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# Effects of Okra-Leaf, Frego-Bract, and Smooth-Leaf Mutants on Pink Bollworm Damage and Agronomic Properties of Cotton[1]

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## ABSTRACT

**Eight isolines of cotton, *Gossypium hirsutum* L., which carried all possible combinations of Okra leaf ($L^o{}_2$), frego bract (*fg*), and Smooth leaf ($Sm_2$) vs. their normal-leaf and normal-bract equivalents in the La 71-7 (a Stoneville) background, were grown in replicated experiments for 3 years in Arizona in insecticide-free environments. Percentage of seed damage caused by pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), and 11 agronomic properties were studied.**

**Mean seed damage in the Okra-leaf isolines was 82% of that in the corresponding normal-leaf lines, a significant reduction. The Okra-leaf isolines were comparable to the normal-leaf types in agronomic properties. Their only negative effect was an 8% lower lint yield (which was significant). Okra leaf interacted with frego bract only for boll size and with Smooth leaf only for seed index. Okra leaf interacted with years for seed damage because the Okra-leaf isolines had 76% as much damage as the normal-leaf stocks in 1979, but 85% as much in 1978 and 88% as much in 1980. Seed damage in the frego-bract isolines was not significantly different from that in its normal-bract counterparts. Frego bract interacted significantly with Smooth leaf for lint percent and with years for seed damage, total lint yield, bolls/plant, boll size, lint percent, and plant height. When closely examined, the interaction for seed damage suggested that frego bract afforded a slight advantage during the years when seed damage was relatively high. However, deficiencies in numerous agronomic properties (including a 24% lint yield reduction) and the five year × agronomic property interactions offset any advantages in reduced seed damage afforded by frego bracts. Smooth-leaf isolines unexpectedly displayed more seed damage than the hirsute-leaf lines. Smooth-leaf isolines were also inferior to the hirsute-leaf types in all agronomic properties except seed index and displayed significant interactions between years and percent lint yield at second and third harvest, total lint yield, bolls/plant, and date of first flower. For PBW resistance and agronomic performance, Okra leaf appears to have value, frego bract does not, and Smooth leaf must be reevaluated.**

***Additional index words:* Host-plant resistance, *Gossypium hirsutum* L., *Pectinophora gossypiella* (Saunders), Okra-leaf cotton, Frego-bract cotton, Smooth-leaf cotton, Isolines.**

Low levels of resistance to pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), have been shown by breeding stocks and cultivars of upland cotton, *Gossypium hirsutum* L., carrying certain mutant characters, among them being Okra leaf, $L^o{}_2$, and Smooth leaf (glabrous), $Sm_2$ (6). Nectariless and Smooth leaf apparently exerted their effects independently in a cotton combining those characters because it displayed significantly lower seed damage than cottons carrying those characters singly (5).

It is important to determine whether a resistance character exerts its effect independently of other characters and whether it interacts with environment because in breeding, independence from other characters (or interaction in a favorable direction), and consistency in response over environments are attributes of a more easily manipulated character.

The recent development of isolines carrying Okra leaf, frego bract (*fg*), and Smooth leaf vs. their normal equivalents in all eight possible combinations (2) allowed us to test the main effects and interactions of those characters with each other in several environments. Frego bract is apparently neutral in its effects on PBW (6), although it has been implicated in resistance to boll weevil, *Anthonomus grandis* Boheman (1, a paper that also includes several earlier references).

The objectives of the study reported in this paper were to determine if the three characters exerted their effects relative to the PBW and agronomic traits in the same manner as in previous tests, if the characters interacted with each other, and if they performed consistently over environments.

## MATERIALS AND METHODS

Eight isogenic strains of cotton in a La 71-7 (a Stoneville) background (2) plus a check cultivar, 'Stoneville 256', were studied over 3 years. The test cottons included all eight possible combinations among the Okra-leaf, frego-bract, and Smooth-leaf mutants vs. their normal equivalents.

Plots were four rows wide; rows were 9.1 m long and spaced 1.0 m apart. Seed were planted with a four-row mechanical planter 25 Apr. 1978 (at the Univ. of Arizona Cotton Res. Center, Phoenix), 19 Apr. 1979, and 18 Apr. 1980 (at the Arizona State Univ. Farm Lab., Tempe). Soil type at the Cotton Res. Center is Avondale clay loam, a member of the fine, loamy, mixed, hyperthermic Torrifluventic Haplostolls. Soil type at the Arizona State Univ. Farm Lab. is Contine clay loam, a member of the fine, mixed, hyperthermic Typic Haplargids. After emergence, seedlings were thinned 30 cm apart within the row. Conventional cultural practices for the area were followed *except* that plots were not sprayed for insect control. The experimental design was a randomized, complete block with four replications.

In 1978 and 1979, date of first flower was obtained for 20 consecutive plants/row; and plant height was measured for 10 consecutive plants/row. Seedcotton was harvested from the same 10 plants/row every 2 weeks for a total of five harvests in 1978 and for four harvests in 1979 and 1980. Seedcotton, seed, and lint sample weights were measured. Agronomic data obtained were number of bolls harvested/plant, total lint yield, (converted into kg/ha), percent lint yield at the first three harvest dates, lint percent (percentage of seedcotton that was lint), boll size (g seedcotton/boll), seed index or size (100-seed wt), and no. of seed/boll. A sample of 200-400 seed was drawn from each plot at each harvest date and x-rayed to provide estimates of percent seed damage (4).

For the analyses of seed damage and agronomic data combined over years, years (Y), replications (R), and isolines (I) were all considered as fixed effects. What has been designated, for convenience, as Y effects are in reality confounded effects between years and locations because this experiment was con-

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**Table 1. Analyses of variance for seed damage by pink bollworm and for nine agronomic properties of cotton isolines.**

| | | Mean squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lint yield | | | | | | | | |
| Source | df | Seed damage | First harvest | Second harvest | Third harvest | Total | Bolls/ plant | Boll size | Lint percent | Seed index | Seed/ boll |
| Years (Y) | 2 | 3,973** | 481** | 5,685** | 6,549** | 17,371* | 4,189 | 5.93** | 42.4** | 10.24** | 56.9** |
| Replications/Y | 9 | 59** | 118** | 277** | 99** | 3,410 | 3,993 | 0.24 | 1.3 | 0.25 | 6.6 |
| Isolines (I) | 7 | 138** | 287** | 287** | 94** | 67,554** | 16,475** | 1.46** | 16.8** | 2.15** | 46.3** |
| Okra leaf (L) | 1 | 523** | 215** | 69 | 69 | 15,811* | 1,536 | 0.01 | 0.1 | 0.18 | 1.9 |
| Frego bract (F) | 1 | 62 | 3 | 12 | 2 | 184,802** | 31,974** | 5.15** | 11.4** | 1.57* | 166.6** |
| Smooth leaf (S) | 1 | 317** | 1,711** | 1,755** | 508** | 250,922** | 60,702** | 3.89** | 93.1** | 11.41** | 106.5** |
| L × F | 1 | 41 | 1 | 13 | 3 | 1,820 | 1,980 | 0.62* | 4.2 | 0.01 | 0.1 |
| L × S | 1 | 21 | 1 | 9 | 5 | 176 | 1,247 | 0.04 | 0.1 | 1.54* | 9.6 |
| F × S | 1 | 4 | 79 | 48 | 6 | 11,572 | 10,292 | 0.49 | 8.4* | 0.34 | 25.0 |
| L × F × S | 1 | 1 | 1 | 106 | 63 | 7,776 | 7,597 | 0.01 | 0.3 | 0.01 | 14.4 |
| Y × I | 14 | 46* | 15 | 176** | 106** | 7,574* | 6,992** | 0.25 | 2.7* | 0.25 | 5.8 |
| Y × L | 2 | 104** | 2 | 61 | 2 | 9,895 | 7,336 | 0.23 | 1.4 | 0.28 | 3.7 |
| Y × F | 2 | 117** | 5 | 116 | 12 | 16,253* | 10,381* | 0.51* | 10.4** | 0.40 | 8.3 |
| Y × S | 2 | 8 | 2 | 786** | 633** | 18,036* | 20,677** | 0.35 | 4.2 | 0.18 | 22.4 |
| Y × L × F | 2 | 6 | 10 | 24 | 1 | 3,902 | 3,954 | 0.21 | 1.4 | 0.15 | 6.4 |
| Y × L × S | 2 | 50 | 13 | 46 | 59 | 2,018 | 1,978 | 0.17 | 0.2 | 0.30 | 8.2 |
| Y × F × S | 2 | 35 | 30 | 89 | 11 | 1,150 | 3,392 | 0.17 | 0.9 | 0.12 | 12.7 |
| Y × L × F × S | 2 | 1 | 45 | 112 | 27 | 1,763 | 1,224 | 0.08 | 0.5 | 0.32 | 19.8 |
| Residual | 63 | 20 | 29 | 57 | 28 | 3,754 | 2,590 | 0.14 | 1.4 | 0.35 | 9.1 |

*,** Differences significant at the 0.05 and 0.01 levels of probability, respectively.

ducted at a different location in 1978 than it was in 1979 and 1980.

## RESULTS

Differences among years were significant for seed damage and for all agronomic properties except bolls/plant (Tables 1 and 2). Years interacted significantly with Okra leaf and frego bract for seed damage, with frego bract for total lint yield, bolls/plant, boll size, lint percent, and plant height; and with Smooth leaf for percent second and third harvest of lint yield, total lint yield, bolls/plant, and first flower date.

Mean seed damage by PBW was reduced significantly in the four Okra-leaf isolines when compared to the four normal-leaf lines (Table 3). These isolines displayed a significantly higher percentage of total lint yield at the first harvest but not at subsequent harvests. They also yielded significantly less total lint ($-8\%$) at the end of the season. The normal and Okra-leaf isolines did not differ significantly in the other agronomic properties measured. Okra leaf did interact significantly with frego bract for boll size and with Smooth leaf for seed index (Table 1).

The means of the four frego-bract isolines did not differ significantly from those of the four with normal bracts in seed damage or in three of the agronomic properties measured (Table 3). The frego-bract isolines, however, yielded less total lint and had fewer bolls/plant, smaller bolls, lower lint percent, smaller seed, fewer seed/boll, taller plants, and were later flowering than their normal-bract counterparts. Frego bract interacted significantly with Smooth leaf for lint percent (Table 1).

The four Smooth leaf isolines had more seed damage, were later in maturity at every harvest, yielded less total lint, had fewer bolls/plant, smaller bolls, a lower lint percent, larger seed, fewer seed/boll, taller plants, and were later in flowering than the four hirsute-leaf isolines (Table 3).

The NNH (normal leaf, normal bract, hirsute leaf) isoline, when compared to the check cultivar, Stoneville 256,

**Table 2. Analyses of variance for plant height and first flower date of cotton isolines.**

| | | Mean squares | |
|---|---|---|---|
| Source | df | Plant height | First flower |
| Years (Y) | 1 | 2,743.14** | 20.25** |
| Replications/Y | 6 | 91.54 | 5.42 |
| Isolines (I) | 7 | 1,734.16** | 28.07** |
| Okra leaf (L) | 1 | 112.89 | 3.06 |
| Frego bract (F) | 1 | 3,495.77** | 64.00** |
| Smooth leaf (S) | 1 | 8,167.64** | 115.56** |
| L × F | 1 | 135.14 | 7.56 |
| L × S | 1 | 54.39 | 1.00 |
| F × S | 1 | 129.39 | 3.06 |
| L × F × S | 1 | 43.89 | 2.25 |
| Y × I | 7 | 111.21 | 2.54 |
| Y × L | 1 | 0.39 | 0.07 |
| Y × F | 1 | 293.26* | 0.25 |
| Y × S | 1 | 0.76 | 14.07* |
| Y × L × F | 1 | 1.27 | 0.56 |
| Y × L × S | 1 | 19.15 | 0.99 |
| Y × F × S | 1 | 178.90 | 1.56 |
| Y × L × F × S | 1 | 284.75* | 0.25 |
| Residual | 42 | 67.93 | 2.45 |

*,** Differences significant at the 0.05 and 0.01 levels of probability, respectively.

had less seed damage, was earlier in maturity at every harvest, yielded less total lint, had fewer bolls/plant, lower lint percent, larger seed, more seed/boll, and an earlier date of first flower. The NNH isoline did not differ significantly from Stoneville 256 in boll size or in plant height (Table 3).

## DISCUSSION

The significantly lower seed damage in the Okra-leaf isolines (82% as much as in normal leaf when averaged over 3 years) agrees with our previous data [60 to 88% (3)]. Consequently, these results support our earlier conclusion as to the value of Okra leaf as a PBW-resistant character. The higher percentage of total lint obtained at first harvest emphasizes the earliness of the Okra-leaf stocks. On the other hand, the absence of a difference in the percentages of lint yield obtained at subsequent har-

**Table 3. Mean seed damage by pink bollworm and mean agronomic properties of cotton isolines and the check cultivar, 'Stoneville 256', over 3 years.**

| Phenotype | Seed damage | Lint yield: First harvest | Second harvest | Third harvest | Total | Bolls/ plant | Boll size | Lint percent | Seed index | Seed/ boll | Plant height | First flower |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | cumulative % | | | kg/ha | no. | g | % | g | no. | cm | date |
| Normal leaf | 26.7 | 16.8 | 68.1 | 87.7 | 748 | 27.6 | 4.18 | 35.6 | 10.53 | 23.2 | 110 | 184.8 |
| Okra leaf | 22.0** | 19.8** | 66.4 | 86.0 | 690* | 26.8 | 4.18 | 35.6 | 10.44 | 22.9 | 107 | 185.2 |
| Normal bract | 25.1 | 18.2 | 67.6 | 86.7 | 818 | 29.0 | 4.41 | 35.9 | 10.61 | 24.3 | 102 | 184.0 |
| Frego bract | 23.5 | 18.5 | 66.9 | 86.9 | 620** | 25.4** | 3.95** | 35.2** | 10.36* | 21.7** | 116** | 186.0** |
| Hirsute leaf | 22.5 | 22.6 | 71.6 | 89.1 | 834 | 29.7 | 4.38 | 36.6 | 10.14 | 24.1 | 98 | 183.7 |
| Smooth leaf | 26.1** | 14.1** | 63.0** | 84.5** | 604** | 24.7** | 3.98** | 34.6** | 10.83** | 22.0** | 120** | 186.3** |
| Stoneville 256 | 30.7 | 13.5 | 63.5 | 85.8 | 1066 | 38.4 | 4.16 | 37.4 | 10.13 | 23.3 | 88 | 186.3 |
| NNH isoline | 24.7** | 21.6** | 74.6** | 91.3** | 950** | 31.7** | 4.43 | 36.5** | 10.38* | 25.1* | 90 | 182.3** |

*,** The mean of the four isolines with the specified mutant character was significantly different from that of those carrying its normal counterpart [or the NNH (normal leaf, normal bract, hirsute leaf) isoline mean was significantly different from Stoneville 256] at the 0.05 and 0.01 levels of probability, respectively.

vests in the Okra-leaf and normal-leaf isolines suggests that resistance cannot be attributed solely to early maturity. Although the differences were significant, total lint yield of the Okra-leaf isolines was 92% of the corresponding normal-leafed cottons. The similarity of the Okra-leaf and normal-leaf isolines for the other agronomic characters measured increases our confidence in the value of this mutant character.

The general lack of interaction of Okra leaf with the other mutants, and with seasonal effects, emphasizes its independent and consistent action. The significant Okra leaf × frego bract interaction for boll size is considered unimportant from the standpoint of breeding for PBW resistance because we intend to discard the frego-bract character (see below). The significant Okra leaf × Smooth leaf interaction for seed index was probably unimportant in a practical sense because seed size differed relatively little among the array of isolines. The significant year × Okra leaf interaction for seed damage was attributed to a greater reduction in seed damage in the Okra-leaf stocks in 1979 (76% as much as in normal leaf) than in 1978 (85%) or in 1980 (88%).

The lack of a significant overall mean effect for frego bract on seed damage agrees with our earlier observations (6). The significant year × frego bract interaction, however, requires a close examination of the response of this character. In 1978, when average seed damage was lower than in 1979 or 1980, seed damage was slightly higher in the frego-bract isolines than in the normal-bract stocks. In 1979 and 1980, seed damage was lower (significant at the 0.10 level of probability) in the frego-bract lines. On the other hand, the reduced lint yield (by 24%), fewer bolls/plant, small bolls, lower lint percent, smaller seed, fewer seed/boll, taller plants, and delayed date of first flower would undoubtedly offset the advantage of the slight decrease in seed damage. The significant year × frego bract interactions for total lint yield, bolls/plant, boll size, lint percent, and plant height, as well as for seed damage, also demonstrate the inconsistent performance of the frego-bract isolines. Consequently, we do not intend to use frego bract in our future breeding efforts for resistance to PBW.

The increased seed damage in the La 71-7 Smooth-leaf isolines was not expected because, in previous tests, similar breeding stocks displayed reduced seed damage (6). For example, W74-4-153, a Stoneville Smooth-leaf stock, showed 20% less seed damage than 'Stoneville 7A' (5). The higher seed damage in the La 71-7 Smooth-leaf isolines could possibly be attributed to later maturity, but W74-4-153 was also later than Stoneville 7A (20, 59, and 89% of total seedcotton yield at first, second, and third harvest, respectively, in W74-4-153 compared to 35, 73, and 92% in Stoneville 7A). The relatively later maturity, in turn, could have been caused by differential loss in fruiting forms to early-season insects, notably lygus, *Lygus hesperus* Knight. Unfortunately, we did not collect lygus data for the La 71-7 stocks. In the earlier test (5), however, W74-4-153 had significantly fewer lygus/100 sweeps than Stoneville 7A (7.0 vs. 23.3; L.S.D. $(_{0.05})$ = 4.4). The greater seed damage in the La 71-7 Smooth-leaf isolines, together with their markedly inferior agronomic properties (including a 28% lint yield reduction), except for seed index, and year × Smooth leaf interactions for total lint yield and other traits have caused us to reevaluate Smooth leaf as a PBW-resistant character. We have begun to test Smooth leaf in a number of genetic backgrounds to more adequately define its ultimate usefulness, if any, in PBW control.

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## REFERENCES

1. Jenkins, J. N., and W. L. Parrott. 1971. Effectiveness of frego bract as a boll weevil resistance character in cotton. Crop Sci. 11:739–743.
2. Jones, J. E., B. R. Williams, J. W. Brand, D. F. Clower, and D. T. Bowman. 1978. Interacting effects of the okra leaf, frego bract and glabrous traits on pest resistance and agronomic characters. p. 84–85. *In* J. M. Brown (ed.) Proc. Beltwide Cotton Prod. Res. Conf., Natl. Cotton Coun., Memphis, Tenn. (Abstr.)
3. Wilson, F. D., and B. W. George. 1981. Breeding cotton for resistance to pink bollworm. p. 63–65. *In* J. M. Brown (ed.) Proc. Belt-

wide Cotton Prod. Res. Conf., Natl. Cotton Coun., Memphis, Tenn.

4. Wilson, R. L., and F. D. Wilson. 1975. Comparison of an x-ray and a green-boll technique for screening cotton for resistance to pink bollworm. J. Econ. Entomol. 68:636-638.

5. ----, and ----. 1976. Nectariless and glabrous cottons: Effect on pink bollworm in Arizona. J. Econ. Entomol. 69:623-24.

6. ----, ----, and B. W. George. 1979. Mutants of *Gossypium hirsutum*: Effect on pink bollworm in Arizona. J. Econ. Entomol. 72:216-219.