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Normal vs. Okra Leaf Yield Interactions in Cotton. I. Performance of Near-Isogenic Lines from Bulk Populations[1]

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ABSTRACT

Okra leaf (L_2°,L_2°) cottons, *Gossypium hirsutum* L., have several advantages over normal leaf cottons, but are rarely used commercially because they usually carry approximately a 5% yield disadvantage. Okra leaf cottons usually have been developed by the backcross method, which presumably places Okra leaf in a physiological background better suited to the normal leaf phenotype. This study was designed to determine if the 5% yield differential could be reduced or eliminated by the use of a different breeding method. 'Stoneville 7A' Okra leaf (nectariless) was crossed with 'Carolina Queen' (smoothleaf) and 'Deltapine 5540' to produce CQ and DPL populations. From each cross, 50 heterozygous (L_2°,l_2) F_7 plants were selected and near-isolines of Okra and normal were developed. In 1981, the normal leaf strains averaged 1068 kg ha^{-1} lint and the Okra leaf strains averaged 1015 kg ha^{-1} lint, a significant difference. Strain × leaf type interactions were significant for both populations. In 1982, we grew the two highest yielding strains, the five Okra leaf strains that outyielded their normal leaf near-isolines, and the five normal leaf strains that outyielded their Okra leaf near-isolines in 1981. Our selection objectives were achieved with the DPL but not with the CQ population in 1982. Okra leaf selections in DPL background yielded 7% more lint than their normal leaf near-isolines, whereas 'Stoneville 213' normal leaf yielded 10% more lint than its backcross-derived (BC_5) Okra leaf isoline. The 1982 DPL and CQ yield patterns were verified with four selections planted at two dates in 1983. Soil type in 1981 and 1982 was a Dubbs silt loam (fine-silty, thermic Typic Hapludalfs), and in 1983 was a Dundee silty clay (fine-silty, mixed, thermic Aeric Ochraqualfs). The results from the three experiments imply that certain populations have the genetic potential of producing Okra leaf cottons with higher yielding ability than that of normal leaf ones.

Additional index words: **Selection, *Gossypium hirsutum* L., Genotype × environment interaction.**

JONES (2), in a review, compared the effects of an open canopy cotton homozygous for Okra leaf ($L_2^{\circ}L_2^{\circ}$) and comparable broad-leaved cultivars on agronomic performance. Okra cottons had less leaf area, which allowed for better penetration of light and insecticides, earlier maturity, less boll rot, more resistance to both banded-wing whitefly, *Trialeurodes abutilonea* (Haldeman), and pink bollworm, *Pectinophora gossypiella* (Saunders), and no deleterious associations between Okra and either fiber properties or fitness for harvesting. Bailey and Meredith (1) reported that Okra cottons were more resistant to two-spotted mite, *Tetranychus urticae* Koch, in the field than broad-leaved siblines.

Despite the seeming advantages listed above, Okra cottons are grown only sparingly in Louisiana. There appears to be two reasons why commercial breeders are reluctant to use the Okra leaf character: i) problems in identification of Okra plants in segregating populations—the heterozygotes have laciniated leaves which requires the removal of border row effects due to greater light penetration in yield trials; and ii) most investigations show no yield advantage of Okra over normal-leaved lines, the exception being in areas of Louisiana where boll rot is prevalent (2).

Meredith (4, 5, and 6) reported yield reductions due to Okra leaf ranging from 0 to 4%. Landivar et al. (3) reported that Okra leaf cottons yielded 5% less than normal leaf cottons. From their modeling studies, Landivar et al. (3) concluded that Okra leaf cottons are very competitive in yield with normal leaf ones under favorable growing conditions, but are likely to be less competitive than normal ones under adverse conditions. Wilson and George (10) reported that the only negative effect associated with Okra leaf was a significant yield decrease (8%).

The historical pattern for developing high yielding cottons has been to make progeny-row yield selections from segregating populations in the F_3 or F_4 generation, followed by reselection within these populations in later generations. The breeding value of Okra leaf has then been evaluated from lines produced by the backcross or modified backcross procedure, in which the recurrent parent has been the well adapted, high yielding normal leaf strain or cultivar. Following this procedure, the resulting Okra leaf cotton strain usually

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has suffered a yield disadvantage relative to normal leaf recurrent parent. A basis for this yield differential may be that the physiological characteristics associated with high lint yields of normal leaf strains are not identical to those associated with high lint yield of Okra leaf strains. Some adjustment of physiological factors other than leaf shape alone would seem to be necessary for the Okra leaf plant to fulfill its yield potential. If so, the backcross method using a high yielding normal leaf cultivar as the recurrent parent would not likely be the best way to obtain the optimum, integrated Okra leaf genotype.

This study was conducted to determine if there was sufficient physiological type (genotype) × leaf type interaction to encourage breeders to develop Okra leaf cottons by breeding methods other than the backcross procedure. This study had the following specific objectives: i) develop new normal and Okra leaf near-isogenic populations by procedures other than the backcross breeding method; and ii) from these populations, evaluate the possibility of producing high yielding Okra leaf cottons with yields superior to those of normal leaf cottons.

MATERIALS AND METHODS

This study was done in three stages as follows: i) 100 pairs of near-isolines of normal and Okra leaf cottons were selected; ii) the presence or absence of a strain × leaf type yield interaction was evaluated; and iii) superior yielding normal and Okra leaf cottons were compared with their alternate near-isogenic leaf type and with normal and Okra near-isolines of a widely used commercial check, 'Stoneville 213'.

The 100 pairs of normal and Okra leaf cottons used in these studies descended from two crosses, 'Deltapine 5540-85' × 'Stoneville 7A' Okra leaf (nectariless) and 'Carolina Queen' (smoothleaf) × Stoneville 7A Okra leaf, (nectariless). Populations descending from these two crosses are designated "DPL" and "CQ", respectively. Seeds from about 7000 plants/population were bulk harvested yearly until 1979, when 50 heterozygous ($L_2{}^{\circ},l_2$) F_7 plants from each cross were identified and harvested individually. In 1980, seeds were planted from each plant and homozygous normal and Okra leaf plants were identified. Open-pollinated seed from about 30 normal and 30 Okra leaf plants of each progeny were harvested and used for the 1981 studies. The rationale for using Okra and normal leaf counterparts was to have two genetically similar groups of progenies, contrasting for leaf type, in which to compare yield selections. From each cross, two sets of 25 pairs each of normal and Okra leaf types were formed. The 200 entries, representing 100 pairs of near-isolines, were planted on two dates, 17 April and 11 May 1981 at Stoneville. The 1981 experimental design was a split-split-plot with four replications. Whole plots were planting dates, split-plots were leaf types, and the subplots were the 25 random genotypes comprising a set. Plot size for subplots was one row, 1 × 5.6 m.

Based on 1981 yield performances, three types of selections were made from each cross for use in 1982. The two pairs of near-isolines whose average lint yield over normal and Okra leaf types were highest for that cross were retained and identified as yield selections. The five pairs were retained whose Okra leaf type exceeded the yield of the normal leaf type the most, and whose yield was greater than the population average. Correspondingly, the five pairs were selected whose normal leaf type exceeded the yield of the Okra leaf type the most, and whose yield was greater than the population average. The latter two selection groups are referred to as the Okra leaf and normal selections, respectively. From each cross, 12 pairs of near-isolines were selected: two based on overall yield, five based on the yield superiority of Okra leaf, and five based on the yield superiority of normal leaf. In one case in the CQ population, the second highest yielding genotype also would have been an Okra leaf selection. In that case, this pair was retained and identified as an Okra leaf selection and the third highest yielding genotype was retained for the yield selection. The 12 pairs of near-isolines were planted in five replications at two Stoneville locations on 27 April and 5 May, 1982. For a check comparison, Stoneville 213 normal and its backcross-derived Okra leaf (BC_5) isoline were included. Stoneville 213 is closely related to Stoneville 7A as both were selected from the cultivar 'Stoneville 7' which itself was a plant selection from the cultivar 'Stoneville 2B' (7). A split-plot design was used, with genotypes as whole plots and leaf types as sub-plots with four replications. Plot size was three 5.6 m rows. The middle row was used for lint yield determinations.

In 1983, the highest-yielding normal leaf strain and its Okra leaf near-isoline and the highest yielding Okra leaf strain and its normal leaf near-isoline from both populations in 1982 were evaluated at two planting dates at Stoneville. Stoneville 213, normal, and Okra leaf, were included in the third study. The dates of planting were 27 April and 27 May 1983. Plots were five rows 1 m apart and 7.5 m in length. The experimental design was a split plot with strains used as whole plots and normal and Okra leaf near-isolines used as sub plots with four replications.

The soil type for the 1981 and 1982 study was a Dubbs silt loam (fine-silty, mixed, thermic Typic Hapludalfs), and for the 1983 study was a Dundee silty clay (fine-silty, mixed, thermic Aeric Ochraqualfs). Lint yield determinations of all plots were made from hand harvesting one row.

Table 1. Lint yield mean squares for 1981 studies.

Source	df	Population‡	
		Carolina Queen	DPL 5540
Date = D	1	106 350**	69 957**
Error (a)	6	935	1 002
Leaf type (I)	1	8 433**	3 307†
I × D	1	26	2
Error (b)	12	656	795
Strains = L (S)§	48	1 791**	1 370**
L × D (S)	48	269	338*
L × I (S)	48	485**	601**
L × D × I (S)	48	317*	306
Error (c)	576	214	239

†, *, ** Significance at the 0.10, 0.05, and 0.01 probability levels, respectively.
‡ Mean squares × 10^{-2}.
§ (S) indicates within sets.

RESULTS AND DISCUSSION

Lint yield mean squares and means of the two base populations were similar in 1981 (Tables 1 and 2, respectively). Large yield differences due to planting dates are evident in Table 1. The average yield from April and May plantings for CQ was 920 and 1150 kg ha^{-1}, respectively, and for DPL was 954 and 1150 kg ha^{-1}, respectively. The mean squares indicate large differences among the 50 strains within each population. The average 1981 yields over populations were 1068 kg ha^{-1} for normal leaf and 1015 kg ha^{-1}, 5% less, for Okra leaf. These results are in accord with those from previous studies (3, 4, 5, 6, and 10). The presence of a significant strains × leaf type interaction suggests

Table 2. Average 1981 lint yield of two populations and three types of selections from those populations.

	Carolina Queen		Deltapine 5540	
Type selection‡	Okra	Normal	Okra	Normal
	kg ha^{-1}			
Population mean (50)	1002	1067**	1027	1068†
Yield (2)	1245	1238	1239	1260
Okra > normal (5)	1177**	1075	1234**	1090
Normal > okra (5)	869	1132**	954	1171**

†,** Significantly higher mean than leaf type counterpart at the 0.10 and 0.01 probability levels, respectively, as indicated by the *t* test.
‡ Numbers in parentheses indicate number of entries within each type.

Table 3. Lint yield in 1982 of Okra and normal leaf strains of three types of selections and Stoneville 213 from two populations.

		Carolina Queen		Deltapine 5540	
Selection type	Entry no.	Okra	Normal	Okra	Normal
		kg ha^{-1}			
Normal > okra	1	930	898	935	1085*
	2	908	819	1006*	894
	3	838	865	885	896
	4	794	868	850	848
	5	776	733	840	790
	Mean	898	837	903	903
Okra > normal	1	898	832	1085*	960
	2	880*	755	997*	852
	3	752	865*	914	885
	4	775	801	880	907
	5	725	759	891	851
	Mean	806	803	953*	891
Yield	1	929**	777	1002	942
	2	710	720	930	909
	Mean	820†	749	966	926
Mean of 12 selections		826	808	934	902
Stoneville 213		876	956†	959	1078*

†,*,** Indicate significantly higher mean than leaf type counterpart as indicated by the "t" test at the 0.10, 0.05, and 0.01 probability levels, respectively.

the potential of developing Okra leaf cottons that are more competitive in yield with normal than those Okra leaf strains tested previously. For CQ, 26% of the Okra leaf cottons had higher yield than their normal counterpart, and for DPL, 40% of the Okra leaf cottons had higher yield than their normal counterpart.

One method of demonstrating the potential usefulness of the strains × leaf type interaction is to compare various types of selections with their near-isoline (Table 2). Little difference in yield between Okra and normal was evident in yield for the two highest yielding strains. For the five Okra superiority selections, the Okra leaf types averaged 9 and 13% higher yields than normal leaf for the CQ and DPL populations, respectively. The five normal selections averaged 30 and 23% higher yields, respectively, than their Okra leaf counterparts for the CQ and DPL populations, respectively.

The results from Tables 1 and 2 indicate that, at least in 1981 with these populations, some Okra leaf cottons were competitive in yield with normal leaf cottons. Would this parity of performance be maintained in another season of environments?

From each population, the average 1982 yields of Okra and normal leaf counterparts of the twelve 1981 selections and Stoneville 213 are given in Table 3. At the time of these studies, Stoneville 213 was a much-used commercial cultivar in both the Mississippi Delta

Table 4. Cumulative 1983 yields of Okra and normal leaf near-isolines of Stoneville 213 and four selections at two planting dates.

	1st harvest†		2nd harvest†		3rd harvest†	
Strain and selection type	Okra	Norm	Okra	Norm	Okra	Norm
	kg ha^{-1}					
			27 April			
Stoneville 213	823**	589	1315	1296	1535	1780**
DPL—Norm > Okra	537	621	1165	1215	1504	1475
DPL—Norm < Okra	802**	479	1573**	1072	1849**	1474
CQ—Norm > Okra	728	643	1229	1177	1400	1431
CQ—Norm < Okra	390	410	903	887	1267	1234
			27 May			
Stoneville 213	716**	560	1170	1018	1290	1196
DPL—Norm > Okra	410	654**	836	1147**	1064	1340**
DPL—Norm < Okra	558*	447	1037*	856	1219	1081
CQ—Norm > Okra	668	597	1065	1008	1176	1166
CQ—Norm < Okra	491	555	873	1037*	990	1196*
LSD 0.05‡	102		153		145	

*,** Significantly higher yield than its near-isoline counterpart using the LSD at the 0.05 and 0.01 probability levels, respectively.
† The three harvest dates for the April and May plantings were 141, 160, and 189; and 129, 145, and 159 days after planting, respectively.
‡ LSD for comparisons within a harvest and planting date for strains and leaf types.

and the USA. Stoneville 213's backcross-derived Okra leaf near-isoline averaged 100 kg ha^{-1} less (10%) lint than Stoneville 213 itself.

For the selected cottons, there was a tendency for Okra leaf to have greater superiority over normal in the May than in the April plantings. Average Okra and normal leaf yields were 760 and 761 kg ha^{-1}, respectively, for the April plantings and 998 and 948 kg ha^{-1}, respectively, for the May plantings. This interaction was significant for the DPL, but not for the CQ population. The tendency of Okra leaf to perform comparatively better than normal leaf for late May plantings has been observed previously (6). The shorter season is probably more compatible with faster maturity of Okra leaf cotton than that of normal leaf cottons.

A significant strain × leaf type interaction was detected for both 1982 populations. Of more importance is whether the selection strategy practiced in 1981 resulted in similar performance in 1982. The two populations did not respond the same in 1982 to previous selection strategies. For CQ, the yields of various selections did not follow their selection history. Since the heritability of yield is generally low in cotton, it is not unusual that yield selections in one environment are not directly translated into similar yield patterns in other environments. For the DPL population, however, the previous selection strategies were in general agreement. The yield selections, averaged over both leaf types, yielded 946 kg ha^{-1}, compared to 922 and 903 kg ha^{-1} for the means of the Okra and normal selections, respectively. Selection for Okra leaf yield superiority was also successful, because yields of the Okra leaf selection averaged a significantly higher 62 kg ha^{-1} than the normal leaf ones. The selection for normal superiority was less successful, because both Okra and normal leaf averaged 903 kg ha^{-1}.

The 1983 yields of four selections and Stoneville 213 normal and Okra leaf counterparts are given in Table 4. The average yield for the April planting was 1495 kg ha^{-1} and for the May planting was 1172 kg ha^{-1}.

There were large strain × leaf type interactions both within and between planting dates. Some of the significant interactions resulted from the previous selection strategies applied. Over both planting dates, Stoneville 213 Okra leaf produced 34% higher average first-harvest yield, but averaged 5% less total yield than normal leaf Stoneville 213. This yield response has been observed generally for Okra leaf near-isolines developed by the backcross method (3, 4, 5, 6, and 10). As in 1982, the two selections from CQ did not yield according to previous selection patterns. Okra leaf averaged 49 kg ha^{-1} or 4% less lint than normal leaf. Previous selection strategies for DPL were more successful, however. The strain selected for normal superiority had a normal average yield of 1408 kg ha^{-1}, 9% greater than that of its Okra leaf near-isoline. In contrast, the Okra leaf strain selected for Okra leaf superiority had an average yield of 1534 kg ha^{-1}, or 20% greater than its normal counterpart. This yield also is competitive with that of Stoneville 213 normal leaf, 1488 kg ha^{-1}.

While this study was limited to two populations, and 50 entries per population, it has some implications to cotton and other plant breeders who wish to modify leaf canopy architecture. Wells and Meredith (8) showed that modern cotton cultivars partition photosynthate more efficiently into reproductive parts than do obsolete cultivars. If this trend were to continue, one method of reducing vegetative plant parts would be to use cottons with less leaf area, such as Okra leaf. Aside from reduced vegetative growth, open canopy cottons have other desirable attributes (2).

What would be the problems of breeding for Okra leaf cottons? Our studies suggest that most of the problems that limit progress in conventional breeding for normal leaf would also be present for Okra leaf. Such problems as genotype × environment interactions were evident in all studies. Probably the greatest problem, as this study suggests, is to find genetic backgrounds which permit high performance for the Okra phenotype.

After at least 75 years of breeding normal leaf cottons for the optimum relationship between yield and physiological attributes, it may require the introduction of exotic germplasm to find the best combination in Okra leaf background. Our success with one small population of Okra leaf plants that yielded more lint than normal leaf ones suggests that other populations may be equally successful. The results of this study offer encouragement to those breeders who wish to improve yield by consciously altering the leaf canopy of cotton. The significant strain × leaf type interactions indicate that the physiological background for obtaining maximum yield of Okra leaf cotton is different than that of normal leaf cotton. That difference is addressed in another study (9).

REFERENCES

1. Bailey, J.C., and W.R. Meredith, Jr. 1983. Resistance of cotton, *Gossypium hirsutum* L., to natural field populations of two-spotted spider mites (Acari: Tetranychidae). Environ. Entomol. 12:763–764.
2. Jones, J.E. 1982. The present state of the art and science of cotton breeding for leaf-morphological types. p. 93–99. *In*: J.M. Brown (ed.) Beltwide Cotton Prod. Res. Conf., Las Vegas, NV. 3–7 Jan. 1980. National Cotton Council, Memphis, TN.
3. Landivar, J.A., D.N. Baker, and J.N. Jenkins. 1983. Application of GOSSYM to genetic feasibility studies. I. Analysis of fruit abscission and yield in okra leaf cottons. Crop Sci. 23:497–504.
4. Meredith, W.R., Jr. 1983. Effect of environments and genetic backgrounds on evaluation of cotton isolines. Crop Sci. 23:51–54.
5. ----. 1984a. Influence of leaf morphology on lint yield of cotton—enhancement by the sub okra trait. Crop Sci. 24:855–857.
6. ----. 1984b. Lint yield genotype × environment interaction in upland cotton as influenced by leaf canopy isolines. Crop Sci. 25:509–512.
7. Ramey, H.H., Jr. 1966. Historical review of cotton variety development. p. 310–326. *In*: Proc. 18th Cotton Improv. Conf., Memphis, TN. 11–12 Jan. 1966. National Cotton Council, Memphis, TN.
8. Wells, R., and W.R. Meredith, Jr. 1984. Comparative growth of obsolete and modern cotton cultivars. II. Reproductive dry matter partitioning. Crop Sci. 24:863–868.
9. ----, and ----. 1986. Normal vs. Okra leaf yield interactions in cotton. II. Analysis of vegetative and reproductive growth. Crop Sci. 26:223–228.
10. Wilson, F.D., and B.W. George. 1982. Effects of okra leaf, frego bract, and smoothleaf mutants on pink bollworm damage and agronomic properties of cotton. Crop Sci. 22:798–801.