# Correlation and Heritability for Yield and Fiber Quality Parameters of Ethiopian Cotton (*Gossypium hirsutum* L.) Estimated from 15 (diallel) Crosses

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## ABSTRACT

Correlation and heritability estimates of the yield and the fiber or lint quality were determined using 15 $F_1$ cotton hybrids obtained from a diallel cross made in the Werer Agricultural Research Center, in Ethiopia, in 2003. The results indicated that the seed cotton yield was highly genetically correlated to boll weight (r = 0.99**), lint yield (r = 0.88**) and lint index (r = 0.96**). The lint yield was highly correlated to lint percentage (r = 0.94**) and the number of seeds per boll (r = 0.96**). The results illustrated that a high lint percentage, more bolls per plant and a small seed size were positively correlated to high cotton lint yield.

Fiber strength was highly correlated to all fiber quality parameters and positive correlations were found between staple length 2.5% (r = 0.99**) staple length 50% (r = 0.64**) and fiber strength. A positive correlation was also found between the fineness indicator (micronaire) and the uniformity ratio (r = 0.61**). However negative correlations were observed between fiber length and the fineness indicator (micronaire) (r = -0.86**), short fiber index (r = -0.85**) and uniformity ratio (r = -0.99**).

Negative genetic correlation coefficients of lint percentage and lint yield with fiber strength were quite high (r = -0.99 and r = -0.96**, respectively), but they had a positive correlation with the fiber-fineness indicator or micronaire (r = 0.99** and 0.79**, respectively). The broad-sense heritability estimates of the yield and yield components were high for lint percentage ($h^2$ = 97%), lint yield ($h^2$ = 72%), lint index ($h^2$ = 79%) and seed index ($h^2$ = 86%). As they also had a strong relationship with other fiber quality parameters as well, they could be considered as indicators of the yield and fiber quality improvement in cotton.

**Key words:** cotton, correlation, heritability, genotypic correlation, phenotypic correlation

## INTRODUCTION

Estimates of genotypic and phenotypic correlations among characters are useful in planning and evaluating breeding programs. Knowledge of the correlation that exists between important characteristics may facilitate the interpretation of results and provide the basis for planning more efficient programs.

The genetic correlation value offers a measure of the genetic inter-relationship between characteristics and may explain the degree of

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relationship between characters genetically, rather than phenotypically. As the phenotypic variance of a trait can be partitioned into environmental and genetic components, the covariance between the two traits can also be partitioned into environmental and genetic components.

Miller and Rawlings (1967a) and Falconer and Mackey (1996) demonstrated a method of computing phenotypic and genetic correlations from covariance analysis. If the genetic correlation between traits is very high, then selection for one trait will simultaneously result in changes in other traits. This association may be either harmful or beneficial, depending upon the direction of the genetic correlation and the objectives of the breeder. The genetic mechanisms of the underlying genetic correlation are either pleiotropic or linkage, or both.

Almost every study that detected genetic variation in two or more traits also obtained evidence of genetic associations. Genetic correlations of lint percentage with lint yield, bolls per plant, seed index, boll weight, fiber length, strength and fineness from three studies were on average 0.80, 0.48, -0.60, -0.36, -0.52, -0.12 and –0.31, respectively (Miller *et al.*, 1958). Generally in cotton, phenotypic and genetic correlations have been found to be in the same direction and of the same magnitude and are highly correlated.

The second important aspect of this study was that heritability referred to a portion of the phenotypic variation among individuals that was due to genetic differences among them**.** It may be defined as the ratio of the genotypic variance to the phenotypic variance**.**

The additive variance, which is the variance of breeding values, is an important component, since it is the chief cause of a resemblance between relatives, and therefore, it is the chief determinant of the observable genetic properties of the population and of the response of the population to selection (Falconer and Mackey, 1996). Moreover, it is the only variance

component that can be readily estimated from observations made on the population. In practice, therefore, the important partition should be into additive genetic variance and all the rest, the rest being non-additive genetic variance and environmental variance.

On a progeny-row basis, Quisenberry (1977) found the narrow-sense heritability in cotton to be 33% for plant height, 76% for fruiting branch internode length, 47% for the number of main stem nodes per plant, 51% for node position of first fruiting branch and 62% for mean maturity date. The narrow-sense heritability ranged from 75 to 93% for the storm-proof characteristic of the boll (Quisenberry *et al.*, 1980).

The objectives of this research were to estimate the genetic and phenotypic correlations and the broad-sense heritability parameters of the yield component and fiber quality parameters of Ethiopian cotton.

## MATERIALS AND METHODS

### Breeding materials

A total of 15 $F_1$ hybrids obtained from half diallel crosses of six parents selected from an Ethiopian cotton breeding project were used to estimate the correlations and the heritability of traits. The 15 hybrids were arranged in a randomized complete block design with three replications, which were planted in plots of four rows of 8.0 m in length, with a spacing of 0.2 m between plants and 0.9 m between rows. All data and samples were taken from the two center rows within a 7 m length, with a total of 70 plants per plot (0.00126 ha).

### Cultural practices

All agronomic and cultural practices recommended for the area were followed. The plots were hoed, weeded, irrigated and sprayed against insect pests. The pesticides sprayed according to recommendations were: Thiodan for

boll worm; Marshal and Polo for aphid; Karate for complex pests; Mitak for white fly and red spider mite; and Deltaphos for jassid. The harvesting was done by hand, twice, on the two center rows within the 7 m length.

**Samples and data collection**

There were 15 $F_1$ hybrids with three replications, making a total of 45 samples (plots), which were used for further data analysis. Three bolls were sampled from each plant, making a total of 210 bolls per plot. These samples were used to determine boll weight and lint percentage. Collected boll samples were saw-ginned to estimate the lint percentage, seed index, lint index and number of seeds per boll.

The components of the yield data, collected according to Worley *et al.* (1976), were:

Seed cotton yield (SCY)
Yield/0.00126 ha (kg/ha)

Bolls per plant (B/P)
(SCY/BW)/numbers of plant per plot

Boll weight (BW)
Weight of bolls/number of bolls
(210 bolls per plot)

Lint percentage (LP)
Lint weight/total weight of seed cotton X 100
(210 bolls per sample)

Lint yield (LY)
(SCY) X (LP)

Seed index (SI)
Weight of total seed /number of seed
(Seeds of 210 bolls per sample)

Lint index (LI)
Total lint weight/number of seed
(Seeds of 210 bolls per sample)

Number of seeds per boll
Average number of seed per boll (SPB)
(Seeds of 210 sample bolls per plot)

The fiber quality parameters measured were:

Fiber length
2.5% and 50% span lengths, the distance in mm spanned by 2.5% and 50% of the fibers as measured on a digital fibrograph. Fiber length is a good indicator of yarn strength and spinning efficiency.

Fiber strength (FS)
Fiber strength measured by a spin lab stelometer with 1/8-inch gage spacing between the clamp jaws and reported in terms of grams per texture (g/tex). Fiber strength is closely related to yarn and fabric strength, and spinning efficiency.

Micronaire value (MIC)
Micronaire readings are a measure of fiber fineness and are related to maturity. Micronaire is measured with an airflow meter (fineness meter) by placing a given quantity (5g) of fiber into compressed cylinder. Fiber fineness affects yarn appearance, yarn uniformity and yarn strength.

Uniformity ratio %
Length uniformity measures the degree of uniformity in a sample, which is related to spinning efficiency, yarn uniformity and yarn strength.

Short fiber index
The ratio by weight of the fiber shorter than half an inch, which is closely related to spinning efficiency

**Fiber quality test**

After ginning, the plot fiber samples were reduced to a lab sample size of 50 g. Forty-five samples were tested six times to produce 270 fiber quality measurements. Lint samples were tested for length, fineness, short fiber index and uniformity ratio. The 2.5% and 50 % staple length, short fiber index, and uniformity ratio were measured using a Fibro sampler 192 and a Digital Fibrograph 730. Fineness was measured using a fineness meter. All measurements were made at the Werer Agricultural Research Center in

Ethiopia, except for fiber strength which was measured by a Stelometer 150 at the Nakhon Sawan Field Crops Research Center in Thailand.

## Data Analysis

Correlations of both types (genetic and phenotypic) were calculated from cross means using analysis of variance and covariance procedures proposed by Al-Jiburi *et al.* (1958) and Falconer and Mackay (1996) as follows:

$$\text{Genotypic correlation } r_G = \frac{COV_G(A,B)}{\sqrt{V_G(A)V_G(B)}}$$

where     $r_G$ = genotypic correlation coefficient,
$COV_G(A,B)$ = (Mg-Me)/r
genetic covariance between variables A and B,
$V_G(A)$ = (Mg-Me)/r
genotypic variance for variable A,
$V_G(B)$ = (Mg-Me)/r
genotypic variance for variable B,
Mg and Me = mean squares of treatments (genotypes) and error, respectively,
r = number of replications.

$$\text{Phenotypic correlation } r_P = \frac{COV_P(A,B)}{\sqrt{V_P(A)V_G(B)}}$$

where   $r_P$ = phenotypic correlation coefficient,
$COV_P(A,B)$ = phenotypic covariance between variables A and B
                = $COV_G(A,B) + V_e(A,B)$,
$V_P(A) = V_G(A) + V_e(A)$
phenotypic variance for variable A,
$V_P(B) = V_G(B) + V_e(B)$
phenotypic variance for variable B,
$V_e$ = Me/r         error variance,
r = number of replications.

The heritability of a character can be computed by a number of methods, with the values obtained by the different methods varying to some extent. In addition, the heritability values of characteristics may be used to compute the genetic correlation among those characters.

Heritability estimates were carried out based on the variance components obtained from an analysis of variance procedure.

$$\text{Heritability } h^2 = \frac{V_G}{V_P} \times 100 \text{ narrow sense}$$

where     $V_G$ = (Mg-Me)/r   genetic variance,
         $V_P = V_G + V_e$      phenotypic variance,
         Mg and Me = mean squares of treatment and error, respectively,
         $V_e$ = Me variation among 15 $F_1$ crosses tested,
         r = number of replications.

## RESULTS AND DISCUSSION

### Correlations

A strong correlation and higher heritability of economically-important traits are highly desirable in breeding and selection work. The genetic variability of most characteristics is correlated with changes in other characteristics. For the most part, the phenotypic and genotypic correlations seem to be of a comparable magnitude.

### Yield components

Seed cotton yield was highly and significantly correlated with lint yield, number of seeds per boll, boll weight, lint index, number of bolls per plant; and moderately and significantly correlated with lint percentage, while lint yield was highly and positively correlated with lint percentage and the number of seeds per boll and moderately correlated with lint index and negatively correlated with seed index (Table 1).

These figures indicated that lint percentage, the number of seeds per boll and the number of bolls per plant played significant roles in the improvement of lint yield. In contrast, the negative association of seed index and lint yield

indicated that smaller seeds could contribute more to increasing lint yield. This was also reported by Miller *et al.* (1958) and McCarty *et al.* (1996). They also found a higher correlation between lint yield and lint percentage. A highly-significant but negative genotypic correlation of lint yield and seed index was recorded. Similar results were also reported by Al-Jibouri *et al.* (1958), Meredith and Bridge (1971) and Scholl and Miller (1976).

The same was true for lint percentage, which was positively correlated with one of its components - lint index, but negatively correlated with seed index. Lint index and seed index were positively correlated. This was due to their relationship, which was expressed by the following formula (Lee, 1980) :

$$LP = \frac{LI}{LI + SI}$$

where    LP= lint percentage,
         LI= lint index,
         SI= seed index.

Additionally, a strong correlation of lint percentage with the number of bolls per plant strengthened the importance of lint percentage as a good indicator of selection. The number of bolls per plant and boll weight were negatively and significantly correlated. Similar findings were reported by Miller *et al.* (1958), Bridge *et al.* (1971) and Tang *et al.* (1996). A strong, negative association of boll weight and the number of bolls per plant might be due to the balanced compensation of either trait.

Highly significant genotypic correlations between the number of seeds per boll and seed cotton yield and lint yield were observed. Positive and moderate genotypic correlations were found between the number of seeds per boll and boll weight, and a highly-significant positive and stronger correlation was found between boll weight and seed index, which indicated that a greater increase in boll weight could be expected from selecting for these traits than for any others (Table 1).

**Table 1**  Genetic and phenotypic correlations of yield components.

| Yield component | | Bolls per plant | Boll weight | Lint yield | Lint percentage | Lint index | Seed index | Seeds per boll |
|---|---|---|---|---|---|---|---|---|
| Seed cotton yield | $r_G$ | 0.72** | 0.99** | 0.88** | 0.65** | 0.91** | 0.17 | 0.99** |
| | $r_P$ | 0.38* | 0.52** | 0.89** | 0.43** | 0.54** | 0.11 | 0.63** |
| Bolls per plant | $r_G$ | | -0.96** | 0.81** | 0.82** | -0.44** | -0.99** | 0.67** |
| | $r_P$ | | -0.59** | 0.57** | 0.62** | -0.31 | -0.82** | 0.41** |
| Boll weight | $r_G$ | | | 0.37 | -0.23 | 0.81** | 0.95** | 0.14 |
| | $r_P$ | | | 0.26 | -0.19 | 0.79** | 0.86** | 0.18 |
| Lint yield | $r_G$ | | | | 0.94** | 0.73** | -0.26 | 0.96** |
| | $r_P$ | | | | 0.79** | 0.56** | -0.21 | 0.65** |
| Lint percentage | $r_G$ | | | | | 0.40** | -0.47** | 0.52** |
| | $r_P$ | | | | | 0.38* | -0.56** | 0.41** |
| Lint index | $r_G$ | | | | | | 0.66** | 0.09 |
| | $r_P$ | | | | | | 0.55** | 0.17 |
| Seed index | $r_G$ | | | | | | | -0.19 |
| | | | | | | | | -0.22 |

$r_G$ and $r_P$ = genotypic correlation and phenotypic correlation, respectively
* and ** = Significant at 0.05 and 0.01 level of probability, respectively

In most cases, the phenotypic correlation was lower than the genetic correlation, showing that the traits were mainly governed by genetic effects. Since lint yield is one of the most important economic traits in cotton, it is worthwhile to examine the possibility of its improvement and to increase the efficiency of selection for this character.

Such correlation results indicated that for the cotton genotype population studied a higher lint percentage, more bolls per plant with smaller seed size (seed index) and medium boll size were expected to result in a higher lint yield. Certain traits like lint percentage were closely correlated with lint yield and had a higher heritability than the more complicated characteristics of yield and consequently, might well serve as a better indicator of the genetic yield potential of the studied genotypes than does yield *per se* (see heritability in Table 4).

**Fiber quality parameters**

Fiber strength, length and fineness are the major fiber quality parameters on which textile processing and the quality of the product depend. Accordingly, premium prices are paid for these quality traits.

The genotypic and phenotypic correlations of fiber quality parameters are shown in Table 2. It was found that fiber strength was highly and significantly correlated with all fiber quality parameters except 50% staple length, which was moderately correlated. Significant, positive and strong, genotypic correlation was also observed for the two most important fiber quality parameters of fiber strength and 2.5% staple length.

A significantly-strong, positive correlation was observed between 50% staple length and 2.5% staple length, while a significant, negative correlation was observed with the short fiber index. Similarly, Meredith and Bridge (1971) and Scholl and Miller (1976) reported that fiber strength and the 2.5% and 50% span lengths had a strong, positive genotypic association with each other. A significantly-negative and strong correlation of 2.5% staple length and short fiber index and a low correlation of fiber fineness with short fiber index and uniformity ratio were also recorded.

A negative association of fiber length and strength with fiber fineness and short fiber index confirmed a similar direction of improvement for these characteristics, indicating that stronger,

**Table 2** Genetic and phenotypic correlations of fiber quality parameters.

| Quality parameter | | Staple length | | Fineness | Short | Uniformity |
| --- | --- | --- | --- | --- | --- | --- |
| | | 50% | 2.5% | | fiber index | ratio % |
| Strength | $r_G$ | 0.64** | 0.99** | -0.86** | -0.85** | -0.99** |
| | $r_P$ | 0.34* | 0.45** | -0.39** | -0.31* | -0.46** |
| Staple length 50% | $r_G$ | | 0.95** | -0.02 | -0.97** | 0.16 |
| | $r_P$ | | 0.84** | 0.02 | -0.93** | 0.20 |
| Staple length 2.5% | $r_G$ | | | -0.30* | -0.96** | -0.40* |
| | $r_P$ | | | -0.22 | -0.93** | -0.36* |
| Fineness | $r_G$ | | | | -0.01 | 0.61** |
| | $r_P$ | | | | 0.02 | 0.44** |
| Short fiber index | $r_G$ | | | | | -0.01 |
| | $r_P$ | | | | | 0.07 |

$r_G$ and $r_P$ = genotypic correlation and phenotypic correlation, respectively

* and ** = significant at 0.05 and 0.01 level of probability, respectively

longer, fine fibers and a lower, short fiber index could be the main target of selection in the cotton variety. A significantly-strong correlation among 2.5% staple length, fiber strength, short fiber index and fiber fineness indicated that selection for fiber quality could be easier, except for the negative association between the fiber quality traits and yield components (Table 3). Other correlations of interest are presented in Table 2. These findings suggested the possibility of mutual improvement of these traits.

**Yield components vs quality parameters**

Cotton production systems are commonly oriented towards yield, which is recognized as a major component of profitability. Lint quality is also a very important crop characteristic and has been an increasingly important issue since the advancement of improved textile factories.

The study of the correlations showed a negative association between the yield component and fiber quality parameters. A negative association of yield and fiber quality brought up the question of the relative importance of both parameters or the level of expected yield reduction, while the study was aimed at an improvement in fiber quality. However, the assignment of relative economic weights for the quality factors is a rather complex problem. Understanding this important association is necessary in conducting an effective selection program.

In this study, except for boll weight, lint index and seed index, all yield components were negatively correlated with fiber bundle strength, 2.5% and 50% staple length at both the genotypic and phenotypic levels. The strongest negative correlation was between: fiber strength and the number of bolls per plant; lint percentage and the number of seeds per boll; 2.5% staple length and the number of bolls per plant; seed index and the number of seeds per boll; 50% staple length and the number of bolls per plant; fiber fineness and boll weight; short fiber index and boll weight; and short fiber index and seed index. Lower positive and negative correlations were recorded between the uniformity ratio and yield components, but it was moderately and negatively correlated with

**Table 3**  Genetic correlation and phenotypic correlation between yield components and fiber quality parameters.

| Correlated characteristic | | Seed cotton yield | Bolls per plant | Boll weight | Lint yield | Lint percentage | Lint index | Seed index | Seeds per boll |
|---|---|---|---|---|---|---|---|---|---|
| Strength | $r_G$ | -0.66** | -0.96** | 0.30 | -0.96** | -0.99** | -0.28 | 0.76** | -0.93** |
| | $r_P$ | -0.30 | -0.48** | -0.13 | -0.48** | -0.58** | -0.14 | 0.40** | -0.34* |
| Staple length 50% | $r_G$ | -0.36* | -0.79** | 0.69** | -0.30 | -0.19 | 0.63* | 0.71** | -0.39* |
| | $r_P$ | -0.22 | -0.78** | 0.54** | -0.24 | -0.19 | 0.55* | 0.65** | -0.44** |
| Staple length 2.5% | $r_G$ | -0.12 | -0.91** | 0.84** | -0.32 | -0.48** | 0.54** | 0.91** | -0.50** |
| | $r_P$ | -0.08 | -0.54** | 0.65** | -0.27 | -0.44** | 0.48** | 0.82** | -0.27 |
| Fineness | $r_G$ | 0.31 | 0.52** | -0.41** | 0.79** | 0.99** | 0.49** | -0.61** | 0.16 |
| | $r_P$ | 0.16 | 0.17 | -0.26 | 0.53** | 0.84** | 0.35* | -0.45** | -0.02 |
| Short fiber index | $r_G$ | 0.07 | 0.84** | -0.86** | 0.15 | 0.22 | -0.78** | -0.81* | 0.28 |
| | $r_P$ | 0.05 | 0.77** | -0.66** | 0.13 | 0.21 | -0.61** | -0.73* | 0.33* |
| Uniformity ratio % | $r_G$ | -0.48** | -0.01 | -0.40** | 0.02 | 0.54** | -0.07 | -0.47** | 0.04 |
| | $r_P$ | -0.26 | -0.07 | -0.28 | 0.04 | 0.45** | 0.06 | -0.37* | 0.02 |

$r_G$ and $r_P$ = genotypic correlation and phenotypic correlation, respectively

* and ** = significant at 0.05 and 0.01 level of probability, respectively

seed cotton yield, boll weight and seed index and moderately and positively correlated with lint percentage. A significantly-moderate and negative correlation between lint yield and fiber strength, and a significantly-moderate and positive correlation with fineness were recorded. Lint percentage had a strongly-negative and significant correlation with fiber strength and a significantly-positive correlation with fineness (Table 3). Several quantitative genetic studies of cotton have documented a strongly-negative correlation between lint yield and fiber qualities (Miller and Rawling, 1967a and b; Meredith and Bridge, 1971; Meredith, 1977).

All these negative associations of economically-important yield and quality traits showed the difficulties in achieving simultaneous improvement in both areas. It seemed that the only important correlation observed herein was between boll weight and fiber quality parameters. Similarly, 2.5% staple length was strongly correlated with seed index and moderately correlated with lint index; the latter two traits had a strong correlation with boll weight.

These strong relationships indicated that boll weight, which was an important component of yield, was a good indicator of fiber quality improvement. However, a strongly negative correlation of boll weight with two important yield components - the number of bolls per plant and lint percentage, indicated the need to identify the optimum number of bolls per plant and boll weight in order that possible improvements of both yield and quality traits could be made, or to improve the existing negative relationships.

Similarly, lint yield has been reported to have a strong, negative, genotypic correlation with 2.5% and 50% span lengths (Meredith and Bridge, 1971), fiber strength (Al-Jibouri et al., 1958; Miller and Rawlings, 1967a; Meredith and Bridge, 1971; Fotiadis and Miller, 1973; Scholl and Miller, 1976; McCarty et al., 1996; Tang et al., 1996) and micronaire or fineness indicator (McCarty et al.,

1996). On the other hand, a strong, positive correlation between lint yield and fiber fineness (micronaire) was also reported by Fotiadis and Miller (1973), Scholl and Miller (1976), and Tang et al. (1996). These findings suggested that selection for a higher micronaire value would result in an increased lint yield. However, as micronaire increased, fibers became coarser and this might require an optimum fineness in order to meet a desirable level from a fiber-quality point of view.

However, there may be possible ways to improve these negative associations of yield components and fiber quality parameters (Meredith, 1977; Meredith and Bridge, 1971). In recurrent selection programs, Miller and Rawlings (1967b) found that as lint yield increased by selection, lint percentage and fiber coarseness increased. Therefore, breeders must concern themselves with the total array of economic characteristics, not just one trait.

This study indicated that an improvement in fiber qualities could result in reduced lint yield in cotton. A strongly-negative, genotypic correlation of lint yield with fiber strength was found to have an r-value of -0.96 (Table 3). Thus, the importance of knowing how much change in one character by selection might cause simultaneous changes in other economic traits was self-evident. Besides the level of correlation of economically-important traits in cotton, the knowledge of the amount of yield reduction per unit improvement of fiber quality is very essential. The estimated relationships based on the findings of this research indicated that to achieve a simultaneous improvement of yield and fiber quality of fiber length by 0.26 mm and of fiber strength by 0.5 g/tex for $F_1$ hybrids, and also a lint yield reduction of 100 kg/ha would be difficult (Zerihun, 2004).

Miller and Rawlings (1967b) and Meredith and Bridge (1971) found that linkage was the primary cause for the negative correlation

**Table 4** Heritability of yield components and fiber quality parameters, estimated from variance among 15 $F_1$ crosses.

| Yield component | Heritability $(h^2)$ % | Fiber quality parameters | Heritability $(h^2)$ % |
|---|---|---|---|
| Seed cotton yield | 44 | Strength | 33 |
| Number of bolls per plant | 59 | Staple length50% | 86 |
| Boll weight | 62 | Staple length 2.5% | 89 |
| Lint yield | 72 | Fineness (micronaire) | 60 |
| Lint percentage | 97 | Short fiber index | 86 |
| Lint index | 79 | Uniformity ratio | 69 |
| Seed index | 86 | | |
| Number of seeds per boll | 57 | | |

between lint yield and fiber quality and they recommended inter-mating to break this association. Scholl and Miller (1976) also suggested that some pleiotropic mechanism was involved in this association. The second important aspect of this finding gave a direction to devise a breeding methodology for simultaneous improvement of fiber yield and quality, involving three-way crosses, modified backcrosses or recurrent selection. Culp *et al*. (1973) demonstrated success in overcoming the yield-fiber quality linkage in cotton breeding by using both the pedigree method of breeding and modified selective backcrossing. Other correlations of interest and the results of heritability are presented in Tables 3 and 4.

**Heritability**

Estimation of the heritable variation of a trait is important in selection and breeding programs. Estimates of the narrow-sense heritability of yield and yield components are presented in Table 4. The heritability values were greater than 70% for most of the studied traits, including economically-important ones, indicating the possibility of progress from selection.

**Yield components**

Higher levels of heritability were found for: lint percentage, seed index, lint index and lint

yield at 97, 86, 79 and 72%, respectively; moderate levels for boll weight, the number of bolls per plant and the number of seeds per boll at 62, 59 and 57%, respectively; with lower levels for seed cotton yield at 44%. Different levels of the heritability of important traits have been found by different authors and for different materials with the same traits. Similar findings were reported by Al-Jibouri *et al*. (1958) with a heritability value of 90% for lint percentage and 41% for the number of bolls per plant by Tang *et al*. (1996).

Higher levels of heritability for lint percentage, lint yield and lint index, and their stronger relationship with other yield components indicated that these two traits could be readily selected as indicators for yield improvement.

**Fiber quality**

Estimates of the heritability of fiber quality parameters are presented in Table 4. Higher levels of heritability were recorded for 2.5% and 50% staple length and for short fiber index at 89, 86 and 86%, respectively; moderate levels for uniformity ratio and fineness at 69 and 60%, respectively; with a lower level for fiber strength at 33%. Different levels of heritability for important traits have been found by different authors for different materials of the same trait. Similarly, high heritability was reported for 2.5% span length (Al-Jibouri *et al*., 1958; Murray and

Verhalen, 1969). Contrary results of relatively low heritability values were also observed for 2.5% span length by Tang *et al*. (1996) and McCarty *et al*. (1996). A low heritability value was also observed by Tang *et al*. (1996) and McCarty *et al*. (1996), for 50% span length. Relatively-lower heritability values were also reported for fiber strength (McCarty *et al*., 1996).

High heritability estimates have been found to be helpful in the selection of superior genotypes based on the phenotypic performance of quantitative characteristics. However, for a characteristic with a low heritability value of less than 40%, selection may be considerably more difficult or virtually impractical, due to the masking effect of the environment on the phenotypic effects. Heritability of yield was generally lower than that of yield components and fiber properties, which indicated that breeders had to focus on strongly-related traits with higher heritability (Table 4).

Finally, it should be noted that the correlations and heritability observed here were applied only to the specific population analyzed. The interrelationships might be quite different in other materials in which different genetic associations exist in the tested genotypes and testing environments. This could be confirmed by the highly-variable results found by different authors with different materials and under different environmental conditions**.**

## CONCLUSIONS

Some negative correlations of yield components and fiber quality parameters demonstrated that the selection for fiber quality improvement in breeding high-yield cotton varieties seems to be quite complicated. The higher heritability and stronger correlation of lint yield with most yield components and the strong correlation of staple length with most quality traits indicated that these traits were important with

regard to lint yield and fiber quality improvement. The negative correlation of some yield components with the fiber quality traits may have been governed by linkage, so inter-mating was recommended to break these associations. In order to simultaneously improve fiber yield and quality, three-way crosses, modified backcrosses or recurrent selection could be suitable breeding strategies, due to some pliotropic mechanisms. In addition, the observed heritability estimates were high in some traits, especially lint yield, lint percentage, lint index and staple length, where they were quite good indicators in the selection of superior genotypes. Selection could be a practical option with regard to these yield components and fiber quality parameters. Fiber length on the other hand could be directly involved with fiber strength, which was considered as one of the most important traits of fiber quality for textile industries.

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