Published September, 1987

Plant Pubescence, Genetic Background, and Seasonal Effects on Agronomic and Fiber Properties of Upland Cotton[1]

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ABSTRACT

Smooth-leaved lines of cotton (*Gossypium hirsutum* L.), although showing resistance to certain insects, have frequently been deficient in some agronomic and fiber properties. In this study, we compared lint yield, yield components, and other agronomic and fiber properties in smoothleaf and hirsute cotton in eight genetic backgrounds in 1981 and 1982, and in two backgrounds in 1983. Plots were grown at Tempe, AZ; soil type was a Contine clay loam (a fine, mixed, hyperthermic Typic Haplargid). The objective of this study was to determine whether certain deficiencies were associated consistently with the smoothleaf phenotype. The 1981 and 1982 results showed that no agronomic or fiber-property deficiencies were associated consistently with smoothleaf. In 1983, however, the smoothleaf line that had been selected for high lint yield in 1981 and 1982 yielded 36% less lint per plant than the hirsute sibling cultivar, and the smoothleaf line that had been selected for low insect damage yielded 30% less lint per plant than the hirsute cultivar. Lower lint yields in both smoothleaf lines mainly were attributable to fewer bolls per plant. These lower yields and interactions of years with level of pubescence reinforced our earlier decision, based mainly on equivocal results from insect-resistance studies, to discontinue smoothleaf lines in our breeding program except for those carrying the delta smooth (more properly, semismooth) allele, t_3

***Additional index words:* Gossypium hirsutum L., Host-plant resistance, Isolines, Smoothleaf, Semi-smoothleaf, Yield components, Genotype × environment interactions.**

Lines of upland cotton (*Gossypium hirsutum* L.) that are resistant to insect pests must also display desirable agronomic and fiber properties. Wilson and Wilson (13) observed a smooth-leaved line, W74-4-153 [carries the $T^{sm}{}_1 = Sm_2$ smoothness allele (3, 7)], that sustained less seed damage from attack by pink bollworm (PBW) [*Pectinophora gossypiella* (Saunders)], than the equivalent hirsute 'Stoneville 7A' cultivar. Wilson and George (11), however, reported equivocal results on PBW response, and noted lower yields and deficiencies in other agronomic properties in a smoothleaf version of La 71-7, also in a Stoneville genetic background. Lee (4, 5) observed, in a smoothleaf isoline of 'Coker 310', a significant reduction in lint percentage and fiber length, and a significant increase in micronaire index (coarser fiber). However, he developed a smoothleaf line, designated NC-177-16-30, that combined high lint percentage with long, strong, and fine fiber (6).

Those conflicting results prompted us to reevaluate smoothleaf in several genetic backgrounds. Wilson and George (12) observed that, in 1981 and 1982, seed damage from attack by PBW was significantly lower for only one of eight smoothleaf isolines, when compared to the respective hirsute or semi-smoothleaf cultivars and breeding stocks. Their data also suggested that some smoothleaf lines may have been more susceptible to early season insects (more squares shed), but more resistant to cotton leafperforator (*Bucculatrix thurberiella* Busck.). Mean seed cotton yield was not significantly different for the smoothleaf lines and the cultivars and breeding stocks. In 1983, the selected smoothleaf line continued to show less seed damage from PBW attack (no other insect data were obtained). However, that line, and another smoothleaf line that had been selected for high yield, yielded significantly less seed cotton than the two comparable hirsute cultivars.

In the current study, we compare lint yield, yield components, and other agronomic and fiber properties of smoothleaf lines with hirsute and semi-smoothleaf cultivars and breeding stocks in a number of genetic backgrounds. There are data from 3 yr, and the objective was to determine whether lower yields or deficiencies in yield components and other agronomic or fiber properties were associated consistently with the smoothleaf trait.

MATERIALS AND METHODS

We grew one semi-smoothleaf cultivar [$2(t_3)$], 'Deltapine 16'; six hirsute cultivars, 'Stoneville 213', Coker 310, 'Auburn 56', 'Coker 201', 'TH-149', and 'Delcot 277'; one hirsute breeding stock, PD 2165; and the eight smoothleaf isolines (designated Aub-Sm-16, Aub-Sm-213, etc.) at the Arizona State University Farm Laboratory, Tempe, in 1981 and 1982. Shepherd (9) described the smoothleaf isolines. The source of smoothleaf was the N.C. Smooth -1 or N.C. Smooth -2 allele ($T^{sm}{}_1$) except for Aub-sm-56. The smoothleaf source of Aub-Sm-56 was probably t_3, because it came from upland sources used in the breeding program at Auburn, AL (9, 10). However, Aub-Sm-56 probably possesses some modifiers because leaves are smoother than the typical phenotype conditioned by t_3. All smoothleaf isolines were BC_6F_3 in 1981 and 1982 except Aub-Sm-56, which was BC_5F_3 in 1981 and BC_5F_4 in 1982. From those experiments we selected the only smoothleaf isoline, Aub-Sm-56, that sustained significantly less seed damage than its hirsute cultivar, and the one that yielded the most lint, Aub-Sm-213. We compared those two smoothleaf isolines with the respective hirsute cultivars, Auburn 56 and Stoneville 213, in 1983. We also included Lee's smoothleaf [$2(T^{sm}{}_1)$] line, NC-177-16-30, in the 1983 experiment.

Soil type at the Tempe location is a Contine clay loam (a fine, mixed, hyperthermic Typic Haplargid). The design for all experiments was randomized complete blocks with four replications. Individual plots were four adjacent rows 9.1-m in length on 1-m centers. Cotton seed was planted with a four-row planter in mid-April each year. In 1981 and 1982, plots were planted on land that had been planted with cotton 4 and 5 yr, respectively. In 1983, plots were planted on land that had been planted to barley (*Hordeum vulgare* L.) the previous season. As a result, soil fertility was significantly higher in 1983 than in 1981 or 1982. Plants were hand-thinned to 30 cm apart in one inside row of each plot. Cultural practices were standard for the area except that no insecticides were applied.

[1] Contribution from USDA-ARS, Phoenix, AZ, in cooperation with the Arizona Agric. Exp. Stn. and the Mississippi Agric. and Forestry Exp. Stn. Received 24 Nov. 1986.

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Published in *Crop Sci.* 27:865–868 (1987).

The number of open bolls from 10 plants in the thinned row of each plot was counted and seed cotton from these plants was harvested biweekly, starting at the time the bolls began to open in mid-August until the harvest was completed in late October or early November.

Data were taken on lint yield per plant and the yield components bolls per plant, seeds per boll, and lint weight per seed (2). We also estimated lint percentage [lint yield/seed cotton yield × 100]. From second-harvest samples we obtained mean weight per seed (based on 100 seed) and fiber properties (based on a 15-g sample of lint per plot). Fiber properties, determined at the USDA-ARS Fiber Testing Laboratory, Phoenix, AZ, included 2.5 and 50% span fiber length, fiber strength (tenacity: T_1), percent fiber elongation (E_1), and micronaire index, a measure of fiber fineness (the lower the index the finer the fiber). The *F* tests were based on a fixed model. Data were analyzed by analysis of variance and means were compared with the use of a preliminary *F* test the least significant difference (FLSD) (1).

RESULTS AND DISCUSSION

The yield and yield component data are not presented for all cultivars, breeding stocks, and smoothleaf lines grown in 1981 and 1982. Briefly, only two of the eight smoothleaf lines yielded significantly less lint per plant than the respective semi-smoothleaf cultivar or hirsute breeding stock. Aub-Sm-16 had significantly less lint per plant than Deltapine 16 because there were fewer seeds per boll and fewer bolls per plant. Aub-Sm-165, however, combined less lint per plant than PD 2165 because it had less lint per seed with fewer bolls per plant. The highest yielding smoothleaf line, Aub-Sm-213, did not yield significantly less lint per plant than any of the hirsute or semi-smoothleaf cultivars and breeding stock, and, in fact, yielded significantly more than three hirsute cultivars and six smoothleaf lines. Aub-Sm-56, selected for lowest seed damage by PBW, did not yield significantly less lint per plant than the six hirsute cultivars and one breeding stock, and yielded significantly more than one smoothleaf line, Aub-Sm-165.

Six of the eight smoothleaf lines had significantly lower lint percentages than the hirsute or semi-smoothleaf counterparts. Lower lint percentages were a consequence of less lint per seed, higher seed weight per seed, or a combination of both. Our results agree with those of Lee (4), who observed that the lower lint percentage of a smoothleaf isoline of Coker 310 was caused by a combination of lower lint index (lint weight per 100 seeds) and higher seed index (seed weight per 100 seeds).

Thus, the 1981 and 1982 data suggested that lint yield was not necessarily lower for a smoothleaf line than for the hirsute counterpart. However, results from the tests of 1983 were quite different. Both of the hirsute cultivars, Auburn 56 and Stoneville 213, yielded significantly more lint per plant in 1983 than in 1981 or 1982, and significantly more than the smoothleaf lines (Table 1). Bolls per plant was the major yield component that contributed to the higher yields of the two cultivars in 1983. We do not know why the smoothleaf lines did not respond in a similar manner to the improved environment in 1983. Increased sus-

Table 1. Lint yield, yield components, and other agronomic properties of hirsute cultivars and smoothleaf lines (Aub-Sm-) of cotton, Tempe, AZ, 1981 to 1983.

Cotton	Year	Lint per plant	Bolls per plant	Seeds per boll	Lint per seed	Seed wt. per seed	Lint percentage
		g	no.		mg		%
Auburn 56	1981	31.6a†	23.5ab	26.7ab	45.4ab	112.5b	31.4bc
Aub-Sm-56	1981	22.3b	16.6c	24.2b	51.3a	124.6a	30.8c
Stoneville 213	1981	28.9ab	20.2bc	29.5a	44.4b	102.1c	35.5a
Aub-Sm-213	1981	34.1a	26.1a	26.8ab	44.2b	107.7bc	32.6b
Auburn 56	1982	27.5b	18.8a	29.0ab	55.1ab	119.0a	35.6b
Aub-Sm-56	1982	30.9a	20.9a	26.4b	59.0a	110.9ab	35.8b
Stoneville 213	1982	31.1a	20.9a	28.0b	55.0ab	104.9b	36.9a
Aub-Sm-213	1982	30.9a	18.7b	32.8a	49.7b	109.7b	36.0ab
Auburn 56	1983	58.3a	39.7a	24.9a	57.4ab	119.1a	34.3c
Aub-Sm-56	1983	37.3b	27.8b	24.7a	54.2ab	120.7a	32.8c
Stoneville 213	1983	53.6a	35.1a	23.8a	60.2ab	104.3b	38.4a
Aub-Sm-213	1983	28.3c	21.8b	26.7a	52.0b	120.3a	33.5c
NC-177-16-30	1983	12.1d	11.2c	18.5b	62.4a	113.4ab	36.6b
Auburn 56	3-yr	39.1a	27.3a	26.9ab	52.6ab	116.9ab	33.7bc
Aub-Sm-56	3-yr	30.2b	21.8c	25.1b	54.8a	118.7a	33.1c
Stoneville 213	3-yr	37.9a	25.4ab	27.1ab	54.2ab	103.7c	36.9a
Aub-Sm-213	3-yr	30.4b	22.2bc	28.7a	48.6b	112.5b	34.1b

Analysis of variance

Source	df	Mean squares					
Years (Y)	2	1198.0**	585.2**	64.1*	440.9**	118.7	50.8**
Reps within Y (R)	9	50.4	19.3	13.1	36.0	61.6	1.4
Pubescence (P)	1	809.3**	233.2**	0.1	16.6	340.8**	35.9**
Genetic background (G)	1	3.3	7.2	44.9*	94.6	1114.6	50.5**
P × G	1	6.7	16.1	35.8*	140.1**	144.5	15.5**
Y × P	2	671.7**	200.9**	19.5	74.3	147.2**	22.6**
Y × G	2	135.5*	72.1*	6.8	29.6	48.6	7.9**
Y × P × G	2	127.5*	83.4*	4.8	4.6	136.5*	5.2*
Error	27	32.3	17.7	5.9	32.4	38.1	1.1

*,** Specified variance is significantly higher than the error variance at the 0.05 or 0.01 levels of probability, respectively (error variance for Y is R mean square; error variance for all other effects is error mean square).

† Means with letter(s) in common, within column and year (or 3-yr mean), are not significantly different, according to the FLSD test (1).

ceptibility to early season insects, leading to higher square or boll shed, could explain the lower yield of Aub-Sm-213, but probably not of Aub-Sm-56 (12). Unfortunately, we have no relevant early season insect data for 1983.

Combined analyses over 3 yr are remarkably similar for lint yield per plant and bolls per plant (Table 1). Year and pubescence (smoothleaf vs. hirsute) effects and all of the year interactions were significant. The interactions occurred mainly because the 1983 results were strikingly different from the 1981 or 1982 results.

The other two yield components, lint weight per seed and seeds per boll, were not significantly higher for the hirsute cultivars than for the smoothleaf lines, although there was a trend in that direction for lint weight per seed. Combined analysis of lint weight per seed showed a significant year main effect and a significant pubescence × genetic background interaction effect. Interactions involving years were not significant. Combined analysis of seeds per boll was similar to that of lint weight per seed except that, for seeds per boll, the genetic background effect was significant. The lack of significant pubescence effects and year × other variable interactions for lint weight per seed and seeds per boll emphasizes the consistency of those yield components for both the hirsute cultivars and smoothleaf lines.

Lint percentage was not significantly lower for Aub-Sm-213 and Aub-Sm-56 than for Auburn 56, but it was significantly lower in all three than for Stoneville 213. The lower lint percentage for Aub-Sm-213 as compared to Stoneville 213 was a consequence of the combined effects of lower lint weight per seed and higher seed weight per seed. Our data on NC-177-16-30 confirm Lee's (6) report that he developed a smoothleaf line with a high lint percentage. Although NC-177-16-30 did not have as high a lint percentage in our experiments as it did in Lee's, and was otherwise not well adapted to the Arizona environment, it had a significantly higher lint percentage than Aub-Sm-56 or Aub-Sm-213. The higher lint percentage of NC-177-16-30 was caused by a combination of higher lint weight per seed and lower seed weight per seed than occurred in the other two smoothleaf lines. Presumably it would not be difficult to increase lint percentage in other smoothleaf lines by using the NC-177-16-30 germplasm because lint weight per seed, seed weight per seed, and lint percentage itself are all highly heritable (8).

All main effects and interactions were significant for lint percentage. The year interactions occurred mainly because the range of means was much narrower in 1982 than in 1981 or 1983. For seed weight per seed, all main effects (except years), the year × pubescence interaction, and the second-order interaction, were significant. The year × pubescence interaction occurred because seed weight per seed was lower for the hirsute cultivars in 1981 and 1983 but not in 1982. The second-order interaction occurred because the smoothleaf vs. hirsute relationship was inconsistent over years in the Auburn 56 background but consistent in the Stoneville 213 background.

Fiber properties are not shown for the smoothleaf lines, cultivars, and breeding stocks in all eight genetic backgrounds that were grown in 1981 and 1982. Briefly, mean fiber elongation was significantly lower for the smoothleaf lines than for the cultivars and breeding stock. However, fiber elongation was not significantly lower for three smoothleaf lines, and was significantly higher for one smoothleaf line than for the respective hirsute cultivars. Mean fiber length and fiber tenacity were significantly higher for the smoothleaf lines but mean micronaire index values were not significantly different.

Combined data for the four cotton entries that were grown all 3 yr show that 2.5% fiber span length was significantly higher for Aub-Sm-213 than for the other three cotton entries, and significantly higher for the Stoneville 213 background than for the Auburn 56 background (Table 2). The pubescence × genetic background interaction occurred because Aub-Sm-213 had longer fiber than Stoneville 213 but Aub-Sm-56 and Auburn 56 did not differ significantly.

Only the genetic background effect was significant for 50% fiber span length and for fiber tenacity. Fiber elongation was significantly lower for the two smoothleaf lines than for the cultivars. All of the year interactions for fiber elongation were significant because of the inconsistent means over years. For example, in 1981, fiber elongation was significantly lower in Aub-

Table 2. Fiber properties of hirsute cultivars and smoothleaf lines (Aub-Sm-) of cotton, Tempe, AZ, 1981 to 1983.

Cotton	Year	Fiber span length 2.5%	Fiber span length 50%	Fiber tenacity	Fiber elongation	Micronaire index
		mm	mm	kN m kg⁻¹	%	
Auburn 56	1981	26.7b†	12.4a	175.8b	6.0a	4.13b
Aub-Sm-56	1981	27.1b	12.5a	188.1ab	4.8b	4.13b
Stoneville 213	1981	26.7b	12.6a	190.3ab	5.7a	4.66a
Aub-Sm-213	1981	28.4a	13.0a	197.0a	5.9a	4.76a
Auburn 56	1982	26.0c	12.1b	187.4a	5.8a	4.29b
Aub-Sm-56	1982	26.6c	12.2b	183.7a	5.7a	4.08b
Stoneville 213	1982	27.8b	12.6ab	188.4a	6.1a	4.27b
Aub-Sm-213	1982	28.8a	13.0a	192.3a	5.1a	4.72a
Auburn 56	1983	26.9b	12.6b	170.5c	9.4a	4.01bc
Aub-Sm-56	1983	27.0b	12.1b	166.8c	7.8b	3.79c
Stoneville 213	1983	27.6b	12.4b	174.4c	8.2b	4.18ab
Aub-Sm-213	1983	30.3a	13.6a	199.4b	6.5c	4.42a
NC-177-16-30	1983	30.4a	14.0a	222.0a	8.9a	4.11a-c
Auburn 56	3-yr	26.5b	12.4b	178.0b	7.1a	4.14bc
Aub-Sm-56	3-yr	26.9b	12.3b	179.5b	6.1b	4.00c
Stoneville 213	3-yr	27.4b	12.5b	184.3ab	6.7a	4.37ab
Aub-Sm-213	3-yr	29.2a	13.2a	196.2a	5.8b	4.63a

Analysis of variance

Source	df	Mean squares				
Years (Y)	2	2.5	0.19	540.1	28.5**	0.44**
Reps within Y (R)	9	1.2	0.65	521.4*	1.3	0.10
Pubescence (P)	1	13.8**	0.91	540.0	10.0**	0.04
Genetic background (G)	1	29.0**	3.34*	1596.2*	1.3	2.21**
P × G	1	6.4*	1.94	319.5	0.1	0.50*
Y × P	2	0.4	0.01	131.7	1.7*	0.01
Y × G	2	2.2	0.06	178.6	2.6**	0.07
Y × P × G	2	1.3	0.75	305.3	1.3*	0.08
Error	27	1.1	0.46	223.8	0.3	0.10

*,** Specified variance is significantly higher than the error variance at the 0.05 or 0.01 levels of probability, respectively (error variance for Y is R mean square; error variance for all other effects is error mean square).

† Means with letter(s) in common, within column and year (or 3-yr mean) are not significantly different, according to the FLSD test (1).

Sm-56 than in the other three cotton entries; in 1982, none of the cotton entries differed significantly; and in 1983, fiber elongation was significantly lower for both smoothleaf cotton entries than for the respective cultivars.

The micronaire index was significantly higher for the cotton entries in Stoneville 213 background than for those in Auburn 56 background. The pubescence × genetic background interaction was caused by a lower value for Aub-Sm-56 than for Auburn 56, but a higher value for Aub-Sm-213 than for Stoneville 213. No year interactions were significant for micronaire index.

As Lee (6) showed, NC-177-16-30 not only has a high lint percentage, the cotton also has superior fiber properties, combining greater length, tenacity, and elongation with an acceptable micronaire index. Aub-Sm-277 was the only one of the eight smoothleaf lines that apparently compared favorably with NC-177-16-30 for fiber properties. We have no direct comparison of those two lines, but do have the comparison of the two with Aub-Sm-213. In 1981 and 1982, Aub-Sm-277 equaled Aub-Sm-213 in fiber length (28.3 vs. 28.6 mm) and had higher fiber tenacity (229.0 vs. 194.6 kN m kg^{-1}), and elongation (7.3 vs. 5.5%) and a significantly lower micronaire index (4.11 vs. 4.74). Similarly, in 1983, NC-177-16-30 equaled Aub-Sm-213 in fiber length, had higher tenacity and elongation, and a lower micronaire index (micronaire index: 0.10 probability level) (Table 2).

Some of our results are at variance with those of Lee (4), who found that a smoothleaf isoline of Coker 310 had shorter and coarser fiber but higher fiber elongation than the hirsute control. None of the smoothleaf lines in our experiments, including Aub-Sm-310, had significantly shorter or coarser fiber, or higher fiber elongation than the respective hirsute cultivars.

In summary, smoothleaf lines have the potential of being equal to hirsute cultivars for agronomic and fiber properties. We identified one smoothleaf line, Aub-Sm-277, with superior fiber properties, and Lee (6) identified another, NC-177-16-30, that combines a high lint percentage with superior fiber properties. Bolls per plant was the only yield component that was deficient for the three smoothleaf lines that were grown in 1983 (except that seeds per boll was also deficient in NC-177-16-30). That deficiency was great enough, however, to cause us to question the advisability of growing cultivars that exceed the level of smoothness associated with t_3, the delta smooth (or more properly, semismooth) allele. In fact, this result reinforces our decision (12) to use semi-smoothleaf germplasm rather than smoothleaf germplasm in our breeding program.

ACKNOWLEDGMENTS

We thank Benny Stapp and Jayne Szaro for technical assistance, J.S. Byrd for maintaining field plots, and C.V. Feaster for processing fiber samples.

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