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Stormproof Boll in Upland Cotton. II. Heritability and Agronomic Relationships[1]

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ABSTRACT

The stormproof boll is an important characteristic of cotton (*Gossypium hirsutum* L.) cultivars grown in regions where severe weather prevails after bolls open and where once-over stripper-type harvesters are used. The objectives of the study were to determine the heritability of the stormproof trait and to evaluate the relationships among stormproofness and other agronomic and fiber characteristics. A composite cross population was developed from six stormproof and four nonstormproof cultivars. From this population, 79 random F_3 plants were advanced by self-pollination to the F_4 and F_5 generations. The study was conducted at two locations in 2 years.

At both locations the mean stormproofness of the F_4 was significantly larger (by 1.5%) than the mean of the F_5 in the same year, indicating residual dominance of the stormproof boll after three generations of selfing in the population. Heritability was high for the stormproof trait when calculated by parent-offspring regression, but was more consistent over locations and years when it was calculated in standard deviation units. Of the 10 agronomic and fiber traits measured, seed size, fiber length, and fiber strength exhibited a consistent positive association with stormproofness. High stormproof values were related to larger seed and longer, stronger fiber. We speculate that the relationships with fiber length and strength were associated with the tendency of fiber in stormproof bolls to be caught in the folds of the carpel walls. Positive correlations between lint yield and stormproofness at both locations in a year with severe environmental stress was explained as a physical holding of the fiber in the boll (rather than as a genetic effect).

Additional index words: Lock tenacity, Storm loss, *Gossypium hirsutum* L., Parent-offspring regression, Yield, Agronomic traits, Fiber traits, Genotype × environment interaction, Residual heterosis.

IN the United States three general groups of Upland cotton (*Gossypium hirsutum* L.) cultivars are grown. These are: *i*) the medium fiber length, medium-to-small boll, medium maturing, nonstormproof (i.e., open boll) cultivars grown in the eastern Cotton Belt, the Mississippi Delta, and the Gulf Coast of Texas; *ii*) the short fiber length, medium-to-large boll, early maturing, stormproof cultivars grown in the Plains area of Texas, Oklahoma, and New Mexico, and in the Texas Blacklands; and *iii*) the long fiber length, large boll, late maturing, nonstormproof Acala-type cultivars grown in the irrigated areas of the Southwest (3). Although these are not discrete groups, they are descriptive of the general types of cultivars grown in these geographical areas. Traits which delineate the Plains cultivars from those in other regions are the storm resistant and stormproof boll, shorter fiber, earlier crop maturity, and relatively lower productivity in high-yield environments. The storm resistant or stormproof boll is considered essential in cultivars grown in this region because seedcotton often must remain in the field attached to the plant and exposed to high wind, rain, and, occasionally, ice and snow before the crop is harvested. Stripper-type harvest machines are used in a once-over harvest to remove burs and seedcotton from the plants after they are killed by harvest-aid chemicals or by frost.

The purpose of this study were *i*) to determine the heritability of the stormproof boll and *ii*) to evaluate the relationship between this trait and other agronomic and fiber characteristics.

MATERIALS AND METHODS

The progeny used in this experiment were from a composite population developed by crossing six stormproof High Plains cultivars with four nonstormproof Acala cultivars (5). The stormproof cottons were used as female parents; the nonstormproof types as males; and all 24 possible crosses were made. Random F_3 plants were advanced by self-pollination to the F_4 and F_5 generations. Initially, 100 F_3 plants were chosen; however, only 79 progenies produced enough seed for subsequent evaluation.

Both F_4 and F_5 progenies were grown at Lubbock and Big Spring, Texas, in 1976, but only F_5's were grown at those locations in 1977. The progenies were planted at each location in a randomized complete-block design with two replications. Irrigation water was applied to the field plots at Lubbock, but not at Big Spring where drought limited productivity during both years.

From each progeny row, 10 mature bolls were harvested and dried in the laboratory to about constant moisture content. Stormproofness was expressed as the tenacity with which the seedcotton was held in the bur, measured as the amount of force required to extract the seedcotton from individual locules (1). The tenacity values were converted to logarithms because prior studies have shown that the distribution of values was normalized with this transformation (1). Besides tenacity values, 10 other agronomic and fiber traits were measured on each F_4 and F_5 progeny row. Traits measured included lint yield in kg/ha, nodal position of the first fruiting branch, boll size in g seedcotton per boll, seed size in mg, number of seed per boll, picked lint percentage, lint index in g lint per 100 seed, fiber length in mm, fiber strength in mN/tex and fiber fineness (micronaire in mg/in).

Analyses of variance were used to compare the 1976 F_4 tenacity values with the F_5 values in the same year. These analyses estimated the amount of residual dominance in the population and the direction of that dominance. An additional analysis of variance was conducted among F_5 tenacity values in 1976 and F_5 generation values in 1977 over locations to determine the effects of locations, years, genotypes, and their interactions on the expression of the stormproof boll. A parent-offspring regression with the mean of the two F_5 progeny rows regressed on a single progeny row of the F_4 was calculated to estimate narrow-sense heritability. Linear correlation coefficients from those regressions were also used to calculate heritability estimates for tenacity values in standard deviation units (2). Linear correlation coefficients were used to define possible relationships between tenacity value and the other agronomic and fiber characteristics.

RESULTS AND DISCUSSION

Mean squares from an analysis of variance among F_4 and F_5 progenies grown in 1976 are shown in Table 1. Location had a significant effect upon the expression of stormproofness in 1976. Plants grown at Lubbock displayed higher tenacity values than did

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Table 1. Mean squares for tenacity values from F_4 and F_5 generation progenies grown in 1976 at two locations.

Source	df	Mean squares
Locations (L)	1	35.303*
Reps/Location (R/L)	2	0.994
Generation (G)	1	0.966**
G × L	1	0.002
G × R/L	2	0.002
Progenies (P)	78	2.274**
P × L	78	0.966**
P × G	78	0.038
P × L × G	78	0.037
Residual	312	0.030

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 2. Mean squares for tenacity values from F_5 generation progenies grown in 1976 and 1977 at two locations.

Source	df	Mean squares
Locations (L)	1	22.89**
Years (Y)	1	19.88**
L × Y	1	0.84
Reps/L and Y	4	0.79
Progenies (P)	78	1.69**
P × L	78	0.15**
P × Y	78	0.13**
P × L × Y	78	0.05**
P × Reps/L and Y	312	0.03

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

those grown at Big Spring. A significant difference also occurred between generations. The mean of the F_4 was 1.5% higher than that of the F_5 at both locations. The higher F_4 mean indicated that residual dominance towards the stormproof parental cultivars existed in the population after three generations of inbreeding. When individual F_4 to F_5 progeny comparisons were made, only four were significantly different; and in all of those comparisons, the F_4 value was higher than that of the F_5. None of the first- or second-order interactions with generations were significant.

Mean squares from an analysis among F_5 progenies grown over two locations and years are shown in Table 2. The 1976 tenacity values (averaged over locations) were significantly larger than the 1977 values. Averaged over years, the location effect was significant; but their first-order interaction was not. Averaged over years and locations, the progenies varied significantly in tenacity. All first- and second-order interactions with progenies were significant, indicating the presence of genotype by environment interactions for the stormproof trait.

Estimates of variance components (data not shown) were derived from the mean squares in Table 2. Genetic variance was 0.19 with a broad-sense heritability among family means of 86%. Although the interaction variance components were significant, their magnitudes compared to the genetic variance were quite small.

Parent-offspring linear regression coefficients and linear correlation coefficients from the mean of two F_5 progeny rows on a single F_4 progeny row were used to estimate narrow-sense heritability in actual and standard deviation units (Table 3). When the F_4 progenies were grown at Lubbock, heritabilities in actual units ranged from 92.3% (when the F_5 progenies were grown in the same year at the same location)

Table 3. Heritability estimates in actual and standard deviation units for tenacity values in 1976 and 1977 at two locations.

Location where 1976 F_4 progenies grown and type of heritability.	Location and year where F_5 progenies grown			
	Lubbock		Big Spring	
	1976	1977	1976	1977
	%			
Lubbock				
Actual	92.3**	58.7**	57.2**	43.9**
Standard	93.1**	88.1**	85.7**	75.3**
Big Spring				
Actual	121.5**	81.4**	82.7**	68.1**
Standard	87.5**	87.5**	88.6**	83.4**

** Significantly different from zero at the 0.01 probability level based on t-tests.

Table 4. Linear correlation coefficients between tenacity values and 10 other agronomic and fiber characteristics in F_5 generation progenies measured in 1976 and 1977 at two locations.

Traits	Lubbock 1976	Lubbock 1977	Big Spring 1976	Big Spring 1977
Lint yield (kg/ha)	−0.14	0.51**†	−0.01	0.28*
Node of first fruiting branch (no.)	−0.13	−0.13	−0.07	−0.11
Boll size (g)	−0.30**	0.07	0.07	0.13
Seed size (mg)	0.09	0.43**	0.22*	0.23*
Seed/boll (no.)	−0.36**	−0.39**	−0.12	−0.10
Lint percentage	−0.15	−0.06	−0.05	0.16
Lint index (g)	−0.06	0.29**	0.15	0.29**
Fiber length (mm)	0.20	0.31*	0.29**	0.22*
Fiber strength (mN/tex)	0.36**	0.28*	0.34**	0.30**
Micronaire (mg/in)	−0.19	0.02	−0.03	−0.13

*,** Significantly different from zero at the 0.05 and 0.01 probability levels, respectively. † When lint that had fallen to the ground was retrieved and added to that harvested, the estimate was −0.06.

to 43.9% (when the F_5 progenies were grown in a different year at the other location). When standard deviation units were used, heritabilities were more consistent ranging from 93.1 to 75.3%. The same trend, but with a smaller range, was evident when the F_4 progenies were grown at Big Spring. The less consistent and generally smaller heritabilities associated with the actual heritabilities showed that they were only relative values highly subject to environmental variation in magnitude. However, the higher and more consistent heritabilities associated with the standard deviation units suggested that if the progenies with the highest tenacity values were selected in one year and location, they would be the most stormproof at all locations and in all years even though their mean level of stormproofness might change with the environment.

Linear correlation coefficients between tenacity values and 10 other agronomic and fiber characteristics are shown in Table 4. No detrimental associations between stormproofness and any other trait were detected. However, several positive relationships were noted. In 1977, high lint yield was correlated with high tenacity at both locations. This relationship was likely a mechanical one (rather than genetic) due to the adverse weather encountered prior to harvest in that year. When the lint that had fallen to the ground was added to that harvested from the plant, the correlation was reduced to a small, nonsignificant value. This correlation vividly demonstrates the importance of the storm resistant and stormproof boll in cotton cultivars grown on the Southern Great Plains – at least in some years.

In three of the four comparisons, large seed and long fiber were associated with increased tenacity. In all four comparisons, stronger fiber was correlated with higher tenacity values. Although the above correlations were significant, they were relatively small and generally accounted for about 10% or less of the variability in tenacity. It is interesting to note that these relationships are reversed from those in the composite-cross parental material. The High Plains parents were stormproof with small seed, and short and weak fiber; whereas, the Acala parents were nonstormproof with large seed, and long and strong fiber (5). The reversal of these relationships in the progenies suggests that these correlations with tenacity were physical rather than genetic. Loffredo (4) has shown that individual fibers in the stormproof boll are caught in the pit at the base of the boll and in folds along the side of the carpel wall. Perhaps, longer fibers are more likely to become entangled at some point along their length in these recesses than are shorter fibers. In both locations and years, a high correlation existed between large seed and long fibers. The correlation between fiber length and seed size suggests that the relationship between stormproofness and seed size may be due to fiber length and not directly due to seed size. The positive correlation between tenacity values and fiber strength can be explained by suggesting that more force should be required to remove a strong fiber from the bur attachments than to remove a weak fiber.

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