Published July, 1986

Effects of Boll Pilosity on Some Traits of 'Pima' Cotton[1]

Joshua A. Lee[2]

ABSTRACT

A genetic stock, E-2, of 'Pima' cotton (*Gossypium barbadense* L.), differs from commercial cultivars of Pima in that the leaves, stems, and fruit (boll) surfaces are densely pubescent, and the fiber is coarser. Because there is no evidence that dense pubescence on leaves and stems of Pima affects fiber traits other than grade, I questioned whether pubescent boll in Pima cotton is accompanied by coarse fiber, as with upland cotton (*G. hirsutum* L.). The first step in testing that hypothesis was to cross E-2 with the very pubescent, although glabrous-fruited, stock, 'Pima S-5-H', and examine an F_2 population. All segregates displayed dense pubescence on leaves and stems but segregated for pubescence on bolls. Two contrasting phenotypes were selected for increase, F_2 plants with pubescent (F_2-HB), and with glabrous bolls (F_2-GB). These were grown in replicated experiments with Pima S-5-H (P-S-5-H), commercial Pima S-5 (P-S-5), E-2 with pubescent fruits (E-2-HB), and E-2 with glabrous fruits and stems (E-2-SS). The P-S-5 entries graded lowest in leaf pubescence, 9.3 trichomes per 1 cm transect of abaxial surface of leaf, with the remaining entries distributed from 16.1 to 17.1. The entries were also significantly higher in lint percentage than the remainder, and had significantly larger bolls. Fiber length measures, 2.5 and 50% span, were about the same for all entries. There were some significant differences in length uniformity index, lint tenacity, and elongation, but these did not relate to differences in density of pubescence on various plant parts. The two entries with pubescent bolls, E-2-HB and F_2-HB, at 5.9 and 5.8, graded significantly higher in micronaire value (fiber perimeter) than the remaining entries at 5.0 to 5.3.

Additional index words:* Gossypium barbadense *L.,* Gossypium hirsutum *L.,* Gossypium tomentosum *Nutt. ex Seem., Agronomic traits, Fiber traits, Plant pubescence, Pleiotropic effect, Trichomes.

A COARSE-FIBERED stock of 'Pima' cotton (*Gossypium barbadense* L.), E-2, in sharp contrast with fine-fibered cultivars such as 'Pima S-3' and 'Pima S-4', displays dense pubescence on leaves and stems [Kirk et al., (4)]. Lee (6) reasoned that coarse fiber accompanied dense pubescence on foliage in *G. barbadense* because Tanguis 52/A, a very pubescent cultivar from Peru, produces coarser fiber than the less tomentose Pima cultivars. To test the hypothesis that micronaire value (fiber perimeter) increases as the density of pubescence on foliage increases, Lee (6) introgressed genes for dense pubescence from the *G. hirsutum* L. (upland) cultivar 'Empire' into 'Pima S-5'. The resulting stock graded 16.5 trichomes per 1 cm transect of abaxial surface of mature leaf as compared with 9.6 for normally-pubescent Pima S-5. Analysis of data from replicated tests grown at two locations in North Carolina revealed no significant differences in lint percentage, fruit size, and several fiber traits when hirsute Pima S-5 was compared with the normally pubescent cultivar.

Subsequent to the experiments reviewed above, I examined several plants of E-2 grown under greenhouse culture and found two distinct phenotypes. One, the more numerous, displayed dense pubescence on stems, the abaxial surfaces of leaves, and the surfaces of mature fruits (bolls). The second phenotype was similar to the first except that the stems were glabrous and there was very little pubescence on the bolls. Cursory examination of lint under magnification suggested that the fiber of the pubescent-bolled stock was coarser than that of the stock with smooth stems and nearly-glabrous bolls.

In *G. hirsutum* background the pilose allele, T_1 in Lee's recent revision of the genetics of pubescence in Gossypium (7), is associated with short, coarse fiber, whereas T_1^o from *G. tomentosum* Nutt. ex Seem., an allele imparting a similar phenotype on leaves and stems, did not significantly alter fiber properties after introgression into the Empire cultivar (5). In phenotype, plants of *G. hirsutum* homozygous for T_1^o differ from plants homozygous for T_1 mostly in lacking pubescence on bolls. I address the following questions: Does the presence of dense pubescence on bolls have effects on an array of agronomic and fiber properties in Pima cotton? Is the presence of pubescence on bolls of Pima cotton accompanied by increased micronaire value?

MATERIALS AND METHODS

Derivation of the Entries

Pima S-5 hirsute (P-S-5-H) was crossed with the pubescent-bolled strain of E-2 (E-2-HB), and F_1 and F_2 populations were grown under greenhouse culture. The F_1 had moderately hirsute bolls, most of the pubescence on fruits shedding before the bolls matured. The F_2 displayed a range of fruit phenotypes, including the parental extremes, that fell roughly into three classes, the lower extreme, the P-S-5-H phenotype, displaying just a few persistent trichomes at the apex of the boll. The extremes were easily separated, and 10 plants of each were selfed to grow F_3 populations. Each F_2 plant bred true for boll phenotype, so the seeds of the 10 plants in each phenotypic class were pooled to form populations that were apparently uniformly pubescent on leaves and stems but that differed markedly in the amount of pubescence on bolls. The following entries were selected for a field trial: i) Pima S-5, normally pubescent (P-S-5), ii) Pima S-5, pubescent leaves and stems and nearly-glabrous bolls (P-S-5-H), iii) E-2, hairy leaves, stems, and bolls (E-2-HB), iv) E-2, hairy leaves, smooth stems, and nearly-glabrous bolls (E-2-SS), v) population stemming from F_2 plants that resembled E-2-HB in phenotype (F_2-HB), and vi) population stemming from F_2 plants that resembled P-S-5-H in phenotype (F_2-GB).

Experimental Procedures

The six entries were planted in randomized complete blocks at the Central Crops Research Station, Clayton, NC in 1985. There were six replications, a plot within a replication consisting of 12 hills of three plants each (maximum) spaced 50 cm apart with the plots on 1-m centers. The soil was Dothan sandy loam, a member of the fine-loamy, siliceous, thermic Plinthic Paleudults. Cultural practices and insect control were standard for growing cotton in North Carolina.

On 12 August trichome counts were recorded from 1-cm transects of abaxial leaf surface of all entries in all replications, a mature leaf being taken from about the fifth node

[1] Contribution from USDA-ARS and the North Carolina Agric. Res. Serv., North Carolina State Univ. Journal Series Paper no. 10299. Received 24 Jan. 1986.

[2] Geneticist, USDA-ARS, and professor of crop science, North Carolina State Univ., Raleigh, NC 27695-7620.

below the terminal from each of three plants per plot. On 14 October a 50-boll sample was harvested at random from each plot and the samples ginned on a microroller gin. Data were taken on grams of unginned cotton per boll, and lint percentage—percent of the harvest that was lint.

Fifteen grams of lint from each plot was assayed for the following fiber traits: i) 2.5% span length—the distance in millimeters on a test specimen spanned by 2.5% of the fibers scanned from the starting point; ii) 50% span length—the distance spanned by 50% of the fibers treated as in (i); iii) length uniformity index—100 times the ratio of 50% span length to 2.5% span 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 set 3.2 mm apart and expressed as kilonewtons per meter in kilograms 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 and can relate to fiber fineness and/or maturity, and vi) elongation—the percentage elongation at breakage of the center 3.2 mm of fiber assayed for tenacity. Elongation is regarded as a measure of fiber elasticity.

RESULTS AND DISCUSSION

The means listed in Table 1 show that P-S-5 was significantly divergent in the density of pubescence on leaves, and that was expected. I had no a priori notions as to how the various hirsute entries would compare. The fact that all graded as not significantly different from P-S-5-H, coupled with what is known about germplasm contributions to Pima cottons (1), suggests that the increased pubescence of all such entries stemmed from *G. hirsutum.*

Lint percentage varied widely among the entries, but obviously did not relate to density of pubescence on any plant part other than the seed coat. In the current test P-S-5-H showed a small, although significant, increase in lint percentage over the parental cultivar, P-S-5. In earlier experiments, the two cotton cultivars did not differ significantly in lint percentage (6). The two P-S-5 entries were about 2 to 3 percentage points above the remaining entries. The advantage of P-S-5 over E-2 in lint percentage probably reflects the advances made in Pima cotton breeding in the interval between the selection of E-2 and the release of P-S-5. The lint percentage values for F_2-HB and F_2-GB were nearer those of the lower parent, E-2-HB, and that is difficult to understand considering the evidence that lint percentage is transmitted mostly as an additive trait (8).

Seed cotton per boll showed that both P-S-5 and P-S-5-H had significantly larger fruits than the E-2 entries, and the F_2-derived entries had fruits of intermediate size. The larger fruits of P-S-5 might, likewise, reflect an advance in breeding.

Means for fiber traits are listed in Table 2. There were no significant differences among the measures of fiber length. That perhaps reflects the fact that Pima cottons have been bred for a standard modal length for more than two decades (2). There were significant variations in uniformity index, F_2-GB being significantly different from P-S-5-H at the 5% level. The difference detected did not, however, relate to degree of foliar or boll pubescence.

There were some significant differences in fiber tenacity, both P-S-5-H and E-2-HB assaying lower tenacity than the remaining entries. Overall, fiber tenacity did not relate in any way to density of pubescence on either fruit or vegetative parts. There were no significant differences in elongation.

Comparison of micronaire values presented a striking pattern. Both E-2-HB and F_2-HB, the entries with pubescent bolls, were significantly higher than the remaining entries. Thus, there seems to be a relationship between increased micronaire and the presence of dense pubescence on mature bolls. The divergence between the E-2 entries was particularly striking. The micronaire value of E-2-HB was the highest of the group, whereas that of E-2-SS was the lowest. That result suggests that glabrous stem allele, T_2^b in the recent pilosity nomenclature of Lee (7), which, apparently, also affects bolls, dampened the effects of a factor, or factors, that would have, otherwise, imparted pubescent boll and coarser fiber.

Possibly, however, E-2-HB and E-2-SS are not products of a common pedigree; that is to say, E-2-SS entered the E-2 population through contamination, or the pooling of breeding lines. Kirk et al. (4) described E-2 as having pubescence on all vegetative parts. Nevertheless, E-2-HB and E-2-SS agree closely in plant form, and in fruit size and shape. The two differ strikingly in micronaire value, and, as stated before, that might relate to the presence of T_2^b in E-2-SS. If E-2-HB and E-2-SS do stem from a common pedigree, the segregates from crossing the two that display pubescent stems should also have pubescent bolls and coarse fiber.

Although the data presented herein strongly suggest that increased micronaire in Pima cotton is associated with pubescent boll, perhaps as a pleiotropic effect, the case could be strengthened by further investigations. I am currently introgressing pubescent boll into P-S-

Table 1. Comparison of some agronomic traits of six entries of Pima cotton.

Entry	Trichomes/ cm leaf transect	Lint percentage	Seed cotton/boll
	no.	%	g
P-S-5	9.3b*	39.8b	4.2a
P-S-5-H	16.6a	40.5a	4.0ab
E-2-HB	16.9a	37.4c	3.6c
E-2-SS	16.2a	36.3e	3.2d
F_2-HB	16.2a	37.2cd	3.7bc
F_2-GB	17.1a	36.6de	3.8bc
HSD (0.05)	2.8	0.6	0.3

* Values within columns followed by the same letter are not significantly different at the 0.05 probability level by Tukey's HSD.

Table 2. Comparison of fiber traits of six entries of Pima cotton.

Entry	Span length 2.5%	Span length 50%	Uniformity index	Tenacity	Elongation	Micronaire
	mm	mm	%	kN m kg^{-1}	%	μmm^{-1}
P-S-5	34.1a*	17.6a	51.8ab	270.0a	7.9a	129.5b
P-S-5-H	33.6a	17.9a	53.1a	251.8bc	8.1a	132.1b
E-2-HB	33.9a	17.7a	52.3ab	248.0c	7.7a	149.9a
E-2-SS	34.0a	17.4a	51.6ab	265.4abc	7.4a	127.0b
F_2-HB	34.0a	17.4a	51.2ab	261.6abc	8.1a	147.3a
F_2-GB	34.2a	17.3a	50.5b	269.5ab	8.0a	134.6b
HSD (0.05)	1.4	0.7	2.3	18.0	0.8	0.4

* Values within columns followed by the same letter are not significantly different at the 0.05 probability level by Tukey's HSD.

5-H through a series of backcrosses. No difficulties have been encountered in transferring the character, but there have been no further assays for micronaire. The coarse fiber trait would need to accompany pubescent boll through several generations of backcrossing before the association can be accepted as proven.

How is pubescent boll inherited? Does the expression of pubescent boll depend upon the presence of increased pubescence on leaves and stems? Earlier I pointed out that the alternatives, glabrous vs. pubescent boll, appeared in the F_2 between P-S-5-H and E-2-HB, along with intermediate phenotypes. No simple segregation ratio could be discerned, but the ease with which the extremes could be fixed suggested that one pair, or at most a few pairs, of alleles was involved. Hau et al. (3) crossed the *G. hirsutum* cultivar 'Allen 333-57' with the *G. barbadense* cultivar 'Mono' and from the ensuing generations selected segregates that had either glabrous or pubescent bolls. Crosses between stocks with the contrasting phenotypes gave F_1 plants with glabrous bolls and F_2 generations that segregated 3 glabrous to 1 pubescent. A test cross of pubescent boll to the F_1 gave a ratio of 1 glabrous to 1 pubescent. Hau et al. concluded that glabrous vs. pubescent boll segregated as allelic alternatives. The authors also mentioned that the foliage and stems of pubescent-bolled segregates were more densely pubescent than leaves and stems of either Allen 333-57 or Mono.

Neither Allen 333-57 nor Mono had pubescent bolls, so pubescent boll apparently arose as the result of an interaction between germplasm contributed by the parent stocks, possibly through the activation of a latent character in one of the two species involved. Very likely, pubescent boll in E-2-HB also derives from some such interaction, because *G. hirsutum* germplasm has a history of use in the breeding of modern Pima cotton (1).

One problem with the interpretation of Hau's et al. data, in the light of what I have presented herein, is that T_2^b could have been present in the glabrous-bolled stocks used in their experiments, and thus the segregation ratios recorded could have been the result of T_2^b segregating against a background that was homozygous for an allele, or alleles, that, in the required background, imparted dense pubescence on bolls. Mono was not described except to point out that the bolls were glabrous, and Allen 333-57 seemed usual for an upland cultivar of *G. hirsutum*, i.e., moderate to dense pubescence on leaves and stems, and glabrous bolls. Standard cultivars of Pima and Egyptian, the only types of *G. barbadense* widely grown today, all seem homozygous for T_2^b.

Even though the inheritance of pubescent boll is not fully understood, the character is easily transferred among *G. barbadense* cultivars. Coarse-fibered *G. barbadense* stocks being used in hybridization experiments with *G. hirsutum* (Dick Davis, 1985, personal communication) need to be upgraded to modern standards of performance, and a connection between pubescent boll and coarse fiber might facilitate such an end.

REFERENCES

1. Feaster, C.V., and E.L. Turcotte. 1962. Genetic basis for varietal improvement of Pima cotton. USDA-ARS 34-31. U.S. Government Printing Office, Washington, DC.
2. ----, E.F. Young, Jr., and E.L. Turcotte. 1980. Comparison of artifical and natural selection in American Pima cotton under different environments. Crop Sci. 20:555–558.
3. Hau, B., F. Koto, and J. Schwendiman. 1980. Detérminisme génétique de deux mutants du cotonnier capsule pileuse et fleur cleistogame. Coton Fibres Trop. 35:355–357.
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. USDA-ARS. Prod. Res. Rep. 171. U.S. Government Printing Office, Washington, DC.
5. Lee, J.A. 1984. Effects of two pilosity alleles on agronomic and fiber traits of upland cotton. Crop Sci. 24:127–129.
6. ----. 1985a. Effects of the density of pubescence on some traits of extra-long-stapled cotton. Crop Sci. 25:517–520.
7. ----. 1985b. Revision of the genetics of the hairiness-smoothness system of *Gossypium*. J. Hered. 76:123–126.
8. Meredith, W.R., Jr. 1984. Quantitative genetics. *In* R.J. Kohel and C.F. Lewis (ed.) Cotton. Agronomy 24:131–150.