.9	183	91
Sm_2Sm_2	459	118	36.3	36.7	4.53	4.35	9.5	10.6	5.4	6.2	30.5	25.9	196	52
Sm_2sm_2	582	253	39.4	39.5	4.91	4.78	9.2	10.7	6.0	7.0	32.5	27.0	207	94
L.S.D. 0.05	73		1.8		0.46		1.9		0.5		3.5		29	
Cultivars														
Parents = P	445	316	36.4	37.6	4.45	4.52	9.6	10.4	5.6	6.4	30.0	26.8	192	193
PX sm_2sm_2	573	410	37.8	38.6	5.18	5.07	10.0	10.9	6.1	6.8	32.1	28.7	208	148
PX Sm_2Sm_2	528	289	36.6	37.4	4.90	4.87	10.3	11.1	5.7	6.6	31.4	27.6	206	115
L.S.D. 0.05†	19		0.5		0.12		0.5		0.1		0.9		8	

† L.S.D. given for any two means within a column calculated using error b, Table 2.

Table 4. Lint yield of 15 strains and their pubescent and glabrous isoline hybrids when grown with small (OPB) and large (+PB) numbers of tarnished plant bugs.*

	Parents			Parents × sm_2sm_2			Parents × Sm_2Sm_2		
Parent	OPB	+PB	Loss	OPB	+PB	Loss	OPB	+PB	Loss
	kg/ha								
Timok 811	255	198	57	514	517	−3	439	395	44
HG-BR-8N	350	308	42	602	450	152	444	379	65
Tamcot 37	512	404	108	613	482	131	573	396	177
TX-GN2	358	286	72	564	361	203	480	268	212
Del Cerro 183	469	277	192	469	309	160	471	257	214
Atlas 66	412	247	165	528	339	189	467	239	228
Delcott 277	439	364	75	612	507	105	520	292	228
PD3-249	474	277	197	557	383	174	564	316	248
DES 24	530	367	163	598	437	161	550	273	277
La-g-72-16	429	225	204	578	343	235	538	251	287
Stoneville 213	566	374	192	624	374	250	581	286	295
Auburn 56	524	443	81	599	432	167	549	239	310
Deltapine 16	555	269	286	550	338	212	534	216	318
DES B8-32	537	481	56	570	455	115	570	245	325
B550	268	225	43	613	418	195	641	281	360
Average	445	316	129	573	410	163	528	289	239

* L.S.D. 0.05 for means within a OPB and +PB column = 91 kg/ha; L.S.D. 0.05 for loss means within a column = 129 kg/ha.

Queen isolines. Average yield reductions for tester parents, pubescent, and glabrous hybrids were 129, 163, and 239 kg/ha, respectively. The field study thus reinforces the greenhouse study in that Carolina Queen was more sensitive to plant bugs than the pubescent strains used and, furthermore, that the glabrous cottons were more sensitive than the pubescent cottons to tarnished plant bugs. The reduction in number of bolls harvested per plot is consistent with the results of the greenhouse studies, in which glabrous cottons retained fewer flower buds than the pubescent cottons. The greater sensitivity of glabrous cottons to plant bugs is thus implicated as one of the primary reasons for the poor yield performance of glabrous cottons. These results reinforce the field studies of Jones et al. (4, 5) who concluded that plant bugs can, on glabrous cottons and without any increase in numbers, delay maturity and decrease yields under some conditions.

The second objective we pursued was to develop a procedure to identify sources of tolerance not related to level of pubescence. We chose a cultivar, Carolina Queen, sensitive to plant bugs. The dominant gene action of Sm_2 indicates that the F_1 hybrid produced from glabrous cottons should also be glabrous. If the F_1 hybrids with Carolina Queen Sm_2 exhibit tolerance, the breeder can reasonably assume that tolerance is transmitted from the non-Carolina Queen parent and that tolerance is due to some factor other than pubescence.

Average yields of 15 parents and their pubescent and glabrous hybrids when grown with and without plant bugs are given in Table 4. A first approach in selecting parents for a breeding program usually is to evaluate the parents. From previous studies and observations many of the 15 parents were suspected of having tolerance to plant bugs. All but one of the 15 parents, Deltapine 16, had lower yield decreases than pubescent Carolina Queen. The yield decrease of sm_3 Deltapine pine 16 was 286 kg/ha (Table 4) while that of pubescent Carolina Queen was 267 kg/ha (Table 3). Eight of the parents' decrease in yield was 129 kg/ha or less. Thus, one would consider these entries as prime candidates for breeding material. Each of the 15 hybrids from crosses with pubescent Carolina Queen had less yield loss and four had significantly less loss than Carolina Queen. Thus, yield performance of the parents and pubescent F_1 hybrids suggest the presence of ample genetic material to initiate a breeding program for tolerance to tarnished plant bugs.

However, the performance of the glabrous hybrids reveals an entirely different situation. Only two Sm_2-hybrids, Timok 811 and HG-BR-8N, showed significantly less yield loss than Carolina Queen. In fact, several of the glabrous hybrids whose parents, such as DES B8-32 and B550, appeared to have good tolerance were very sensitive to plant bugs. Inspection of the Timok 811 "glabrous" hybrid showed that it was in fact hirsute. Timok 811 had previously shown superior field tolerance to tarnished plant bugs (3). As Lee (7) pointed out, the dominance gene action of glabrous alleles is not complete in all germplasm. Ramey (12) reported that the H_1 allele for increased pubescence was epistatic to Sm_1^{sl} and suppressed the expression Sm_1^{sl}. Timok 811 is hirsute and may harbor the H_1 or H_2 alleles for increased pubescence. HG-BR-8N is a high gossypol, nectariless strain. While nectariless cottons suppress populations of tarnished plant bugs (11), the effect of heterozygous nectariless cottons is not known. Lukefahr (10) reported that high gossypol in plant tissues suppresses number of plant bugs.

Therefore, none of the glabrous hybrids that we studied showed tolerance to plant bugs that was not confounded with another known resistance factor. In spite of this result, the screening technique as outlined below should identify sources of tolerance independent of the level of pubescence, if such sources exist.

The results from this study suggest a method for screening pubescent germplasm for resistance to plant bugs: (i) screen, by either greenhouse or field evaluation techniques, for tolerance among pubescent germplasm and identify tolerant germplasm; (ii) Cross tolerant strains to a glabrous cultivar that has ultrasensitivity to tarnished plant bugs; (iii) Evaluate, by use of greenhouse or field techniques, the F_1 hybrids for tolerance to plant bugs and inspect hybrids to ensure that all hybrids are glabrous; (iv) initiate a breeding program using newly identified sources and previously identified tolerant or resistant traits.

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