Published November, 1986

Pink Bollworm Resistance, Lint Yield, and Lint Yield Components of Okra-Leaf Cotton in Different Genetic Backgrounds[1]

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ABSTRACT

The two leaf (L) types, Okra leaf [$2(L^0_2)$] and normal leaf, from seven genetic backgrounds (G) of cotton, *Gossypium hirsutum* L., were subjected over two seasons (Y) to natural populations of pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), at Tempe, AZ. In other experiments, one of the seven Okra-leaf strains and an Okra-leaf cultivar, 'Gumbo 500', were compared with 'Stoneville 213', a normal-leaf cultivar, for one to three seasons. Objectives of this study were to determine whether (i) L interacted with G or Y for seed damage caused by PBW, for lint yield, or for earliness; and (ii) yield of Okra-leaf strains could be increased by selecting for improved yield components. An important goal is to determine whether PBW-resistant, Okra-leaf cottons will yield as much lint as normal-leaf cottons in stressful environments. In the leaf shape–genetic background experiments, significant L × G and Y × G interactions were detected for seed damage by PBW, but not for lint yield or earliness. Mean yield per plant and percent seed damage for the seven normal-leaf cultivars were significantly higher than those of the Okra-leaf strains, 36.0 vs. 30.7 g/plant, and 17 vs 14%, respectively. Okra-leaf strains were not significantly earlier than normal-leaf cultivars. Examination of lint yield components suggested that selection for lint per seed, a highly heritable trait, should increase lint yields of some Okra-leaf cottons. However, bolls per plant, expected to have low heritability, was the main yield component that limited lint yield of most of those cottons. The Okra-leaf strains and cultivar, when compared to Stoneville 213, generally had less seed damage and yielded less lint. An exception was in 1985, when Gumbo 500 did not yield significantly less lint than Stoneville 213. In a preliminary experiment in 1985, two Okra-leaf advanced breeding stocks outyielded the normal-leaf counterparts by 23 and 18%, respectively.

Results thus show that Okra-leaf breeding stocks in certain genetic backgrounds have a modest level of resistance to PBW and also may yield as much or more lint than do normal-leaf cultivars. However, the inconsistent response of some Okra-leaf cottons emphasizes the importance of comparing those cottons with normal-leaf cultivars over a range of environments.

***Additional index words:* Gossypium hirsutum L., Host-plant resistance, Leaf shape, Genotype × environment interaction.**

CULTIVARS of cotton, *Gossypium hirsutum* L., carrying Okra leaf [$2(L^0_2)$] have shown resistance to the boll-rot disease complex, to boll weevil, *Anthonomus grandis* Boh., and to bandedwinged whitefly, *Trialeurodes abutilonea* Haldeman (4). The resistance to boll rot and boll weevil has been attributed to the warmer, drier microclimate under the canopy of Okra-leaf isolines than of normal-leaf cultivars. Canopies of Okra-leaf cotton were easier to penetrate with spray than were those of normal-leaf cotton (3).

Wilson and George (15) reported that mean damage over three seasons caused by pink bollworm, *Pectinophora gossypiella* (Saunders), was 82% as high in Okra-leaf isolines as in normal leaf isolines in La 71-7 background, a significant reduction and a value that agreed with earlier data (14). Wilson and George (15) also showed that Okra leaf acted independently and consistently over environments for the amount of seed damage and for several agronomic properties. The Okra-leaf isolines were significantly earlier than the normal-leaf isolines, as measured by the percentage of total lint harvested at the first of four harvests (19.8 vs. 16.8%, respectively), but yielded significantly less total lint (690 vs. 748 kg ha^{-1}, respectively, an 8% decrease).

Subsequently, we have evaluated a number of Okra-leaf and normal-leaf cottons for seed damage and agronomic and fiber properties, including strains in seven different cultivar backgrounds. Objectives of this study were to determine whether (i) leaf shape (L) interacted with genetic background (G) or with seasons (Y) for seed damage, lint yield, or earliness; and (ii) yield of Okra-leaf strains could be increased by selecting for improved yield components. An important goal of our ongoing investigation is to ascertain whether PBW-resistant, Okra-leaf cottons will yield consistently as much lint as normal-leaf cottons in stressful environments, such as encountered in the irrigated deserts of the western USA.

MATERIALS AND METHODS

Six of the seven Okra-leaf isolines grown in the leaf shape–genetic background experiments and listed in Table 1 were developed by R.L. Shepherd, USDA-ARS, Mississippi State, MS (12). Unfortunately, Stoneville 213 Okra leaf also carried frego bract and was discarded, but 'Stoneville 213' was retained because it was used as the check cultivar in the experiments reported in this paper. Stoneville 7A Okra leaf (La Okra-2) was developed by J.E. Jones, Louisiana Agric. Exp. Stn. 'Stoneville 7A' and Stoneville 213 were obtained from C.W. Manning, Stoneville Pedigreed Seed Co., Stoneville, MS. The regional short-season test, carried out under the auspices of Southern Regional Project S-155, has included Stoneville 213 as a full season check cultivar, and sometimes Okra-leaf cultivars or breeding stocks. 'Gumbo 500' was developed by J.E. Jones (5). The MD-28 normal leaf and MD-28 Okra leaf isolines were developed by W.R. Meredith, Jr., USDA-ARS, Stoneville, MS.

The leaf shape–genetic background experiments were grown in 1982 and 1983 at the Arizona State University Farm Laboratory, Tempe (ASU). Soil type was Contine clay loam, a member of the fine, mixed, hyperthermic Typic Haplargids. The regional, short-season experiments were grown in 1980 and 1983 at ASU and in 1984 and 1985 at the University of Arizona Maricopa Agricultural Center, Maricopa (MAC). Soil type at MAC was Denure sandy clay loam, a member of the coarse-loamy, mixed hyperthermic Typic Camborthids. Plot size at ASU was 4 rows × 9.1 m; rows were spaced 1 m apart. Plot size at MAC was 4 rows × 18 m; rows were also spaced 1 m apart. Experimental design was a randomized complete block with four replications at both locations. Cultural practices were standard except that no insecticides were applied. At both locations, plants in one inside row per plot were hand-thinned to a uniform spacing of 30 cm apart. Seedcotton was harvested every 2 weeks from 10 plants of the thinned row, beginning in mid-August, when bolls started to open, until early November, when all bolls had opened.

[1] Contribution from USDA-ARS, Phoenix, AZ 85040 in cooperation with the Arizona Agric. Exp. Stn. Received 27 Dec. 1985.
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Seedcotton from the composite, 10-plant samples was weighed and ginned and lint and seed samples were weighed. Lint yield per plant was based on the 10-plant samples. Earliness was estimated by calculating the cumulative percentage of total lint yield at the third harvest. Volumetric seed samples (35 mL) were drawn and X-rayed, and the number of undamaged seeds and those damaged by pink bollworm were counted on the ensuing radiographs (16). Data were analyzed by ANOVA methods. Means were compared with the use of the FLSD test (1).

RESULTS AND DISCUSSION

In the leaf shape–genetic background experiments, mean percent seed damage and mean lint yield were significantly higher in 1983 than in 1982, for normal-leaf cultivars than for Okra-leaf strains, and for some genetic backgrounds than for others (Table 1). No significant differences were shown for the cumulative percentages of total lint yields at third harvest (earliness).

Table 1. Seed damage caused by pink bollworm and lint yield of normal-leaf cultivars and Okra-leaf strains of cotton, Tempe, AZ, 1982 and 1983.

	Seed damage		Yield: Lint per plant		Earliness: Cum. yield, third harvest	
Cultivar	Normal	Okra	Normal	Okra	Normal	Okra
	%		g		%	
Delcot 277	22.8a‡	17.1b-d	34.7b-d	30.3c-e	84.3	85.5
Auburn 56	22.0ab	13.7e	34.2b-d	31.3c-e	76.6	82.8
Coker 310	19.8a-c	16.3c-e	36.4a-c	33.7b-d	77.5	85.8
Stoneville 7A	17.0cd	8.4f	42.8a	32.0b-e	77.3	82.8
Stoneville 213(ck)	15.8c-e	--	37.7a-c	--	79.5	--
Coker 201	14.8de	11.5ef	38.9ab	29.2de	88.9	85.8
Deltapine 16	13.9e	15.1c-e	35.3b-d	31.9b-e	80.0	80.9
TH-149	11.9ef	11.7ef	29.3c-e	26.4e	90.2	85.4
Means§						
1982	12.1	9.4	29.0**	24.3	80.2	83.7
1983	22.8*	17.4	42.9**	37.1	84.0	84.6
2-yr	17.4**	13.4	36.0**	30.7	82.1	84.1

Analysis of variance

Source	df	Mean squares		
Years (Y)	1	2445.4**	5000.6**	155.1
Replications wn Y	6	45.2	137.2*	141.2
Leaf shape (L)	1	455.8**	776.8**	114.8
Gen. background (G)	6	159.8**	136.5*	195.8
L × G	6	56.4†	48.2	96.8
Y × L	1	51.2	118.2	61.8
Y × G	6	103.8**	41.7	196.6
Y × L × G	6	49.4	18.0	197.0
Error	78	26.7	51.6	157.7

*,**,† Difference between normal-leaf cultivar and Okra-leaf strain is significant, according to the FLSD test, or specified variance is significantly higher than the error variance, at the 0.05, 0.01, and 0.10 levels of probability, respectively.
‡ Means with letters in common are not significantly different at the 0.05 level of probability, according to the FLSD test.
§ Means exclude Stoneville 213, the check cultivar.

The significant L × G interaction effect for seed damage showed that the normal-leaf cultivars did not sustain more seed damage consistently than the Okra-leaf strains; in fact, only three of the seven had significantly more damage. The significant Y × G interaction effect for seed damage was caused by a difference in rankings among the cottons for the 2 yr. The Y × G interaction was not significant for lint yield or earliness. Meredith (10), on the other hand, reported a significant years × genetic background interaction effect for lint yield.

In the regional short-season experiments, Gumbo 500 and Stoneville 7A Okra-leaf had significantly less seed damage and yielded significantly less lint than Stoneville 213 in 1980 (Table 2). Stoneville 7A Okra leaf was significantly earlier than the other two cottons in 1980. In 1983 but not in 1985, Gumbo 500 also had less seed damage and yielded less lint. In the 1984 experiment, the MD-28 Okra-leaf isoline had significantly less seed damage than MD-28 normal leaf (13 vs. 21%; LSD (0.05 = 3.4) and yielded significantly less lint in machine-picked plots (18.3 m^2; 1012 vs. 1144 kg ha^{-1}; LSD (0.10) = 122). This result does not agree with that of Wells and Meredith (13), who reported that MD-28 Okra leaf yielded 26% more lint than MD-28 normal leaf in Mississippi.

For five of the seven Okra-leaf strains and normal-leaf cultivars, bolls per plant was the major lint yield component that contributed to a lower yield of the Okra-leaf strains (Table 3). For 'Deltapine 16', all three components were about equal in their effects on yield. For 'Auburn 56', the Okra-leaf strain had 8% more

Table 3. Lint yield and lint yield components of Okra-leaf strains or cultivars as percentages of the corresponding normal-leaf cultivars or of Stoneville 213 normal leaf.

Cultivar or strain	Year(s)	(Okra leaf/normal leaf) × 100: Lint yield per plant	Bolls per plant	Seeds per boll	Lint per seed
		%			
Delcot 277	1982, 1983	87.3	81.4	114.4	91.4
Auburn 56	1982, 1983	91.5	108.8	95.8	89.8
Coker 310	1982, 1983	92.7	93.2	97.4	100.0
Stoneville 7A	1982, 1983	74.8	84.1	100.0	90.0
Coker 201	1982, 1983	74.9	77.5	99.3	96.5
Deltapine 16	1982, 1983	90.3	95.1	93.4	97.5
TH-149	1982, 1983	89.8	89.4	106.1	92.0
Gumbo 500 Okra†	1980	77.5	83.4	94.7	94.6
Gumbo 500 Okra†	1983	74.4	78.0	101.2	99.5
Gumbo 500 Okra†	1985	90.9	87.4	107.0	98.5
Stoneville 7A Okra†	1980	79.7	87.8	94.7	87.2

† Stoneville 213 = 100% lint yield and lint yield components.

Table 2. Seed damage caused by pink bollworm and lint yield of normal-leaf and Okra-leaf cultivars and strains of cotton, Tempe, AZ, 1980 and 1983, and Maricopa, AZ, 1985.

Cultivar or strain	Leaf shape	Seed damage 1980	1983	1985	Lint yield per plant 1980	1983	1985	Earliness (cum. yield/3rd har.) 1980	1983	1985
		%			g			%		
Stoneville 213	Normal	24.6a*	30.1a	29.7a	40.4a	53.6a	42.0a	61.0b	89.3a	93.3a
Gumbo 500	Okra	18.1b	17.8b	24.1a	31.3b	39.8b	38.2a	58.6b	84.3a	89.5a
Stoneville 7A	Okra	18.5b	--	--	32.3b	--	--	71.5a	--	--

* Means with letter(s) in common, within year, are not significantly different at the 0.05 level of probability, according to an FLSD test.

bolls per plant, but yielded less lint than its related normal-leaf cultivar because it had less lint per seed.

Of the three lint-yield components listed in Table 3, lint per seed should have the highest heritability and thus be the easiest to increase through breeding. Meredith (9) lists heritabilities as follows: lint per seed (lint index)=0.78 to 0.81; seeds per boll=0.34; bolls per plant is not listed but would be expected to have low heritability under the severe environmental stresses of the Arizona and California deserts (2,17). If the nine Okra-leaf strains and cultivars listed in Table 3 each had as much lint per seed as Stoneville 213, expected lint yield per plant would vary from 77 to 104% of that of the check, rather than 74 to 93% as shown by the actual data. Auburn 56 Okra-leaf would have yielded at least as much lint as the normal-leaf Stoneville 213.

The relatively sparse plant spacing (30 cm) within the row may have reduced the advantage of the open canopy of the Okra-leaf cottons (J.E. Jones, personal communication, 1985). Plant bugs have also been implicated in reduced yield of Okra-leaf cotton (4), but we do not have plant-bug data from the experiments reported in this paper. Since the experiments received no insecticides, it is possible that differences among genotypes in plant bug attractiveness may have affected yield and earliness data.

Our data and those of others suggest, therefore, that Okra-leaf cottons will not inevitably yield less lint than their normal-leaf counterparts under stressful conditions, but in general they will tend to do so. Meredith (10) compared lint yields of Okra-leaf isolines with normal-leaf cultivars at Stoneville, MS, during a favorable year when rainfall was above average and temperatures and light intensity were below average and during the following year, which was characterized by relatively hot, dry weather. Okra-leaf isolines yielded 6% less lint than normal-leaf cultivars when planted in April, but 12% more when planted in May of the favorable year. On the other hand, Okra-leaf isolines yielded 4% less lint when planted in April and 16% less when planted in May of the unfavorable year. In a separate experiment, Meredith (8) observed that Okra-leaf isolines yielded 4% more lint than the normal-leaf cultivars during the favorable year but 17% less during the unfavorable year. Landivar et al. (7), using a computer model of plant growth, predicted that Okra-leaf cottons would yield more lint than normal-leaf cottons under optimal conditions, but less under adverse conditions.

As mentioned already, cotton plants are subjected to temperature and moisture stress in the southwestern irrigated deserts. Guinn and Mauney (2) and Wilson and Stapp (17) observed that boll retention of 'Deltapine 61' decreased significantly with an increase in the number of days after irrigation. Kerby and Buxton (6) observed that an Okra-leaf strain produced more fruiting points but also shed more bolls than a normal-leaf cultivar.

All of these data taken together show that, in certain genetic backgrounds, Okra-leaf cottons have a modest amount of resistance to pink bollworm, apparently independent of their earliness. The data also show that most of the Okra-leaf cottons that were evaluated did not yield as well as the normal-leaf cultivars with which they were compared. However, none of those cottons were developed specifically for the desert areas. Also, they were all developed via backcrossing, which may not always be the best breeding method to integrate Okra leaf with an optimum physiological background (11). In a 1985 experiment, however, two of four nectariless, Okra-leaf advanced breeding stocks, developed at Phoenix via a backcrossing scheme, yielded 23 and 18% more lint than did nectariless, normal-leaf counterparts (Wilson, unpublished data). It remains to be seen whether those stocks will continue to yield well. The other two nectariless, Okra-leaf stocks yielded 16 and 25% less lint than nectariless, normal-leaf counterparts. Thus, the inconsistent performance of Okra-leaf cottons emphasizes the necessity of comparing those cottons with normal-leaf cultivars in a number of genetic backgrounds and in multiple environments.

ACKNOWLEDGMENTS

Thanks are extended to Benny R. Stapp and Jayne L. Szaro for technical assistance, and to J. S. Byrd and Laurel Leavitt for maintaining field plots.

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