Influence of Leaf Morphology on Lint Yield of Cotton—Enhancement by the Sub Okra Trait[1]

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ABSTRACT

Sub okra leaf (L^u) is a trait in cotton (*Gossypium hirsutum* L.) which displays greater indentation of sinus and more lobing than does normal leaf (*l*). This study was initiated because no previous research on the influence of this trait for lint yield or its components had been reported. In 1981, 48 populations descending from 24 crosses were initiated to compare the influence of this trait on yield relative to that of normal and two other mutant leaf types. The populations developed were from crosses of eight normal with three mutant leaf types of cotton. The eight normal leaf cultivars and strains wee 'Deltapine 26', 'Deltapine 5540', 'Stoneville 825', 'SC-1', 'DES 422', 'Tamcot CAMD-E', MD 69, and DES 2-10. The mutant leaf types were La 1363L^{s}ne, La 500C, and HYC 79-6 which possessed the super okra (L^s), okra (L^o), and sub okra (L^u) leaf traits, respectively. Two populations were produced from each cross, i.e., one normal and one homozygous for the mutant leaf type. In 1982, the 48 F_3 populations were grown in replicated experiments at three locations near Stoneville, Miss. Mean lint yield ranged from 870 to 1175 kg/ha for the three locations and from 927 to 1099 kg/ha for the eight sources of normal leaf types. No interactions with the eight sources of normal types were detected with environments, mutant leaf source types, or normal vs mutant types. Super okra populations averaged 95 kg/ha (8.8%) less lint yield than their corresponding normal populations. No differences in lint yield of okra vs normal leaf populations were detected, averaging 1053 and 1055 kg/ha, respectively. In contrast, lint yield of sub okra was significantly higher, averaging 47 kg/ha (4.8%) more than its corresponding normal populations. The yield superiority of sub okra over normal at the three locations ranged from 18 to 83 kg/ha. This investigation indicates a potential increase in the lint yield of cotton grown in the Mississippi Delta through the incorporation of the sub okra leaf trait.

Additional index words: Light interception, Isogenic lines, *Gossypium hirsutum* L., Leaf canopy, Okra leaf, Super okra leaf, Yield components, Lint percentage, Boll size, Seed index.

N UMEROUS leaf types influence leaf area and canopy architecture in cotton (*Gossypium* spp.). Okra (L^o), Sea-Island (L^e), super okra (L^s), sub okra (L^u), and normal leaf (*l*) are members of a multiple allelic series that occur at the "L" locus on chromosome 15 of the "D" genome (Stephens, 1945). There is an additional series of at least five alleles determining leaf shape at the "L" locus of chromosome 1 of the "A" genome (White and Endrizzi, 1965). Jones (1982) reviewed the history, effect on yield, pest resistance, and plant development of these alleles in cotton. The presence of the multiple allelic series in both genomes suggests that leaf types have adaptive value for survival in the "wild" and suggests the relationship of the A and D genomes in the evolution of cotton.

In upland cotton (*G. hirsutum* L.), nearly all cultivars are of the normal (*l*) genotype. The only excep-

tions to date in the USA have been the release of L^s and L^o cultivars in Louisiana. These two types of cultivars have a yield advantage over normal leaf in environments characterized by high rainfall and humidity because of their reduction of boll rot. While such types of cotton also induce earliness of maturity, they are not generally competitive in yield with normal leaf cotton in most parts of the USA. Very little on the performance of the mutants L^e and L^u has been published. All Pima (*G. barbadense* L.) cultivars have the L^e genotype. Green (1953) indicated L^u was transferred into upland cotton using Beasley's triple hybrid involving *G. arboreum* L. and *G. thurberi* Tod. Based on the parents' phenotypes, L^u is assumed to have come from *G. thurberi*. L^u is phenotypically similar to L^e and to heterozygous okra ($L^o l$). Tests to determine if Sea-Island and sub okra are controlled by the same allele have not been published. Their differences may be more in size than in leaf shape, with Sea-Island having larger leaves than sub okra. Heterozygous okra leaf is expressed earlier in plant development than either Sea-Island or sub okra. Sea-Island and sub okra are not clearly evident at Stoneville until about the time of flowering, whereas heterozygous okra leaf is expressed very early in development, at about the fourth true leaf stage. Normal leaf cotton has either wider leaf lobes and/or less indentation between the major lobes than do the mutant types. With the more extreme mutants, such as okra and super okra, leaf area per leaf is reduced (Jones, 1982). The effects on leaf area per leaf for Sea-Island and sub okra have not been reported either.

The mutant leaf types are often referred to as "open-canopy" cottons because they permit greater light penetration and air movement into the inner and lower parts of the canopy than does normal leaf cotton. Okra and super okra probably eliminate too much leaf area while allowing greater light penetration. In the early growth stages of cotton, light is not usually a limiting factor in the lower canopy because leaf area has not reached an optimum level. As leaf area increases with growth and maturity, the lower leaves are shaded. Open-canopy cotton could also allow greater air movement within the canopy, allowing greater CO_2 exchange. Open-canopy cotton also results in temperature changes within the canopy. Landivar et al. (1983) speculated on the basis of cotton plant modeling studies that less extreme reductions in leaf area than that from okra leaf would have some advantages in light interception and subsequently increase yield of cotton. Sub okra is a less extreme type than okra or super okra.

Is there an optimum leaf architecture other than the present normal type?

The objective of this study was to compare the effect of a modified leaf type, sub okra, in various genetic backgrounds on the lint yield and yield com-

ponent performance of cotton relative to normal, okra, and super okra leaf types.

MATERIALS AND METHODS

Outline drawings of normal, sub okra, Sea-Island, heterozygous okra, okra, and super okra are given in Fig. 1 to illustrate the major differences in leaf-lobe indentions among the six leaf genotypes.

Twenty-four populations were produced from crossing eight normal leaf types of cotton with La 1363L^{S}ne, a super okra strain; La 500C, an okra line; and HYC 79–6, a sub okra strain. La 1363L^{S}ne and La 500C were obtained from J. E. Jones, Agronomy Dep., Louisiana Agric. Exp. Stn., Baton Rouge, La. HYC 79–6 was obtained from W. P. Sappenfield, Missouri Agric. Exp. Stn., Portageville, Mo. The eight normal leaf cultivars and strains used were 'Deltapine 26', 'Deltapine 5540', 'Stoneville 825', 'SC1', 'DES 422', 'Tamcot CAMD-E', MD 69, and DES 2–10. The eight cultivars and strains were crossed with the three mutant leaf types in the summer of 1980. F_2 seed were produced at the winter increase nursery in Iguala, Mexico. In 1981, F_2 populations from the 24 crosses were grown at Stoneville, Miss. From each cross the F_2 was divided into two groups. In one group, only normal plants were retained; in the other group, only mutant leaf types were retained. The minimum number of plants/group was about 125, but most groups contained about 200 plants. No intentional selection was practiced for any characteristic except leaf type. A total of 48 populations was produced: eight super okra and their eight comparable normals; eight okra and their eight comparable normals; and eight sub okra and their eight comparable normals. In the fall of 1981, equal numbers of bolls/plant were harvested from plants within the 48 populations to produce F_3 seed for 1982 studies.

Because the method of producing genetically similar populations in this study is not the usual method of developing isogenic material for the evaluation of traits, a brief explanation of its use and history may be in order. Burton (1966) proposed using "near isogenic populations", such as in this study, over the conventional backcross procedure of developing isogenic lines. He indicated the advantages of the proposed method was that only three generations were required for the evaluation trial, while the conventional method of producing isogenic lines required about 8 to 10 generations. Further, the development of a few isogenic lines might not be representative of a broadly based breeding program. Burton suggested using this method for crops with large numbers of chromosomes, such as wheat (*Triticum aestivum* L. em Thell.), and where the heterozygous and both types of homozygous plants could be identified in the F_2 generation. Burton et al. (1968) discussed the possible influence linkage might have on pearl millet (*Pennisetum americanum* L. Leeke) near-isogenic popula-

tions. These populations differed in early and late maturity which were conditioned by at least three major genes. The proposed method was used by Meredith (1980) in searching for favorable genotypes X nectaried types interaction in cotton.

In 1982, the 48 populations were grown at three locations near Stoneville. Planting dates were 26 April, 4 May, and 11 May. The respective soil types were a Dundee silty clay (fine-silty, mixed, thermic Aeric Ochraqualfs), a Dubbs silt loam (fine-silty, mixed, thermic Typic Hapludalfs), and a Beulah fine sandy loam (coarse-loamy, mixed, thermic Typic Dystrochrepts).

The experimental design was a split-split plot with five replications at each location. The three whole plots consisted of the crosses originating from each mutant type parent. The two subplots consisted of the mutant leaf type vs the corresponding normal populations. Sub-subplots consisted of the eight populations of the same leaf type descending from the eight crosses with that leaf type. All plots of normal leaf types were grown adjacent to normal cotton, and all mutant leaf types were grown adjacent to that specific mutant type. Plot size for a sub-subplot was one row 1.0 X 5.5 m long.

The yield components (i.e., lint percentage of seed cotton in percent, boll size in grams of seed cotton/boll, and seed index in grams) were determined from 50-boll samples taken from three replications at each location. Lint yield in kg/ha was determined after hand harvesting of all plots at each location.

RESULTS AND DISCUSSION

This research was conducted over three locations and with diverse germplasm. Mean lint yields for the three environments were 1175, 1052, and 870 kg/ha. Yield of the eight normal leaf sources varied greatly (F value = 21.6) and ranged from 927 to 1099 kg/ha for the Tamcot CAMD-E and Deltapine 26 populations, respectively. No interactions with the eight normal source populations were detected with environments, mutant leaf type sources, or normal vs mutant comparisons. The mean results for lint yield and three of its components are given in Table 1. Lint percentages of super okra and okra leaf were significantly higher than their corresponding normal leaf populations, but no significant differences between sub okra and normal leaf were detected. Boll size of normal leaf cotton tended to be larger than that of the mutants though the differences were significant only in the case of super okra leaf. Seed size
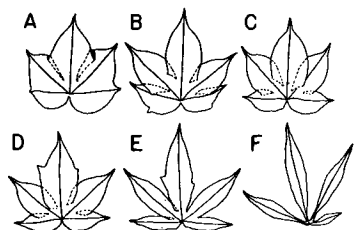
Table 1. Lint yield and yield component means of normal vs mutant leaf types over locations and genetic backgrounds.

Leaf type	Lint yield	Lint percentage	Boll size	Seed weight
	kg/ha	%	g	mg
Normal	1079**	37.0	5.49**	104**
vs				
Super okra	984	38.2**	5.28	101
Normal	1055	38.1	5.42	106**
vs				
Okra	1053	38.8**	5.35	102
Normal	988	36.8	5.75	114**
vs				
Sub okra	1035**	37.1	5.69	110

** Significantly higher LSD at the 0.01 level than its near-isogenic counterpart.

Fig. 1. Leaf outline drawings of six cotton genotypes [A. Normal (*l*), B. Sub okra (*L^u*), C. Sea-Island (*L^e*), D. Normal X okra leaf (*L^{o}l*), E. Okra leaf (*L^o*), and F. Super okra (*L^s*)].

was significantly larger in the normal leaf than in their corresponding mutant populations.

Super okra populations averaged 95 kg/ha (8.8%) less lint than their corresponding normal cotton. The interaction of super okra vs normal with environments was significant with super okra yields over genotypes varying from 32 to 207 kg/ha less lint than that for normal. No significant influence of okra vs normal leaf was detected on lint yield over locations and genetic backgrounds, i.e., they produced 1053 vs 1055 kg/ha, respectively. The mean lint yield for environments varied from an increase of 45 to a decrease of 31 kg/ha for okra leaf. The most favorable yield comparisons for super okra and okra vs normal leaf occurred in the environment which promoted the most rank growth and presumably resulted in the most shading of lower canopy leaves. Under such conditions, Jones (1982) indicated that open-canopy cotton should have its greatest competitive advantage.

In contrast to super okra and okra leaf, sub okra populations produced significantly higher lint yields than their normal leaf counterparts. Sub okra averaged 47 kg/ha (4.8%) higher yields than its corresponding normal leaf populations, and mean yields ranged from 18 to 83 kg/ha higher at the three locations averaged over genotypes than their normal counterparts. Jones (1982) compared the yield of normal leaf 'Stoneville 213' with its near-isogenic Sea-Island leaf type under Louisiana conditions and found no significant differences between the two genotypes. Sub okra and Sea-Island leaf types may be conditioned by the same gene. This investigation is the first to compare the lint yielding ability of normal vs sub okra leaf types and indicates a potential for increasing lint yields of cotton grown in the Mississippi Delta by about 5%. The genetic mechanism responsible for the increase in yield could be either linkage or pleiotropy or both.

From a probabilistic model and previous experience, the likelihood that linkage is a major contributor to the increase in yield is small. Upland cotton has 26 pairs of chromosomes; 25 pairs would be expected to be randomly distributed among the F_2 plants, independent of sub okra and normal leaf. Sub okra is located on the short arm of chromosome 15, about three recombination units from the centromere (Endrizzi et al., 1984). From its position on chromosome 15, it seems likely that at least 50% of the chromosome is 50 or more recombination units from sub okra. Assuming the chromosome region adjacent to the sub okra to be about average in the number of yield genes, then 98.1% [(25/26 + 1/2 × 1/26) × 100] of the yield genes would be distributed randomly among F_2 plants. The remaining 1.9% within 50 recombination units of sub okra will be further reduced, as some recombination occurs between the

F_1 and the F_2 generations. This region is not in linkage equilibrium, and yield genes closely linked with sub okra may introduce a bias (either positive or negative) in the yield evaluation. For a specific gene the bias due to linkage is $(1-2\theta)$, where θ is the recombination fraction. For example, if $\theta = 0.1, 0.25$, and 0.5 the bias is 0.8, 0.5, and 0.0, respectively, multiplied by the specific yield gene's effect. Generally, the influence of linkage on yield derived from triple-hybrids or other exotic germplasm has been negative. For the specific case at hand, however, we do not know the number of yield genes linked with sub okra, their recombination values, nor their effects on yield. Generally, mutants of cotton are less productive than their "normal" alleles (Kohel, 1974).

From physiological modeling studies, Landivar et al. (1983) speculated that a cotton leaf type intermediate between normal and okra leaf might confer an advantage over either leaf type. Sub okra is expressed later in plant development than other mutant leaf types and, probably for this reason, has not been used much by applied breeders. While this delayed expression of sub okra may be a negative factor in the selection process, it may be a positive factor in the developmental physiology of the plant. The sub okra type has the leaf area advantages of normal leaves in the early stages of canopy development and some of the light penetration advantages of an open-canopy cotton thereafter. This temporal alteration of canopy architecture may be responsible for the average 4.8% yield advantage observed in these studies.

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