# Primitive accessions of cotton as genetic sources for improving yield and fiber properties


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## ABSTRACT

*The breeding of cotton, Gossypium hirsutum L., to improve lint yield and fiber quality is an on going process. To meet textile mill requirements and producer demands both fiber quality and lint yield must be increased. The U. S. collection of primitive cotton accessions contains a broad range of variability for pest resistance and agronomic traits; however, because many of the accessions are photoperiodic, this variability is not readily useable by plant breeders. Day-neutral selections have been made that contain variability for agronomic and fiber traits. A study was conducted to evaluate yield, yield components and fiber quality traits when fourteen day-neutral lines derived from selected primitive accessions with high fiber strength were crossed as male parents to each of five commercial cultivars. The $F_2$ hybrids and parents were grown in two different field locations in 1998 and 1999; whereas the $F_3$ hybrids and parents were grown in two locations in 2000. Combination of locations and years were considered as environments for data analyses. All traits measured were significantly affected by environment with genotype by environment interactions. The cultivars produced more yield, had larger bolls and higher lint percentages than the accession-derived male parents. Fiber strength for male parents exceeded that of cultivars. The mean lint yield for $F_2$ and $F_3$ hybrids exceeded the mid-parent value within each environment. Lint percentage, boll size, micronaire, elongation, and fiber length were similar between $F_2$ and $F_3$ hybrids. Most traits were highly correlated between $F_2$ and $F_3$ generations; however, seed cotton yield and lint yield were not correlated between $F_2$ and $F_3$. Genetic variance components analyses revealed that additive, dominance, and additive by additive epistasis effects were significant for most traits measured. Additive effects were important for controlling lint percentage, fiber length and fiber strength; whereas, dominance effects were important for yield and boll size. This study will contribute to the use of primitive accession germplasm in cotton breeding programs.*


## Introduction

Cotton (*Gossypium hirsutum* L.) continues to be an important cultivated crop in the United States and many parts of the world. It is grown mostly for its source of spinnable fibers (lint) for the textile industry; however, there are markets for its oil, meal, seed hulls, and linters. Technology changes in the textile industry particularly in the area of increased spinning speeds have placed new demands for improved fiber quality. Producers have seen yield plateau in many growing regions. To meet the textile mill requirements and producer demands both fiber quality and lint yield must be increased. The breeding of cotton, to improve lint yield and fiber quality is a long term on going processes. To improve the breeding efficiency it is important to have a better understanding of yield components and fiber traits which make up quality.

The demand for improved fiber quality increases the need for new sources of genetic variability and additional research efforts. The primitive accessions of *Gossypium* are diverse and contain many desirable traits. The collection, distribution, and evaluation of *Gossypium* germplasm was reviewed by Percival and Kohel (1990). Many of the accessions in the collection have been reported to have useful genetic variability (Percival, 1987; Meredith, 1991; McCarty and Jenkins, 1992; McCarty *et al.*, 1995). Their use in cotton breeding programs has been limited by their short-day flowering habit. A backcross breeding program has been used to introduce genes for day-neutrality into the primitive accessions (McCarty *et al.*, 1979).

The relationship of yield and fiber quality has been studied in the form of $F_2$ hybrids. In crosses between pest-resistant germplasm and commercial cultivars, Tang *et al.* (1992, 1993a, b) found that most of their high yielding $F_2$ hybrids had commercially acceptable fiber properties. Robinson *et al.* (1997) reported that when root-knot nematode, Meloidogyne incognita (Kofoid and White) Chitwood, resistant germplasm lines were crossed to cultivars, resulting $F_2$ populations combined root-knot resistance with acceptable yield and fiber quality. Meredith (1990) reported that $F_2$ hybrids had significantly longer and finer lint than the parents; however, the improvements were too small to be of practical value. He suggested that $F_2$ hybrids have the genetic potential for increasing cotton yields and fiber quality.

Traditionally, the data of $F_2$s and or their parents are analyzed by ANOVA methods. Recently, mixed linear model approaches have been used in cotton to estimate the genetic variances and covariances and to predict the genetic effects (Wu *et al.*, 1995; Tang *et al.*, 1996, McCarty *et al.*, 1998). However, many studies were based on additive-dominance (AD) and its G E genetic models (Meredith, 1990; Tang *et al.*, 1993a, b; Cheatham, 2001; Shoemaker, 2000).

Primitive accession germplasm may provide needed sources of variability for improving fiber quality and cotton yield. Fourteen lines derived from primitive accessions with good fiber strength (McCarty *et al.*, 2000) were used as male parents and crossed with five high yielding cultivars. The objectives of this research were to evaluate the utility of high fiber strength selections from primitive accessions of cotton as sources of genes for agronomic traits and fiber properties and to estimate genetic effects. The ADAA genetic model developed by Zhu (1994) was used to estimate genetic variances and predict the hybrid performances for different generations using 70 $F_2$ and $F_3$ hybrids and their 19 parents. The genetic information obtained will be useful in maximizing breeding progress in selection of hybrids or pure lines with high fiber quality and yield simultaneously.

## Experimental procedure

Five cultivars used as female parents were crossed to each of fourteen male parents in 1997. Cultivars used were designated as parents 1 through 5 and are as follows: 1. 'Deltapine 50' (DPL50), 2. 'DES119', 3. 'Stoneville 474' (ST474), 4. 'Deltapine Acala 90' (DPL90), and 5. 'Sure-Grow 125' (SG125).

The male parents were derived from day-neutral selections from crosses of cultivars with primitive, *G. hirsutum* L., race accessions. The males were designated as parents 6 through 19. Parent 6 was developed from accession T75 (PI 549138), 7 through 9 from T1388 (PI 415112), 10 through 16 from T239 (PI 163693), and 17 through 19 from T237 (PI 163657). Lines developed from the same accession were sister lines selected from $F_2$ individuals of the same cross.

Crosses and subsequent evaluations were conducted at the Plant Science Research Center, Mississippi State, MS (33.4 N, 88.8 W). Male parents and $F_1$ crosses were increased and advanced at a winter nursery. Seed from the 70 $F_2$ hybrids and the 19 parents (five female cultivars and 14 males) were grown at two locations each year in 1998 and 1999. Seed were harvested from the 1999 test and the resulting $F_3$ populations and parents were grown at two locations in 2000.

The experimental design was a randomized complete block with four replications at each location each year. The combination of year and location was considered as environments for the purpose of statistical analyses. Standard productions practices were followed at all environments.

A 25-boll, hand-harvested sample was collected, weighed and ginned on a laboratory 10-saw gin to determine boll weight, lint percentage and provide lint samples for fiber analysis. Lint samples were used for determination of micronaire, elongation (E1), fiber strength (T1), 2.5 % span length (2.5% SL), and 50% span length (50% SL). A mechanical picker was used to harvest plots and data collected was used to calculate yields. Environment 1 in 1998 was not machine harvested due to late season weather conditions.

Data were subjected to ANOVA using proc GLM, SAS version 8.0 (SAS Institute, 1999). An ADAA (additive-dominance additive x additive) model was employed for genetic data analysis (Zhu, 1994). A mixed linear model approach, minimum norm quadratic unbiased estimation (MINQUE) was used to estimate genetic variance components based on the ADAA model. The data was analyzed by programs written in C++.

## Results and Discussion

All traits were significantly affected by environmental conditions. Environment contributed the largest source of variation for seed cotton yield, lint yield, fiber micronaire value and fiber length. The largest source of variation for lint percentage, boll size, fiber elongation and fiber strength was due to 'generation type'. Generation type was defined as female cultivar, male line, $F_2$ or $F_3$ hybrid. The genetic expression of all traits was not only significantly different among different generation type, but the genotypes within each generation type also showed significant variations for all traits measured. These differences were expected considering the range of germplasm used in this study.

An overall summary for important yield and fiber traits can be found in Tables 1 and 2. Lint yield for females (commercial cultivars) was greater than that for males (primitive derived lines) across all environments. The $F_2$ hybrids produced lint yields between those of females and males, but it was greater than that for the mid-parent. Numerically the mean lint yield for the $F_3$ generation was higher than that for cultivars. Generally, the five female parents showed less variation than the 14 male parents across the different environments. The $F_3$ hybrids and parents were evaluated in 2000, where as the $F_2$ hybrids were evaluated in 1998 and 1999. Females yielded slightly less cotton in 2000 than in 1998-1999 environments, while male parents produced more cotton. One possible reason is that the 2000 growing season was relatively dry compared to the 1999 season during July and August when cotton was blooming and setting bolls and the male derived lines held up better under these stress conditions. Lint yield for the $F_3$ generation was also higher than that for female parents. This is an indication that yield may be controlled by some other genetic effects in addition to additive and dominance effects.

Lint percentage for female parents was generally significantly higher than that for $F_2$ and $F_3$ hybrids, while lint percentage for male parents was significantly lower than that for $F_2$ and $F_3$ hybrids. The lint percentage for $F_2$ and $F_3$ were close to the mid-parent value. This indicates that lint percentage may be mainly controlled by additive genetic effects. Female parents produced bolls that were larger than male parents and close to $F_2$ in 1998-1999 environments; however, male parents produced larger bolls in 2000 than female parents. This was due to the 2000 growing season environment.

Values for fiber micronaire and strength for $F_2$ and $F_3$ hybrids were between the means for parents in most environments. The fiber length for $F_2$ and $F_3$ hybrids was equal to that of high parents for most environments. Male parents tended to have higher micronaire, shorter but stronger fibers than female parents. Variations among $F_2$ hybrids was numerically greater than that among $F_3$ hybrids for yield, lint percentage, boll size, micronaire, and 2.5% span length. Minimum and maximum values for fiber strength were close between $F_2$ and $F_3$.

The performances of the parents, $F_2$ and $F_3$ hybrids were quite different across the different environments for most traits. In general, female parents produced more consistent results than male parents and their hybrids, while male parents performed better during the relative dry year, indicating there may be an opportunity to select some drought-resistant hybrids or pure lines among these populations.

Correlations between $F_2$ and $F_3$ hybrids indicated that lint percentage, boll size, fiber strength, and 2.5% span length was highly correlated, while lint yields were poorly related. This result is in agreement with what Meredith and Bridge (1973) reported. Results suggested that selection at early generations could be conducted for lint percentage, boll size, fiber strength, and 2.5% span length, and selection at late generations should be conducted for lint yield.

The estimated proportions of variance components to phenotypic variance and narrow sense heritability, expressed as a percentage, for important agronomic and fiber traits are given in Table 3. Major genetic effects (additive, dominance, and additive by additive epistasis) were about equal to genetic by environmental effects in controlling lint yield. Major genetic effects were more important than genetic by environmental effects for controlling lint percent, boll size and 2.5% span length; however, genetic by environment interaction effects were more important for micronaire and fiber strength.

Significant additive effects were detected for all traits; however, they were more important in controlling lint percentage. Dominance effects were important for lint yield and boll size and were close to additive effects in controlling 2.5% span length and strength. Micronaire was controlled by additive effects, but the major portion of variance was due to genetic by environmental interaction effects. We partitioned the genetic by environmental effects into, additive by environment, dominance by environment, and additive by additive by environment (data not shown). We found the largest proportion was due to dominance by environment interaction for lint yield, lint percent, micronaire and fiber strength. Dominance by environment interaction effects was very small for boll size and 2.5% span length. Residual variances were approximately equal (about 30% of total) for all traits except lint percentage, which was about 18% of total. Narrow-sense heritability estimates were highest for lint percentage and lowest for lint yield.

The results of this study will aid cotton breeders in utilizing these lines derived from primitive accession germplasm that have high fiber strength.

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***Table 1.*** *Minimum, maximum, mean and standard error for lint yield, lint percentage and boll size for female (5 cultivars), male (14 primitive accession derived lines) and their $F_2$ or $F_3$ hybrids over environments.*

| Lint yield (kg/ha) based on 3 environments | | | |
|---|---|---|---|
| Type | Minimum | Maximum | Mean (se) |
| Female | 479 | 1304 | 904 (72) |
| Male | 62 | 832 | 427 (34) |
| F2 | 245 | 1289 | 806 (21) |
| Lint yield (kg/ha) based on 2 environments | | | |
| Female | 520 | 1076 | 824 (47) |
| Male | 499 | 943 | 726 (22) |
| F3 | 471 | 1091 | 842 (11) |
| Lint percentage (%) based on 3 environments | | | |
| Female | 36.49 | 43.22 | 40.02 (0.54) |
| Male | 26.06 | 33.22 | 30.13 (0.28) |
| F2 | 27.34 | 37.93 | 34.96 (0.09) |
| Lint percentage (%) based on 2 environments | | | |
| Female | 34.99 | 42.83 | 39.30 (0.72) |
| Male | 29.87 | 33.89 | 32.41 (0.23) |
| F3 | 31.88 | 38.25 | 34.90 (0.11) |
| Boll size (grams) based on 3 environments | | | |
| Female | 4.16 | 4.93 | 4.59 (0.06) |
| Male | 3.21 | 4.88 | 4.19 (0.07) |
| F2 | 3.44 | 5.59 | 4.60 (0.03) |
| Boll size (grams) based on 2 environments: | | | |
| Female | 3.68 | 4.71 | 4.40 (0.12) |
| Male | 4.12 | 5.18 | 4.56 (0.05) |
| F3 | 4.01 | 5.37 | 4.62 (0.02) |

*Table 2.* Minimum, maximum, mean and standard error for fiber micronaire, 2.5% span length and strength for female (5 cultivars), male (14 primitive accession derived lines) and their $F_2$ or $F_3$ hybrids over environments.

| Type | Minimum | Maximum | Mean (se) |
|---|---|---|---|
| **Micronaire values based on 4 environments** | | | |
| Female | 4.65 | 5.33 | 4.96 (0.049) |
| Male | 3.40 | 5.58 | 4.84 (0.063) |
| F2 | 3.84 | 5.59 | 4.96 (0.017) |
| **Micronaire values based on 1 environment** | | | |
| Female | 4.53 | 4.70 | 4.63 (0.036) |
| Male | 4.25 | 4.85 | 4.62 (0.051) |
| F3 | 4.13 | 5.00 | 4.59 (0.021) |
| **2.5% span length (mm) based on 4 environments** | | | |
| Female | 27.78 | 29.75 | 28.59 (0.13) |
| Male | 25.21 | 31.15 | 27.93 (0.14) |
| F2 | 26.73 | 31.27 | 28.68 (0.05) |
| **2.5% span length (mm) based on 1 environment** | | | |
| Female | 28.70 | 29.34 | 29.08 (0.12) |
| Male | 28.19 | 30.10 | 28.84 (0.13) |
| F3 | 27.59 | 30.35 | 29.08 (0.06) |
| **Strength (kNm/kg) based on 4 environments** | | | |
| Female | 181 | 226 | 202.6 (2.7) |
| Male | 220 | 276 | 243.1 (1.9) |
| F2 | 200 | 258 | 222.7 (0.7) |
| **Strength (kNm/kg) based on 1 environment** | | | |
| Female | 197 | 224 | 209.1 (4.8) |
| Male | 232 | 255 | 242.4 (2.1) |
| F3 | 206 | 251 | 228.4 (1.0) |

*Table 3.* Estimates of proportion of variance components to phenotypic variance and narrow sense heritability, expressed as a percent, for agronomic and fiber traits.

| Parameter† | Lint yield | Lint % | Boll size | Micronaire | 2.5 % SL | T1 strength |
|---|---|---|---|---|---|---|
| $V_A / V_P$ | 6.1** | 34.7** | 18.4** | 13.5** | 33.3** | 19.4** |
| $V_D / V_P$ | 25.4** | 10.5** | 34.4** | 1.9* | 30.9** | 15.0** |
| $V_{AA} / V_P$ | 3.0** | 7.6** | 4.4** | 3.0* | 0 | 4.1** |
| $V_{GE} / V_P$ | 37.3** | 29.4** | 14.9** | 49.1** | 3.4** | 30.8** |
| $V_e / V_P$ | 28.2** | 17.8** | 27.9** | 32.6** | 32.3** | 30.8** |
| $h^2_N$ | 9.1** | 42.3** | 22.8** | 16.5** | 33.3** | 23.5** |

*,** Significantly different from zero at the 0.05 and 0.01 levels of probability, respectively.

† Phenotypic variance ($V_P$) was partitioned into additive ($V_A$), dominance ($V_D$), additive × additive ($V_{AA}$), genetic interactions with environments ($V_{GE}$) which included $V_{AE}$, $V_{DE}$, $V_{AAE}$, and residual ($V_e$). Narrow sense heritability calculated as $h^2_N = (V_A + V_{AA}) / V_P$.