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Effects of Super Okra Leaf Shape on Boll Rot, Yield, and Other Characters of Upland Cotton, *Gossypium hirsutum* L.[1]

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ABSTRACT

The effects of the super okra leaf shape on boll rot. yield, plant and fiber characters of Upland cotton, *Gossypium hirsutum* L., were investigated at three locations in Louisiana. Near isogenic populations of super okra leaf and normal leaf on each of three varietal backgrounds were used.

Super okra leaf shape, as an average of varieties and locations, caused a significant reduction in boll rot, yield, fiber length, and total leaf surface area in comparison with normal leaf cotton. Super okra leaf shape caused an increase in earliness, lint percentage, fruiting rate, and micronaire value, but had no effects or inconsistent effects on boll size, fiber length uniformity, fiber strength, and fiber elongation. The interactions of variety × leaf shape and location × leaf shape were significant for some of the characters studied.

A mixed population of super okra leaf and normal leaf plants in a 1:1 ratio was investigated. The mixed leaf population was found to have no advantage over the pure populations of the contrasting leaf shapes.

Additional index words: **Lint percentage, Fiber fineness, Fiber length, Fiber strength, Leaf surface area.**

YEARLY losses from boll rot in Louisiana have been estimated to range from 8 to 12% of the total cotton crop for the past 3 years (4, 5, 6). The identification of plant characteristics that reduce losses from this disease and the incorporation of such traits into adapted commercial varieties would be expected to have important beneficial effects on the economical production of cotton. Frego bract (10) and okra leaf (1, 9) are two characters reported to be associated with important reductions in losses from this disease complex.

The super okra leaf character has extremely deeply cleft and narrowly lobed leaves. The leaves are frequently reduced to a simple, strap-shape or willow-like leaf (Fig. 1). This leaf shape results in a more open type of plant canopy than okra leaf and substantially more open than that of normal leaf cotton. Since the microclimate within a more open plant canopy is known to be less favorable for fungi and bacterial development than within a dense canopy[3], the possible value of super okra leaf as a boll rot supressing character was considered to be worthy of study.

The earliest reference to the super ogra leaf character found in the literature was the super okra leaf mutation reported by Harland (8) to have originated in a planting of Acala Okra Leaf cotton in Trinidad. According to Stephens (13) and Green (7), the super okra leaf character is controlled by one pair of genes and is a member of an allelomorphic series having a minimum of five members: L^s (super okra), L^o (okra), L^e (Sea Island), L^u (sub okra), and l (normal). The locus for the super okra leaf allelic series has been placed in linkage group II, on chromosome 15, and in genome D by Kohel et al. (11).

Although several studies are reported in the literature on the effects of the okra leaf shape on yield, plant and fiber characters (1, 2, 3, 9, 12), no reports were found of similar studies with regard to the super okra leaf shape. This paper is a report on the effects of the super okra leaf shape on the incidence of boll rot, yield of lint, and certain plant and fiber characters in Upland cotton, *Gossypium hirsutum* L.

MATERIALS AND METHODS

The materials used in this study were derived from the F_2 generation following the third backcross of super okra leaf "L_s" to each of three broadleaf "l" varieties of Upland cotton. M-8 Super Okra, obtained from Dr. Norman E. Justus, was the parental line common to all three crosses. The varieties used as recurrent parents were 'Bayou,' 'Stoneville 7A' (St. 7A). and 'Deltapine Smooth Leaf' (Dp. S. L.). Bayou is a locally developed experimental variety; Stoneville 7A and Deltapine Smooth Leaf are adapted commercial varieties.

Two semi-isolated, seed-increase plots were planted with the same F_2 seed lot of each variety. One plot of each variety was thinned to a pure stand of homozygous super okra leaf plants; the other was thinned to a pure stand of homozygous normal leaf plants. The genotypes L^sL^s, L^sl. and ll can be easily distinguished by their phenotypes. The seed from approximately 150 to 200 plants in each plot were harvested in bulk and used to plant replicated tests at Baton Rouge, St. Joseph, and Alexandria La. in 1967.

Each experiment consisted of nine entries arranged in a randomized block, split-plot design with four replications. For each varietal background, three leaf shape treatments were established: (a) a pure population of homozygous super okra leaf plants, (b) a pure population of homozygous normal leaf plants, and (c) a mixed population of super okra leaf and normal leaf plants in a 1:1 ratio. The three varieties

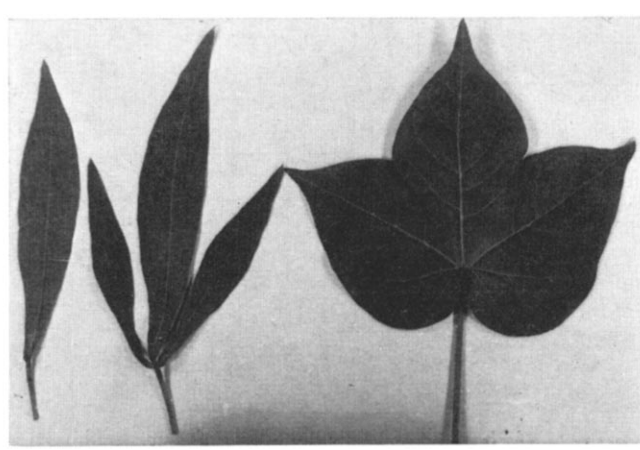

Fig. 1. Typical leaves of normal (right) and super okra leaf (left) cottons.

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[3] Newton, O. H.. and C. D. Ranney. 1964. The effect of bottom defoliation on the micriclimate. Proc. 24th Cotton Disease Council. 89-90.

were assigned to the main plots, and the three leaf shape entries were assigned to the subplots.

Four row plots, 15.2 m long at Baton Rouge and St. Joseph and 12.2 m long at Alexandria were planted during the last week of April. A uniform stand of three to four plants per 30 cm was obtained in rows 107 cm apart at Baton Rouge and 102 cm apart at St. Joseph and Alexandria. The tests were fertilized with 110-114-114, 134-0-0, and 112-67-67 kg/ha of N-P-K at the three respective locations. A defoliant was applied to all plots 10 days before first picking at St. Joseph and Alexandria and between first and second picking at Baton Rouge. The Baton Rouge test was harvested once by hand and twice with a mechanical picker; the St. Joseph test was harvested twice with a mechanical picker, and the Alexandria test was harvested twice by hand. Yield data were collected from the two center rows at all locations in order to avoid border effects.

The characters studied were the incidence of boll rot. yield, earliness, fruiting rate, boll weight, lint percentage, micronaire value, fiber length, fiber length uniformity, fiber strength, fiber elongation, and leaf surface area. These characters were measured according to the methods described by Andries et al. (1).

The data collected were subjected to an appropriate analysis of variance on each test separately and as a combined analysis of the three locations. Duncan's Multiple Range Test was used to test the significance of differences among treatment means.

Comparisons in each case were between the super okra leaf segregates and the normal leaf segregates from the same base population and not between the super okra leaf segregates and the recurrent parent. Since the super okra leaf and normal leaf biotypes of each variety were random populations established from the same F_1 plants following the third backcross to that variety and selected only for leaf shape, they may be considered to be the equivalent of near isogenic populations. Differences observed between the super okra leaf and normal leaf biotypes for the several characters under study were attributed to the genetic factor for leaf shape, or to other genes closely linked with it.

RESULTS

Boll Rot. The incidence of boll rot was moderate to severe at the three test locations. Boll rot was most severe at St. Joseph where, as a test average, 447 kg/ha of lint were lost from boll rot. This represented a loss of 23.1% of the total crop. The loss at Baton Rouge averaged 248 kg/ha or 17.5% of the crop, and at Alexandria, 114 kg/ or 7.7% of the total crop was lost from boll rot.

The super okra leaf biotypes averaged significantly fewer rotten bolls than the mixed leaf and normal leaf biotypes at each location (Table 1). This trait was associated with an average reduction in the number of rotten bolls, relative to normal leaf, of 61% at St. Joseph, 56% at Baton Rouge, and 31% at Alexandria. The mixed leaf populations averaged significantly fewer rotten bolls than the normal leaf populations at St. Joseph, but not at Baton Rouge and Alexandria. The interaction of location $\times$ leaf shape (Loc $\times$ LS) was highly significant.

As an average of the three varieties and locations, the super okra leaf character was responsible for a highly significant reduction in the number of rotten bolls per 6.1 m of row from 92 for the normal leaf biotypes to 41 for the super okra leaf biotypes (Table 1). This amounted to a reduction in the loss of lint due to boll rot from 338 kg/ha for the normal leaf entries to 154 kg/ha for the super okra leaf entries. When expressed as a percentage of the total crop lost from boll rot, the percentages were 19.9% and 10.8%, respectively. This amounted to an overall reduction of approximately 55% in the incidence of boll rot that could be attributed to this trait.

A significant variety $\times$ leaf shape (Var $\times$ LS) interaction occurred at St. Joseph and in the combined analysis, but not at Baton Rouge and Alexandria. In each case, however, the super okra leaf entry of each variety was significantly less than its mixed leaf or normal leaf counterpart.

Yield. The three leaf shape treatments did not differ significantly for yield of lint at Baton Rouge and Alexandria, but they did at St. Joseph (Table 2). The effects of leaf shape on yield at St. Joseph was influenced by the varietal background. The super okra leaf entry of Bayou yielded significantly less than normal leaf Bayou, while the super okra leaf entry of St. 7A yielded significantly more than normal leaf St. 7A. The super okra leaf and normal leaf entries of Dp. S. L. were comparable in yield. The mixed leaf entry of each variety had a slightly higher yield than its normal leaf, but in no case was the difference significant.

As an average of the three varieties and locations, the yield of the super okra leaf entries was 1,278 kg/ha, as compared to 1,381 kg/ha for the mixed leaf and 1,364 kg/ha for the normal leaf entries. The mixed leaf and normal leaf means did not differ significantly, however they both significantly exceeded the mean of the super okra leaf treatment in the combined anal-

Table 1. Rotten bolls per 6.1 m of row for three varieties of cotton at three locations in Louisiana as affected by super okra leaf shape.

Biotypes	Locations* Baton Rouge, no.	St. Joseph, no.	Alexandria, no.	Avg no.
Bayou S. Okra	32	52 x†	27	37 x
Bayou Mix	64	101 y	31	65 y
Bayou Normal	66	122 z	22	70 y
Bayou avg	54	92	27	57
St. 7A S. Okra	29	66 x	13	36 x
St. 7A Mix	95	169 z	31	98 y
St. 7A Normal	87	161 y	30	93 y
St. 7A avg	70	132	25	76
Dp. S. L. S. Okra	51	64 x	35	50 x
Dp. S. L. Mix	91	125 y	57	91 y
Dp. S. L. Normal	103	183 z	57	114 z
Dp. S. L. avg	81	124	50	85
Average S. Okra	37 a	61 a	25 a	41 a
Average Mix	83 b	132 b	40 b	85 b
Average Normal	85 b	155 c	36 b	92 b
Avg. for test	68	116	34	73

* Average for four replications at each location. † Means within columns followed by a letter in common do not differ significantly at the 5% level of probability. "a", "b", and "c" indicate significant differences among leaf shape treatment means. "x", "y", and "z" indicate significant differences among the leaf shape treatments within a variety when the variety × leaf shape interaction was significant.

Table 2. Mean yield of lint per hectare of three varieties of cotton at three locations in Louisiana as affected by super okra leaf shape.

Biotypes	Locations* Baton Rouge	St. Joseph	Alexandria	Average
	kg/ha			
Bayou S. Okra	1,057	1,245 y†	1,439	1,234
Bayou Mix	1,048	1,559 x	1,380	1,329
Bayou Normal	1,121	1,506 x	1,284	1,305
Bayou avg	1,075	1,437	1,367	1,289
St. 7A S. Okra	1,191	1,522 x	1,246	1,320
St. 7A Mix	1,258	1,475 xy	1,284	1,339
St. 7A Normal	1,278	1,419 y	1,512	1,403
St. 7A avg	1,242	1,473	1,347	1,354
Dp. S. L. S. Okra	1,145	1,500 x	1,165	1,270
Dp. S. L. Mix	1,241	1,599 x	1,586	1,475
Dp. S. L. Normal	1,150	1,535 x	1,469	1,385
Dp. S. L. avg	1,178	1,546	1,407	1,376
Average S. Okra	1,131 a†	1,422 b	1,283 a	1,278 b
Average Mix	1,182 a	1,544 a	1,417 a	1,381 a
Average Normal	1,182 a	1,487 ab	1,422 a	1,364 a
Average for test	1,166	1,485	1,374	1,342

* Average of four replications at each location. † Means within columns followed by a letter in common do not differ significantly at the 5% level of probability. "a", "b", and "c" indicate significant differences among leaf shape treatment means. "x", "y", and "z" indicate significant differences among the leaf shape treatments within a variety when the variety × leaf shape interaction was significant.

ysis (Table 2). These small differences take on added significance when one considers that the super okra leaf entries had considerably less lint cotton lost from boll rot than the normal leaf and mixed leaf entries. Had there not been any boll rot, the normal leaf and mixed leaf cottons may have outyielded the super okra leaf cottons by as much as 18.7%, as indicated by their average projected yield (harvested lint + rotten lint).

The Loc × LS and Var × LS interactions were nonsignificant, but the second order interaction, Var × LS × Loc, was highly significant in the combined analysis, indicating that the interaction of Var × LS was not the same at all locations.

Earliness. Highly significant differences were observed among the three leaf biotypes for percentage of total crop harvested at first harvest at each location and in the combined analysis. At each location and for each variety, the super okra leaf biotype, as an average, was significantly earlier than the mixed leaf biotype and the mixed leaf biotype was signifcantly earlier than the normal leaf biotype (Table 3). Although significant interactions involving Loc × LS and Var × LS were detected in the combined analysis, they were considered to be of minor importance since they resulted from differences in magnitude of similar effects.

Results from the more detailed study of earliness conducted at Baton Rouge and St. Joseph are summarized in Fig. 2. The data are reported as an average of the two locations since an examination of the data indicated that the effect of leaf shape on earliness was not greatly influenced by location. The data indicate that if first harvest had been delayed until approximately 70% of the total crop was open, as is generally recommended, the super okra leaf plots could have been harvested 10 days earlier than the mixed leaf plots and 12 days earlier than the normal leaf plots.

Table 3. Mean effects of leaf shape on certain plant and fiber characters of cotton at three locations in Louisiana.

Characters	Leaf shape	Test location* Baton Rouge	St. Joseph	Alexandria	Avg
Percentage of crop harvested at 1st picking	S. Okra	65.9a†	86.6a	87.3a	79.9a
	Mix	36.1b	69.8b	77.2b	61.1b
	Normal	33.5c	61.6c	64.1c	53.0c
Boll weight, g	S. Okra	6.3a	5.8b	5.6b	5.9a
	Mix	5.8b	6.1a	5.8a	5.9a
	Normal	5.7b	6.0a	5.9a	5.9a
Lint percentage	S. Okra	41.3a	40.4a	38.5a	40.1a
	Mix	40.2b	39.8a	36.9b	39.0b
	Normal	39.4c	39.6a	35.8c	38.3c
Micronaire, value	S. Okra	4.17a	4.18b	4.20b	4.18b
	Mix	4.21a	3.96ab	4.17ab	4.11b
	Normal	4.18a	3.74a	4.04a	3.99a
Fiber length, 2.5% span length, inches	S. Okra	1.09b	1.09a	1.12b	1.10c
	Mix	1.11ab	1.10a	1.16a	1.12b
	Normal	1.12a	1.12a	1.16a	1,13a
Fiber length uniformity, %	S. Okra	45.6a	44.3a	45.2b	45.0a
	Mix	45.3a	44.9a	45.5ab	45.2a
	Normal	45.8a	44.5a	46.7a	45.7a
Fiber strength, T_1, g/tex	S. Okra	18.0a	18.4a	18.0a	18.1a
	Mix	17.8a	18.0a	17.9a	17.9a
	Normal	18.4a	17.9a	17.8a	18.1a
Fiber elongation, E_1, %	S. Okra	8.7a	8.4b	9.4a	8.8b
	Mix	8.9a	8.7ab	9.4a	9.0ab
	Normal	9.0a	9.1a	9.7a	9.3a

* Average of four replications and three varieties at each location. † Means within columns followed by a letter in common do not differ significantly at the 5% level of probability.

Table 4. Mean number of white blooms per row at Baton Rouge and Alexandria as affected by leaf shape on the Stoneville 7A variety in 1967.

Locations	Dates counted	Leaf shape treatment S. Okra, no.	Mix, no.	Normal, no.	S. Okra as percent of Normal
Baton Rouge*	Jul 19	87.5	48.0	43.5	201.1
	Jul 27	89.8	48.0	26.0	345.2
	Aug 4	109.2	73.5	66.7	164.4
	Aug 24	5.2	19.0	22.7	23.1
	Total	291.7	188.5	158.9	183.6
Alexandria†	Jul 26	98.5	57.2	46.2	213.0
	Aug 5	93.5	63.0	54.5	171.6
	Aug 22	90.0	55.0	48.4	184.6
	Total	282.0	175.2	149.1	189.7

* Average of 4 replications, 15.2 m length rows. † Average of 4 replications, 12.2 m length rows.

Fruiting rate. The super okra leaf plants of St. 7A produced two to three times more blooms than the normal leaf plants of this variety on the three dates that counts were made in July, and from 65 to 85% more blooms than normal leaf on the first three counts in August (Table 4). The plants were mature and in the "cut-out" stage at Baton Rouge on the August 24th date, as was indicated by a marked reduction in number of flowers. Fewer flowers were observed on the super okra leaf plots than on the normal leaf plots at this date. As an average of all counts made at both locations, the super okra leaf plants produced approximately 85% more blooms than the normal leaf plants. The mixed leaf plots were intermediate between the super okra leaf and normal leaf plots, but nearer to the normal leaf in number of blooms.

Boll weight and Lint Percentage. Significant differences were noted among the three leaf shape treatments for average boll weight at each location (Table 3). At Baton Rouge, the super okra leaf plants had significantly larger bolls than the mixed leaf and normal leaf plants. However at St. Joseph and Alexandria, the super okra leaf plants had significantly smaller bolls than the mixed leaf or normal leaf plants. The mixed leaf and normal leaf treatments did not differ significantly for boll weight at any location. As an average of the three locations and varieties, the

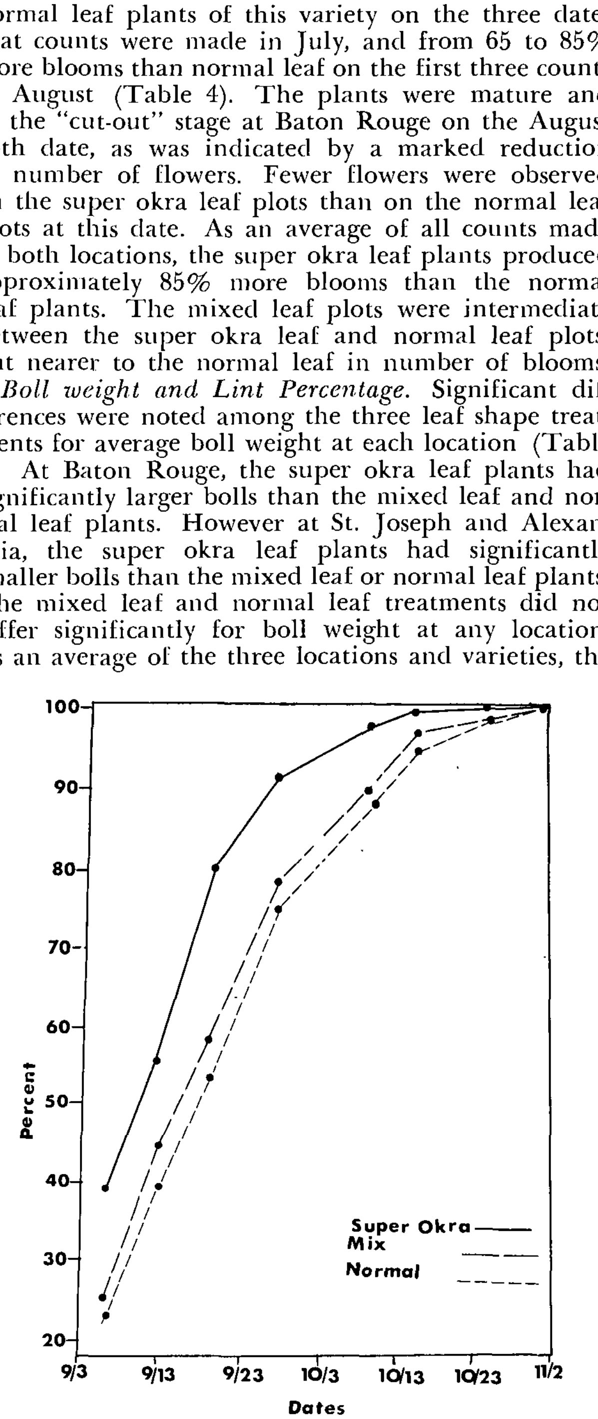

Fig. 2. Effect of super okra leaf shape on percentage of total crop harvested, by dates, as an average of three varieties and two locations.

three leaf shape treatments were identical for average boll weight, 5.9 g. The significant Loc × LS interaction may have been related to sampling and the percentage of bolls open on a plot at the time that the samples were taken. Fewer bolls were open at Baton Rouge at the time of sampling than at the other locations.

The super okra leaf treatment, as an average of varieties, had a significantly higher mean lint percentage than the mixed leaf treatment, and it, in turn, had a significantly higher mean lint percentage than the normal leaf treatment at Baton Rouge and Alexandria. The three leaf shape treatments did not differ significantly in lint percentage at St. Joseph (Table 3). As an average of the three locations and varieties, the lint percentages were 40.1, 39.0, and 38.3% for the super okra leaf, mixed leaf, and normal leaf treatments, respectively. These means were significantly different from one another in the combined analysis. The interactions of Var × LS and Loc × LS were statistically significant in the combined analysis, but again their interactions were due to differences in magnitude of similar effects.

Fiber Properties. The effects of the three leaf shape treatments, as an average of the three varieties, on micronaire, fiber length, length uniformity, strength, and elongation are given in Table 3.

The three leaf shape treatments did not differ significantly for micronaire at Baton Rouge. At St. Joseph and Alexandria, the super okra leaf treatment was significantly higher than the normal leaf treatment, but the mixed leaf treatment did not differ significantly from either the super okra leaf or normal leaf treatments. In the combined analysis, the super okra leaf and mixed leaf strains did not differ significantly, however they both had a small, but significantly higher, micronaire value than the normal leaf treatment. Interactions involving leaf shape with varieties and locations were nonsignificant for this trait.

The super okra leaf cottons had significantly shorter fibers than normal leaf at Baton Rouge, Alexandria, and in the combined analysis, but not at St. Joseph. A significant Loc × LS interaction was observed in the combined analysis, but the effects of leaf shape on the three varieties were similar.

Super okra leaf shape was associated with a significantly lower fiber length uniformity ratio at Alexandria, but since this effect was not observed at other locations nor in the combined analysis, it was assumed to be unimportant.

Fiber strength, as an average of varieties, was not significantly affected by leaf shape at any location or in the combined analysis. However, the three varieties did not behave alike in this regard. Leaf shape, as an average of locations, had no effect on fiber strength for the Bayou and St. 7A varieties, but the lint from the super okra leaf entry of Dp. S. L. was significantly stronger than the lint of the mixed leaf and normal leaf entries of this variety. This resulted in a significant Var × LS interaction in the combined analysis.

The super okra leaf cottons, as an average of varieties and locations, were significantly lower in fiber elongation than the normal leaf cottons (Table 3), but again, the effects of leaf shape were influenced by varietal background. The super okra leaf entries of Bayou and Dp. S. L. were significantly lower in fiber elongation than their respective mixed leaf and normal leaf entries, but leaf shape either had no effect or the opposite effect on the St. 7A variety.

Leaf Area. The total leaf surface area of the five plant samples of the super okra leaf entry of St. 7A ranged from 16,290 sq cm to 24,206 sq cm, with an average of 20,329 sq cm. This compares with a range of 33,432 sq cm to 46,135 sq cm and an average of 39,387 sq cm for the five plant samples of the normal leaf entries. The super okra leaf plants, as an average of the four replications had approximately 52% as much total leaf surface area as the normal leaf plants.

DISCUSSION

Super okra leaf "L^s" proved to be an effective boll rot suppressing character. It may be somewhat more effective than okra leaf "L^o" in this regard. The 55% reduction in average boll rot losses attributed to super okra leaf in these experiments may be compared with the 45% average reduction in boll rot losses attributed to okra leaf by Andries et al. (1). The two studies were conducted at the same locations and under comparable conditions. The effectiveness of super okra leaf as a boll rot suppressing character probably is due to the openness of its leaf canopy. The marked reduction in leaf area and the short internodes and small plant structure consistently observed to be associated with L^s gives the super okra leaf cottons a very open plant type.

Although the super okra leaf character resulted in considerable reductions in boll rot losses, the harvested yield of the super okra leaf strains was slightly below the yield of the normal leaf cottons. This suggests that L^s may have an important depressing effect on yield in years when boll rot is not a serious problem. This factor could seriously hinder the utilization of this trait in commercial cottons, unless the reduction in yield attributed to L^s was compensated for by lower production costs, or unless different production practices were developed to take advantage of the particular plant type of super okra leaf cotton.

The accelerated rate of fruiting and early maturity conferred by L^s could result in significant savings in boll weevil control, both by diluting the boll weevil population and by reducing the period of time during which the crop would require protection. Also, the determinant fruiting habit and early maturity associated with L^s suggest that super okra leaf may afford additional savings in once over harvest. There is also the possibility that super okra leaf, because of its small plant structure and open canopy, may respond favorably in yield to a narrower row and higher plant population than that used in the experiments reported here.

The reduced leaf area and small plant size of super okra leaf cottons would be expected to increase the difficulty of weed control in fields after the last cultivation. The development of lay-by herbicides, however, has greatly reduced the seriousness of this problem. Weeds were controlled in the experiments reported here by a combination of chemical and mechanical cultivation. The test at Alexandria did not receive a lay-by application of diuron, and the super okra leaf plots had more weeds at harvest than the mixed and normal leaf plots. The plots at Baton Rouge and St. Joseph received a lay-by application of diuron herbicide; no differences in efficiency of weed control were detected among the leaf shape treatments in their tests at harvest.

The super okra leaf character was associated with a slight increase in micronaire value and a slight decrease in fiber length as compared with normal leaf cotton. It was not determined whether the associations were due to genetic linkage or to pleiotrophy of the L^s gene. In any case, the effects of L^s were small enough to suggest that the desired level of each could be obtained in a selective breeding program of super okra leaf cotton.

The mixed leaf populations were included in this study to determine if a semi-open plant canopy, induced by a mixture of super okra leaf and normal leaf plants, may have an advantage over the pure populations of the contrasting leaf shapes. This was not adequately evaluated since the plant canopy of the mixed leaf plots became almost as dense at the end of the season as the plant canopy of the normal leaf plots. This condition occurred because of the poor competition offered by the small, open plants of the super okra leaf. The normal leaf plants almost completely dominated the row by early August. Under these conditions, the mixed leaf populations were found to have no overall advantage over the pure populations of the contrasting leaf shapes.

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