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Effects of the Density of Pubescence on Some Traits of Extra-long-stapled Cotton[1]

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ABSTRACT

Most modern cultivars of extra-long-stapled cotton (*Gossypium barbadense* L.) display glabrous stems and variable densities of pubescence on leaves. These cottons produce long, strong, and fine fibers. The Tanguis cultivars, and the American Pima Stock, E-2, produce coarse, although lengthy and strong, fibers. Because Tanguis and E-2 have dense tomentum on leaves and stems, there arose the question of whether grade of plant vestiture affected fiber fineness and perhaps other fiber and agronomic traits. Three phenotypes, normally pubescent, hirsute, and glabrous, were fixed in 'Pima S-5', Coastland Sea Island, and 'Seabrook Sea Island', selection AS-2. The nine resulting entries were grown in replicated experiments at two locations in North Carolina in 1983. Compared with normal, the hirsute phenotype of AS-2 showed significantly increased lint percentage, and glabrousness reduced lint percentage significantly in AS-2 and Pima S-5. Hirsuteness significantly reduced g seed cotton boll^{-1} and lint index in Coastland. Glabrousness significantly reduced 2.5% span fiber length in AS-2 and length uniformity index was reduced in both hirsute and glabrous Coastland. Fiber tenacity was significantly reduced in glabrous Coastland, and hirsute Coastland showed a significant reduction in fiber elongation. None of the phenotypes affected micronaire values in any of the families. Increased pubescence was associated with fewer deficits in agronomic and fiber traits than glabrousness, and each of the Sea Island cottons showed more significant changes in the traits sampled than Pima S-5.

***Additional index words:* *Gossypium armourianum* Kearn., *Gossypium barbadense* L., *Gossypium hirsutum* L., *Gossypium tomentosum* Nutt. ex Seem., Fiber length, Fiber tenacity, Fiber elongation, Lint percentage, Lint index, Seed index.**

MOST cultivars of *Gossypium barbadense* L., cotton that furnishes long and strong fibers for the production of sewing thread and luxury fabrics, display sparse to moderately dense pubescence on leaves and glabrous stems. The Tanguis cultivars of Peru are exceptional in that these cottons do not display glabrous stems, the entire plant of a typical cultivar, such as 'Tanguis 52/A', being extremely pubescent. This pubescence is conditioned, according to Knight (5), by an allele, H_1, acting in concert with an array of modifiers.

Unlike Egyptian, Pima, and Sea Island cvs., all of which display glabrous stems and sparse to moderately dense pubescence on leaves, Tanguis cotton produces coarse, although lengthy, fibers. A fiber specimen of Tanguis 52/A grown at the Central Crops Research Station, Clayton, NC in 1983 assayed a 2.5% span fiber length of 34 mm and a micronaire value of 5.2 in comparison with 'Pima S-5' which assayed corresponding values of 33 mm and 4.1 from material grown in the same row.

Kirk et al. (4), working in west Texas and New Mexico, compared the performances of E-2, a pubescent line of Pima cotton, and 'Pima S-4', a less pubescent cultivar favored at the time. E-2 was significantly more productive than Pima S-4 and differed in fiber traits only in that micronaire was significantly greater. The authors concluded that the dense vestiture of E-2, which included pubescent stems, was causally related to the stock's superior performance, of which increased micronaire was thought to have been an important component.

Workers in the Sudan have attempted to incorporate the hairiness alleles, H_1 and H_2, into the Egyptian cv. Domains Sakel to promote resistance to jassids (*Empoasca* sp.). Dark (1) stated that H_2, the fuzzy leaf, or Pilose, allele, did not alter fiber length in Sakel background. Earlier Simpson (18) reported that

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in *G. hirsutum* L. background Pilose drastically shortened fiber and increased micronaire. Dark gave no measures of fiber fineness.

In 1954, Knight (6) stated that the presence of H_1 in Sakel did not alter fiber quality, but in 1959 Rose (16) reported that increased hairiness impaired fiber quality in Sakel and reduced fiber yield. No comparative measures of fiber traits were given. Thus, the only reasonably clear documentation for any association between tomentum grade and changes in fiber properties of *G. barbadense* concerns fiber fineness.

Some "primitive" accessions of *G. hirsutum* are entirely glabrous on all vegetative surfaces (7). Lee (10, 11) showed that certain of the alleles conditioning such glabrousness, and particularly the Sm_2 allele, were associated with unfavorable alterations of some fiber traits, and with a reduction in lint percentage. Later, Lee (12) showed that the involvement of Sm_2 with fiber quality and quantity deficits was not irrevocable. Indeed, an experimental stock of *G. hirsutum*, NC-177-16-30, a cotton homozygous for Sm_2, exceeded some cultivars in agronomic and fiber traits. Changes in linkage relationships were believed to have promoted the improvements.

Glabrousness of an extreme grade, such as is noted in the *G. hirsutum* accession WH-219 for example (7), does not appear to occur naturally in *G. barbadense*. Although glabrous stem, imparted by the Sm_1^{sI} allele (8), is widespread in the species, I have not noted any cultivars or race stocks with entirely glabrous leaves. Such a phenotype can be readily recovered from hybrid populations stemming from crosses between *G. barbadense* and *G. hirsutum* and fixed on backgrounds that are essentially *G. barbadense*. In this report, I compare the effects of three phenotypes, normally pubescent, increased pubescence (hirsute), and glabrous on some agronomic and fiber traits in the backgrounds of three stocks of *G. barbadense*.

MATERIALS AND METHODS

Derivation of the Entries

In 1972, a stock of *G. barbadense*, Coastland Sea Island, was crossed with the *G. hirsutum* cv. Empire and in 1973 an F_2 was grown from the cross in the field. Coastland displays moderately dense pubescence on leaves and glabrous stems. Empire is more hirsute than Coastland, and the pubescence extends to the stems. Among the segregates were some that were entirely glabrous and others that were more pubescent than Empire. Smooth and densely pubescent segregates were crossed back to Coastland, and, after five additional generations of backcrossing, I selected, on what was essentially Coastland background, true-breeding populations that were entirely glabrous, normally pubescent, and very pubescent.

The glabrous phenotype assorted as a monogenic alternative to the normally pubescent phenotype of Coastland, which led me to conclude that some unidentified factor from Empire was interacting with Sm_1^{sI}, the glabrous-stem allele of Coastland (8), to impart the new phenotype. At least two genetic substitutions were involved in increased pilosity. One was the exchange of the sm_1 (first pubescence) allele of Empire for Sm_1^{sI} and the other involved a marked increase of pilosity on leaves, possibly from the inclusion of the sm_2 (second pubescence) allele of Empire. I did not determine whether the introduction of sm_1 alone conditioned increased pubescence on the leaves of Coastland, but did become aware that increased leaf pubescence could be obtained in the presence of the smooth stem allele, as had been reported earlier by Saunders (17) for Domains Sakel.

Subsequent to the fixing of increased pubescence and glabrousness in Coastland, both characteristics from Coastland were transferred to the modern *G. barbadense* cv. Pima S-5 and from Pima S-5 to selection AS-2 from the obsolete *G. barbadense* cv. Seabrook Sea Island. Pima S-5 is noted for long and strong fiber, medium fiber fineness, and high yield in the Southwestern USA (3). AS-2 produces long, strong, and fine fiber, but has a very low yield potential. Coastland is intermediate between Pima S-5 and AS-2 in most agronomic and fiber traits.

Seed were increased for the planting of nine entries, the three phenotypes on each of the cultivar backgrounds. The normally pubescent entries were taken as segregates from the final generation of backcrossing used for fixing glabrousness and increased pubescence in the three cottons, "normal" seeds from each program being pooled to supply the control entries.

Experimental Procedures

Experiments were planted in randomized complete blocks at two locations in North Carolina in 1983. There were six replications per location, each plot within a replication consisting of 12 hills of three plants (maximum) planted 50 cm apart; the plots were on 1 m centers. At the first location, the Central Crops Research Station, Clayton, the soil was Dothan sandy loam, a member of the fine-loamy, siliceous, thermic Plinthic Paleudults, and at the second location, the Upper Coastal Plains Research Station, Rocky Mount, Marlborough silt loam, a member of the clayey, kaolinitic, thermic Plinthic Paleudults. Except for 70 mm of irrigation at the first station, and 40 mm at the second, in July, cultural practices standard for cotton in the region were used throughout the season.

On 20 August trichome counts were taken from 1 cm transects of abaxial leaf surface of the normal and hirsute entries, two mature leaves from about the fifth node below the terminal being taken from each plot at both locations.

At harvest—20 October—a 50-boll sample was taken at random from each plot at both locations and the samples ginned on a microroller gin. Data were taken on i) lint percentage—percent of the harvest that was lint, ii) g of unginned cotton per boll, iii) lint index—mg lint 100 seed^{-1}, and iv) seed index—mg 100 seed^{-1}.

Fifteen grams of lint from each entry in three replications per location were sent to the USDA-AMS Fiber Laboratory, Clemson SC, for analysis. Data were taken on the following traits: i) 2.5% span fiber length—the distance in mm on a test specimen spanned by 2.5% of the fibers scanned at the starting point; ii) 50% span fiber length—the distance in mm spanned by 50% of the fibers treated as in (i); uniformity index—100 times the ratio of 2.5% span fiber length to 50% span fiber length; iv) tenacity—the force required to break a flat bundle of fibers divided by the linear distance when the jaws of the breaking device are spaced 3.2 mm apart and expressed as kilonewtons per m in kg of force; v) micronaire—a measure of airflow through a specimen of fiber that relates to the surface area of the fibers exposed to the air. Micronaire can be a measure of fiber fineness and/or maturity, and vi) elongation—the percentage elongation at breakage of the center 3.2 mm of fiber assayed for tenacity.

All data were processed through ANOVA to secure error variances for the estimation of Tukey's honestly sig-

Table 1. Trichomes per 1 cm transect of abaxial surface of leaf for six entries of *Gossypium barbadense*.

Entry	Mean
Pima S-5	
normal	9.6 d
hirsute	16.5 c
AS-2	
normal	2.9 e
hirsute	23.1 a
Coastland	
normal	8.7 d
hirsute	20.7 d
Tukey's $HSD_{0.05}$	2.1

Table 2. Comparison of various agronomic traits of three phenotypes within three cultivars of *Gossypium barbadense*.

Entry	Lint percentage	Seed cotton/boll	Seed index	Lint index
	%	g	mg	
Pima S-5				
normal	40.1 a	3.48 b	117 c	80 b
hirsute	40.1 a	3.42 bc	120 c	83 a
glabrous	37.0 b	3.49 b	127 bc	75 c
AS-2				
normal	20.0 e	3.10 cd	144 ab	38 h
hirsute	22.2 d	2.81 d	138 b	41 g
glabrous	14.9 f	2.79 d	151 a	28 i
Coastland				
normal	31.2 c	3.60 ab	130 bc	61 e
hirsute	31.1 c	3.10 cd	120 c	55 f
glabrous	30.8 c	3.92 a	136 b	64 d
Tukey's $HSD_{0.05}$	1.8	0.35	11	2

nificant differences at the 0.05 level of significance. The means and differences were presented in Tables 1 through 3.

RESULTS AND DISCUSSION

In Table 1, Pima S-5 and Coastland normals were about equally pubescent, and normal AS-2 was only sparsely hairy. Among the hirsute entries, AS-2 was the most pubescent, followed closely by Coastland. Pima S-5 was significantly less hirsute than the Sea Island entries, and that afforded somewhat of a surprise. There was no reason, a priori, to suspect that the least pubescent entry would become the most pubescent after the introduction of germplasm from *G. hirsutum*. It is unlikely that Pima S-5 received less such germplasm than the other cultivars because the transfer was routed from Coastland, through Pima S-5, to AS-2. The most obvious explanation seems to be that the Pima S-5 background has less potential for the development of pubescence than those of the Sea Island stocks. All glabrous entries were devoid of trichomes on all vegetative parts.

In Table 2 only AS-2 among the hirsute entries showed a significant change in lint percentage when compared with the control. The gain of 2.2% seemed related to a significant gain in lint index—41 mg against 38 mg for the control—coupled with no significant change in seed index. Among the glabrous entries, both Pima S-5 and AS-2 showed significant losses in lint percentage. In both entries there was a significant diminution in lint index, when compared

Table 3. Comparison of various fiber traits of three phenotypes within three cultivars of *Gossypium barbadense*.

Entry	2.5% span fiber length	50% span fiber length	Uniformity index	Fiber tenacity	Elongation	Micronaire
	mm		%	kNm kg^{-1}	%	μg in^{-1}
Pima S-5						
normal	32.7 e	17.6 ab	52.8 a	270.1 bc	7.5 abc	4.2 abc
hirsute	33.0 de	17.5 ab	52.2 ab	259.9 c	7.9 a	4.4 ab
glabrous	33.4 de	18.3 ab	54.0 a	274.6 bc	7.7 ab	4.6 a
AS-2						
normal	42.5 a	18.7 ab	43.2 c	287.3 ab	5.7 fg	2.6 d
hirsute	43.0 a	18.7 ab	43.0 c	296.7 a	5.5 g	2.6 d
glabrous	40.3 b	17.4 b	42.5 c	272.4 bc	6.2 efg	2.6 d
Coastland						
normal	34.0 cde	18.8 a	54.3 a	270.1 bc	7.1 bcd	4.0 bc
hirsute	34.6 cd	17.8 ab	50.3 b	270.9 bc	6.3 ef	3.8 c
glabrous	35.0 c	17.8 ab	50.0 b	225.3 d	6.9 cde	4.2 abc
Tukey's $HSD_{0.05}$	1.8	1.3	2.7	21.0	0.7	0.4

with the control, and no significant change in seed index.

Data on fiber traits are presented in Table 3. Disturbances were few. Only glabrous AS-2 differed significantly from the family control for 2.5% span fiber length, and both of the experimental entries for Coastland differed significantly from the control in length uniformity index. Thus, overall, the effects of the degree of hirsuteness on fiber length measures were minimal.

The glabrous entry for Coastland showed a drastic reduction in fiber tenacity. Neither the glabrous, nor the hirsute, entry for AS-2 differed in fiber tenacity from the control, although the experimental entries diverged significantly, changes that were not accompanied by divergences in micronaire values. In fact, there were no significant changes in micronaire value within any of the families, and that came as somewhat of a surprise. The bulk of the evidence from past work, and particularly that of Kirk et al (4), suggests that increased hirsuteness in *G. barbadense* should be accompanied by increased micronaire. The current evidence suggests that there is no general relationship between density of plant vestiture and fiber fineness, but does not negate the possibility that there are specific genes that simultaneously increase pilosity and micronaire.

Lee (9) reviewed the evidence that the Pilose allele is associated with increased micronaire in *G. hirsutum* and found it compelling. Still, in the same report Lee showed that the H_2 allele from *G. tomentosum* Nutt. ex Seem., an allele at the same locus as Pilose (2), and one with similar effects on vegetative parts, did not increase micronaire nor significantly shorten lint of the upland cv. Empire. Thus, not all tomentum alleles affect lint fibers in a like manner.

As shown earlier, Tanguis cottons produce coarse, although lengthy, fibers. I have not counted trichomes on leaf sectors of Tanguis, but casual observations of plants of Tanguis 52/A suggests that the density of pubescence on leaves is as great as, or greater than, that on hirsute AS-2. Knight (5) attributed the dense pubescence of Tanguis to H_1, an allele known from several species of *Gossypium*. Since Endrizzi and Ramsay (2) showed that H_1 and H_2 occur at a common locus in the A subgenome of tetraploid cottons, the identity of the tomentum allele of Tanguis became moot. To this observer, the tomentum of Tanguis 52/A resembles that imparted by H_2 more closely than that conditioned by the H_1 allele of MU8b, Knight's classical source of the gene. That belief is supported by the observation that Tanguis 52/A is homozygous for Sm_1^{sl}, the dense tomentum masking the effects of the smooth stem allele (13). Similarly, Ramey (14) showed that in *G. hirsutum* the Pilose morph of H_2 masked the expression of the D_2 Smooth allele, the *G. armourianum* Kearn. morph of Sm_1^{sl}. Ramey further showed that H_1 is not epistatic to D_2 Smooth.

Tanguis has been used in programs to improve Pima cotton (Carl Feaster, personal communication). Knight (6) documented the use of hairiness genes from Tanguis in Domains Sakel cotton, stating that the genes had no detrimental effects on fiber quality, a conclusion later contradicted by Rose (16). The hirsuteness and increased micronaire of E-2 might have stemmed from Tanguis, but the fact that a sample of E-2 grown at Raleigh displayed both hirsute and smooth stems suggests that the increased tomentum came from *G. hirsutum*. If so, there seems to be little likelihood that there is a direct relationship between the hirsuteness of E-2 and the coarse fiber of the strain. Still, the increased micronaire of E-2 could have stemmed from *G. hirsutum* independently of increased tomentum on leaves and stems.

In summary, I could find little evidence that merely increasing the density of pubescence on vegetative parts of an assortment of *G. barbadense* cultivars had any significant effects upon a series of fiber traits, and there were no pronounced effects on the abundance of lint on the seed. Glabrousness was associated with more effects on fiber, particularly on length and tenacity in the Sea Island cultivars. Moreover, glabrousness reduced lint percentage in two of the cultivars. The loss in lint percentage associated with glabrousness was the only significant deficit recorded for the Pima S-5 family.

As far as I am aware, glabrousness is novel in *G. barbadense*, and it is perhaps not surprising that there are pleiotropic effects associated with the character and that cultivars differ in the extent of such effects. Lint hairs are modified trichomes, and glabrousness seems to have impinged upon the abundance and/or quality of these in all of the families.

The presence of trichomes on the leaves of *G. barbadense* is not novel, and, perhaps as a result, the ancillary effects of increased pubescence were minor. The most notable was an increase in lint index in AS-2, the cotton that showed the greatest increase in trichome number per unit of leaf surface.

Kirk et al. (4) emphasized that increased pilosity in Pima cotton probably is undesirable even if associated with increased fiber yield. The lowering of fiber grade associated with increased trash content would very likely compensate for gains in field performance in terms of monetary losses to the grower. Fiber grade should be less of a problem with machine-harvested cotton from glabrous cultivars. Indeed, there should be a gain in grade, and the possibility of antixenosis to lepidopterous pests, as demonstrated by Robinson et al. (15) for smooth stocks of *G. hirsutum*. It remains to be seen if smooth stocks of *G. barbadense* are more susceptible to some other insect pests, and the problem of lowered lint percentage would require correction.

REFERENCES

1. Dark, S.O.S. 1960. Plant hairiness and staple length in cotton. Emp. Cotton Grow. Rev. 37:266–267.
2. Endrizzi, J.E., and G. Ramsay. 1983. Inheritance of H_1, H_2 and Sm_2 genes in cotton. Crop Sci. 23:449–452.
3. Feaster, C.V., E.F. Young, Jr., and E.L. Turcotte. 1980. Comparison of artificial and natural selection in American Pima cotton under different environments. Crop Sci. 20:555–558.
4. Kirk, I.W., C.K. Bragg, E.F. Young, Jr., and J.E. Ross. 1977. Ginning and spinning performance of standard and pubescent strains of American Pima cotton. Prod. Res. Rep. no. 171, Agric. Res. Ser., USDA.
5. Knight, R.L. 1952. The genetics of jassid resistance in cotton. I. The genes H_1 and H_2. J. Genet. 51:47–66.
6. ----. 1954. Cotton breeding in the Sudan. Emp. J. Exp. Agric. 85:68–184.
7. Lee, J.A. 1968. Genetical studies concerning the distribution of trichomes on the leaves of *Gossypium hirsutum* L. Genetics 60:567–575.
8. ----. 1976. Transfer of a smooth leaf allele from *Gossypium barbadense* L. to *Gossypium hirsutum* L. Crop Sci. 16:601–602.
9. ----. 1984a. Effects of two pilosity alleles on agronomic and fiber traits of upland cotton. Crop Sci. 24:127–129.
10. ----. 1984b. Effects of plant smoothness on agronomic traits of upland cotton—lint percentage. Crop Sci. 24:583–587.
11. ----. 1984c. Effects of plant smoothness on agronomic traits of upland cotton—fiber properties. Crop Sci. 24:716–720.
12. ----. 1984d. North Carolina 177-16-30, a somewhat unusual cotton. p. 95–98. *In* J.M. Brown (ed.) Proc. Beltwide Cotton Prod. Res. Conf., Atlanta, GA, 7-9 Jan., 1984. Natl. Cotton. Counc., Memphis, TN.
13. ----. 1984e. Two new alleles at the sm_1 locus in cotton. Crop Sci. 24:945–947.
14. Ramey, H.H., Jr. 1962. Genetics of pubescence in upland cotton. Crop Sci. 2:269.
15. Robinson, S.H., D.A. Wolfenbarger, and R.H. Dilday. 1980. Antixenosis of smoothleaf cotton to ovipositional response of tobacco budworm. Crop Sci. 20:646–649.
16. Rose, M.F. 1959. Cotton research and development of the commercial crop in the Sudan. Emp. Cotton Grow. Rev. 36:1–11.
17. Saunders, J.H. 1963. The mechanism of hairiness in *Gossypium*. 2. *Gossypium barbadense*—the inheritance of stem hair. Emp. Cotton Grow. Rev. 40:104–116.
18. Simpson, D.M. 1947. Fuzzy leaf in cotton and its association with short lint. J. Hered. 38:153–156.