

**GENETIC ANALYSIS OF YIELD AND FIBRE CHARACTERS IN COLOURED  
LINTED COTTON (*Gossypium hirsutum* L.)**

Thesis submitted in part fulfilment of the requirements for  
the Degree of Master of Science (Agriculture) in  
Plant Breeding and Genetics to the  
Tamil Nadu Agricultural University  
Coimbatore

By

**K.AMUDHA, B.Sc. (Hort.)**

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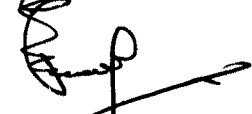
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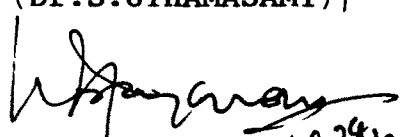
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*Dedicated to My  
Beloved Parents*



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*K. Anudha*

# Abstract

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**ABSTRACT**

**GENETIC ANALYSIS OF YIELD AND FIBRE CHARACTERS IN COLOURED  
LINTED COTTON (*Gossypium hirsutum* L.)**

By

**K. AMUDHA**

Degree : MASTER OF SCIENCE (AGRICULTURE)  
IN PLANT BREEDING AND GENETICS

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Ten coloured linted cotton genotypes including two green and eight brown types were subjected to variability studies and genetic analysis by making top crosses with five standard white linted varieties. Sixteen characters comprising yield, 9 yield components, 5 fibre quality parameters and lint colour were evaluated.

There were wide differences between the coloured linted types and white linted varieties in view of their position in separate  $D^2$  clusters. High heritability together with genetic advance noticed for seed cotton yield suggested

pedigree breeding to be effective in enhancing the yield potential of coloured linted varieties.

Boll number has been found to be the most important selection criterion. Colour of the lint showed positive association with fibre fineness and ginning outturn and negative relationship with bundle strength in parents. In hybrids, lint colour was negatively related to 2.5% span length and bundle strength.

Predominance of additive genes was noticed for all characters except number of sympodia per plant, lint index, seed index and colour of the lint for which, non-additive genes were important. Due to the presence of epistatic gene interaction as inferred from the combining ability analysis for different characters, recurrent selection procedures are suggested for converging yield, colour of the lint and fibre qualities. Higgin Botham and Algerian Brown with brown lint are the most superior parents possessing high gca and mean performance. Among the hybrids, Nankeen Brown x KC-1 was the best.

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# Introduction

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## 1. INTRODUCTION

Cotton is the most important commercial crop in the world and is considered to be the "Queen" among the fibre crops. Cotton production in India has made great strides during the past three decades. It has reached a production of more than 100 lakh bales per annum and India has become not only self sufficient but also a surplus country during this period. This was made possible mainly because of the commercial exploitation of heterosis particularly, in tetraploid cotton.

The upland cotton, *G.hirsutum* provides tremendous variability in respect of not only yield components, but also lint colour. While cotton with "white lint" is much preferred for spinning in the textile industry in view of its good economic values, spinning cottons "in natural colours" is beset with the inherent lower yield, poor fibre quality of the coloured linted varieties.

Extensive investigations on the genetic mechanism responsible for the development of lint colour have been made from the beginning of this century (Fletcher, 1907). However, practically no studies were made in the field of recombination breeding for harnessing simultaneously the good genetic potential of the "whites" in the background of coloured lint. Such phenotypes will be of greater importance

in the hosiery industry if not in the textile mill. An "ecofriendly" situation can thus be created to avoid the health hazards brought about by the bleaching and dyeing processes in these factories.

Investigations were therefore, taken up for eliciting information with the following objectives.

1. To evaluate the "coloured linted cotton" genotypes for genetic variability, heritability and genetic divergence for yield and its related characters.
2. To study the correlation of the character "coloured lint" with other economic and fibre characters.
3. To estimate the general combining ability of the parents and specific combining ability of the hybrids involving coloured linted varieties and also to know the gene action governing the important economic traits.
4. To assess the extent of heterosis in hybrids involving coloured linted varieties.
5. To find out suitable parents as well as hybrids for further exploitation either directly or for further breeding work.
6. To suggest suitable breeding strategy for developing coloured linted cultivars.

## Review of Literature

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## 2. REVIEW OF LITERATURE

### 2.1. Lint colour

Lint colour in cotton may be white, creamy white, dirty grey, black and various shades of brown upto almost a mahogany red, khaki or a bright green which speedily fades to a greenish rust brown (Martin and Leonard, 1949; Cardozier, 1957; Yegna Narayan Aiyer, 1958; Wolfe and Kipps, 1959 and Sethi *et al.*, 1960).

#### 2.1.1. Lint colour in diploids

Balls (1907), Richharia (1945) and Balasubramaniam (1963) have noticed the existence of coloured lint in old world cultivated cottons. Fletcher (1907) reported that colour was dominant over white. Kottur (1923) crossed a reddish tinged dull white *herbaceum* with a white-linted *arboreum*. The  $F_1$  possessed reddish tinged dull white lint and  $F_2$  segregated into three whites (or) dull white to one brown. He further reported that main lint colour genes were extremely susceptible to modifier gene action. In a cross between white-tinged red-linted Dharwar No.1 (*G. herbaceum*) and white-linted Rosea (*G. neglectum*), he observed segregation of plants for deep brown, pure white and dull white coloured lint in  $F_2$  generation. A negative correlation between lint colour and fibre length in *arboreum-herbaceum* crosses was discernible. The lint colour in *G. obtusifolium*,

*G.indicum* and *G.herbaceum* was found to be determined by three genes (Ayyar and Iyer, 1933), a basic gene X being essential for colour production.

Ramanathan and Balasubramanyan (1933) reported that intensification of colour was a result of the introduction of modifiers. They indicated that lint colour in the old world cotton was due to three factor pairs. One basic gene 'X' essential for colour, could produce pigmentation of the lint only in the presence of  $K_1$  and/or  $K_2$ . None of them could impart colour individually but when either  $K_1$  or  $K_2$  was present with X, the lint was cream coloured. The three genes together produced brown lint. Both  $K_1$  and  $K_2$  were of equal potency in colour production. Several modifiers seemed to influence.

The lint colour of the old world cotton was found to be determined by a single khaki gene, 'K' linked with leaf shape locus as was reported by Hutchinson (1934). Later, however, in 1935, he postulated the existence of three factors controlling the characters. Of these, K was linked with leaf shape and the others were symbolised as  $d_1$  and  $d_2$ . Hutchinson (1934a) detected multiple allelomorph series linked with a gene for brown lint, which he termed as K, with about 30 per cent crossing over. The lint colour modifier system in *herbaceum* was less pronounced than that

in *arboreum* (Silow, 1941). He also stated that no more than two main genes were responsible for the lint colour of *anomalum*.

Silow (1944) opined that lint colour in the cultivated Asiatic diploid species (*G. arboreum* and *G. herbaceum*) was due to main genes at three loci,  $LC_1$ ,  $LC_2$  and  $LC_3$  and by a variable complex of minor genes. The brown genes were cumulative in effect. Lint colour intensifiers have no colour expression by themselves, in the absence of main colour gene. Colour was negatively associated with lint length. Silow (1945) reported the existence of a fourth locus  $LC_4$ . At  $LC_1$ , only one fully dominant brown gene  $LC_1^K$  existed. In interspecific crosses, the main genes were not affected much by the modifier and the colour was not subjected to fading. Occasional mutation of this gene to white was also observed. At  $LC_2$ , a multiple allelomorph series including khaki, medium brown, light brown, very light brown and white was identified. Brown occurred at  $LC_2^K$ ,  $LC_2^M$ ,  $LC_2^B$ ,  $LC_2^V$  and  $LC_2$ .  $LC_2^K$  was regarded as duplicate of  $LC_1$ . It possessed a slightly lower degree of dominance.  $LC_2^B$  exhibited low dominance and was highly susceptible to modifier displacement and fading. At  $LC_3$ , only one brown gene  $LC_3^B$  which was indistinguishable duplicate of  $LC_2^B$  existed. At  $LC_4$  only one khaki linted gene,  $LC_4^K$  was known. Brown genes were cumulative in effect when  $LC_2^B$  and

LC<sub>3</sub>B occurred together in homozygous condition, their expression was darker than that of khaki allele.

As a result of high dominance of khakis, they showed stability. On exposure, both F<sub>2</sub> and back cross progenies segregating from them displayed comparative uniformity in the coloured class, whereas the light browns showed fading and resulted in considerable variability in the above generations. **Arboreum** browns were usually quite distinct from whites and did not fade below grade 5.

Silow (1944, 1944a) distinguished two classes of genes affecting the lint colour situation in old world cottons, colour genes which changed clear white to some shade of brown and modifiers, which affected the intensity of brown when a colour gene was present. Wherever cotton was spun by non-industrial communities, naturally coloured lint was used as a contrast to white or cream in pattern weaving. He pointed out that for such purposes, intermediate colours were useless and textile craftsman would demand only highly coloured or white lint and not pale brown and greys.

Silow (1944 a) reported high variability in the colour of commercial cocanadas. He noticed modifier content of the coloured strains of the race **indicum** was likely to be at a higher level than their white or near white sibs. The

environment played a very important role in the colour expression and fading in cocanadas cotton.

Balasubramanyan et al. (1950) showed that different strains of Cocanada (*arboreum*) carried  $LC_2B$  and  $LC_2V$ . Further, due to environmental effect and on exposure, considerable colour variability was noticed in  $LC_2V$ . Inheritance pattern indicated white linted cocanada pure line '45' was simple recessive to khaki ( $LC_1K$ ). Nanking khaki behaved as a simple dominant trait over cocanadas-1 ( $LC_2V$ ). A study of the association between staple length and lint colour revealed a uniform reduction in the length of brown segregated in all the hybrid progenies.

#### 2.1.2. Lint colour in tetraploids

Thadani (1925), Hutchinson et al. (1947), Brown and Ware (1958) have noticed the existence of coloured lint in upland species. The green colour of lint was found in certain strains of cotton which occurred spasmodically among American Uplands (Balls, 1908). The green colour appeared to be identical with the green colour of the fuzz. These green cottons faded to brown on exposure to sunlight and further to dingy white. Brown cottons especially Egyptians also faded in the sun, but more slowly than green.

Interspecific New world cottons were subjected to lint colour studies by Balls (1912) and the results

reported. In a cross of Egyptian variety having brown lint and a white linted upland variety, he obtained lint colour intermediate to the parents in  $F_1$ . The lint was creamy in colour. The  $F_2$  generation of this cross segregated into brown, creamy white and white with a frequency of 12:21:11 plants respectively. The plants with brown lint and with white lint bred true upto the fifth generation while the creamy coloured types continued to break up as in the  $F_2$  generation. The extra brown-linted plants never transgressed the limits of 'brownness' and they were not uniform. Some individuals were much darker in colour than that of the Egyptian plants, while others were lighter in colour than the brown parent. In a charara x King cross where the parents were very light brown Egyptian and white upland, Balls secured an intermediate  $F_1$  which on selfing produced 9 brownish, 60 creamy and 109 white plants.

Thadani (1923) reported yellow (or) yellowish brown and white were allelomorphic in upland varieties. Texas Rust lint was a monohybrid character and inherited according to a modified 3:1 Mendalian ratio due to incomplete dominance (Hayes and Garber, 1927). A few  $F_3$  plants were grown. Those bearing rust coloured (or) white lint in the second generation bred true in  $F_3$  for the respective character. The  $F_2$  plants with pale rust coloured

or intermediate lint, segregated for lint colour in the third generation.

Harland (1929) detected the existence of two factors for lint colour, khaki and green respectively. An interesting case of correlation was observed between green lint and lint fineness. The green segregates were invariably finer than white. In 1932, the same author found a pale brown upland type from Guatemala to segregate into brown, intermediate brown and white in a 1:2:1 ratio. According to Ware (1932), texture of brown lint was coarse and short, texture of green lint was soft but not short in length. In the upland cottons (*G.hirsutum*) he found each of the four lint colours, rust, dingy brown, yellowish brown and green, were allelomorphic to white. It was pointed out that the  $F_1$  generation was an intergrade between the respective coloured parent and the white parent showing that the lint colour to be incompletely dominant over white lint.

Harland (1935) summarised the lint colour situation in the New world cottons. The summary revealed that brown lint in the New world cotton was conditioned by duplicate genes.

$$K^B - K^B = \text{Brown to light brown in } \mathbf{barbadense}$$

$$K^H - K^H = \text{Brown to white in } \mathbf{hirsutum}$$

Negative correlation between lint colour and length was reported by Harland, in an intra-**barbadense** cross. A main brown lint gene was found associated with reduction of 5.1 mm in the homozygous phase and 2.7 mm in the heterozygous phase in lint length and minor lint colour intensifiers further reduced lint length but to a lesser extent. Lint colour was graded against a series of standards first established by him. Harland's records showed that in some  $F_2$  progenies heterozygous browns as high as grade 5 were obtained, whereas in others the heterozygotes were graded 2 or occasionally 3. Mahogany lint was very much shorter, more immature and coarser than white lint. There was little difference between grade 8 and grade 9 mahogany. Harland concluded that in **G. barbadense** both the main gene  $LC_2K$  and minor genes responsible for the development of light brown in the absence of  $LC_2K$  had a considerable effect on lint length. Of the colour genes, the independence of  $LC_1K$  in upland and  $LC_2K$  in Egyptian cottons were demonstrated by him.

The inter-**barbadense** cross, Egyptian brown x Sea Island white studied by Harland (1935) gave intermediate  $F_1$  and complicated segregation of the blending types in  $F_2$ . This was demonstrated to be due to the fact that the factor  $K^B$  of the brown parent was accompanied by a number of plus modifiers which were absent in the white parent. Repeated

back-crossing of heterozygotes to the brown parent had the effect of equalising the plus modifiers of both the dominant and recessive phases of the factor  $K^B$ . The blending type of inheritance of brown lint in Egyptian cotton (Enan's Brown) x Sea Island (pale cream) was considered to be due to the disintegration of an original brown-lint factor complex by human agency while the cross of brown *barbadense* x brown *hirsutum* was found to involve duplicate genes for lint colour. Harland (1935) had suggested that predominance of white lint cotton was the result of disintegration of a primitive brown lint character complex due to human selection for lint length. Brown (1938) reported that the lint of the wild cottons was brownish or khaki colour. Less, frequently, plants were found which had a green lint similar to that of the green fuzz on some seeds. This lint possessed a clear green colour when the boll first opened, but on exposure to light it faded to a tawny brown.

According to Hutchinson and Ramaiah (1938), lint colour was determined on cleaned lint as per standard colour chart. The trade classification was white, white to creamy white, creamy white, creamy white to creamy and creamy. All these could be classed as white on the *kapas* colour standards. There were only three main colours viz., white, grey and brown. In the studies on green lint cotton, Harland

(1939) found that green lint was determined primarily by a single pair of genetic factor. Green was incompletely dominant over white.  $F_2$  segregation consisted of green, intermediate green and white segregates in a ratio of 1:2:1. Progenies of the  $F_2$  green and white phenotypes bred true in the  $F_3$  and progenies of the  $F_2$  intermediate-green phenotypes again segregated into three classes proving the monogenic inheritance. The gene symbols,  $K^B$  and  $K^H$  as  $LC_1K$  and  $LC_2K$  were designated by Hutchinson and Silow (1939). *G.hirsutum* included forms with bright green lint fading on exposure to light to brownish green. It was a simple dominant to white, the factor pair responsible being  $Lg - lg$  as designated by Hutchinson and Silow.

Carl (1943) reported that the Arkansas Green lint cotton was not suitable for commercial production because of its low yield and ginning outturn. Richmond (1943) opined that green lint was softer and silkier than either brown lint or white lint. The fibres from pure green lint were actually finer or smaller in cross-sectional area than those from white or brown. The lint colour in Texas green, Nankeen, and Texas Rust each were conditioned by a single dominant gene in crosses with white lint. The gene for Texas Green was found to be independent of those for Nankeen and Texas Rust. The genes for Nankeen and Texas Rust were also alleles. Higgin Botham brown lint appeared to be genetically

different from, Nankeen and Texas Rust. The respective genes for green lint and brown lint appeared to inhibit the development of fibre.

Winston Neely (1943) made crosses between two strains (Arkansas Green lint and white linted half and half of upland cotton (*G.hirsutum*).  $F_1$  was intermediate green with a mean lint index value that was intermediate between those of the two parents. The  $F_2$  segregated in 1:2:1 ratio indicating the monogenic control of the colour. Green lint and low lint index were very closely associated and green lint gene suppressed the expression of the lint-index genes. The green pigment may be seen soon after the fibres begin to thicken and was apparent by 25 days after flowering. As the fibres develop, the colour was intensified until the boll opened, displaying the bright-green pigmentation which on exposure to light, gradually faded to a brownish green. Green pigment occurred in the cell wall and that this colouration was not present in the protoplasmic contents of the cell. The secondary genes that modify the expression of the green-lint factor also modified the lint index showing a linkage relationship. The two genes also segregated independently. When these genes were combined with white-lint character, the lint index of the white  $F_2$  was lower than that of the white parental line. It was concluded that

the green-lint and lint-index association was largely due to the pleiotropic effect of the basic gene for green lint and that, green-lint types with a lint index approximating that of commercial white cottons cannot be developed through breeding.

Silow (1944) reviewing the literature pertaining to inheritance of lint colour in the New world cottons, suggested that lint colour situation in New world cotton had a close parallellism with that of old world cotton. Main lint colour genes were uncommon in *hirsutum* except near the centre of diversity but the species as a whole had a high level of modifying gene complexes. In *barbadense*, on the other hand, the modern slight creamy Egyptian and Sea Island particularly, possessed one main brown gene and a strongly suppressing modifier background. Hutchinson (1946) reported the association between general shortening of metric length of cotton fibres with colour.

Genes determining brown lint in *G.punctatum* and *G.darwinii* were reported to be independent of  $LC_1K$ . Mahogany was distinct from all these in intensity of colour and it was highly dominant. It also had pronounced effects on lint length, maturity and fineness. Two brown genes were reported in *G.tomentosum*. In upland cotton a gene that intensified brown but had no effect on white, was reported. In *hirsutum*

racess **punctatum** and **Marie Galante** and in **barbadense** and **tomensotum**, minor lint colour genes that changed white to off white or even pale brown or intensity brown were reported. It was shown that the lint colour was a consequence of the comparatively recent origin of allopolyploidy from a cross between an old world cotton and an American wild species with light brown seed hairs, followed by human selection for widely contrasted lint colours (white and deep brown or mahogany) for use in the weaving of patterned textiles.

In a genetic study of brown lint character in five **hirsutum** types and one **barbadense** type, Brain (1950) noticed that four of the upland browns, Nankeen, Arvin, Algerian and Texas Rust were members of the same series of alleles and Brymer was controlled by a gene at another independent locus. Mohaux, a **barbadense** brown was shown to be non homologous to the Nankeen locus in upland cottons.

Christidis and Harrison (1955) expressed that in the case of New world cotton and with inter-**hirsutum** crosses, the genes for coloured lint proved to be allelomorphic to white and incompletely dominant to it. In the  $F_1$  the lint was intermediate in colour while in the  $F_2$ , segregation for 1:2:1 ratio conforming to the monohybrid ratio, occurred. More or less similar results have been

obtained with inter-**barbadense** crosses, but in the case of interspecific crosses between upland and Egyptian varieties, there was an indication for a complex type of inheritance. Ware and Benedict (1962) described seven brown linted cotton and two green linted cotton and reported their fibre characteristics.

## 2.2. Studies on heritability

Simmonds (1979) had explained that any estimate of heritability was unique. It was a property of a specific population in a specific experiment. Therefore, the numerical use of estimates out of context was illegitimate though it was sometimes reasonable to consider general orders of magnitude of heritabilities in a wider frame work. Moderate to very high estimates of heritability for ginning outturn, seed index, lint index, halo length, fibre maturity and fibre fineness were reported by Singh et al. (1972). Similar values were also realised by Singh et al. (1972a) for yield per plant, number of bolls per plant, boll weight, number of loculi per boll, number of seeds per locule and final plant height.

Baker and Verhalen (1973) suggested mass selection for improvement of fibre fineness and fibre strength based upon high values of heritabilities obtained by them for these traits. Heritability in broad sense was high for yield

and boll number (Kalsy et al., 1977). The gossypol content in the flower-bud was found inherited additively conferring 94 per cent heritability in the studies of Yang and Davis (1977).

Patil and Chopde (1983) reported moderately high heritability for yield per plant, days to 50 per cent flowering, days to first boll bursting, boll weight and lint index. All the traits recorded very high heritability estimates, ranging from 84.7 per cent for fibre fineness to 97.0 per cent for 2.5 per cent span length in the studies made by Nadarajan and Sree Rangasamy (1990).

### **2.3. Studies on Correlation and path relationships**

A knowledge on genetic correlation between different characters is very essential for a plant breeder to plan the crop improvement programmes. In cotton, both yield of seed cotton and fibre quality characters are very important to meet the requirements of the farming community as well as the textile industry. It is usually easy to combine positively inter-correlated characters but the programmes for combining the negatively related characters have to be carefully drawn up. To have a pre-view of the relationship existing between different characters in cotton, a brief report on correlation between different characters is presented below.

Alves (1970) reported that yield was positively correlated with plant height in *G.hirsutum* cotton. In the same species Balakotaiah (1973) made a path analysis and reported that monopodia, sympodia and seed index had direct positive effects on lint yield. According to him, boll weight and halo length exhibited indirect effects on yield. The direct effect of lint index on ginning percentage was the highest and positive in *G.hirsutum* varieties (Chandramathi, 1973). The weight of seed coat and the weight of kernel were highly correlated with lint index. Both of these characters indirectly played an important role in deciding ginning percentage.

Quisenberry et al. (1975) noticed positive correlation between lint index and fibre length as well as fibre fineness and a negative association between lint yield and fibre fineness in upland cotton. Culp and Harrel (1975) and School and Miller (1976) observed a positive association between ginning percentage and yield in *G.hirsutum* cotton.

A high positive genetic relationship between boll number and yield of seed cotton in *G.hirsutum* was noticed by Kalsy et al. (1977). Yield showed a negative association with halo length and ginning percentage in the above study. Narayanan (1978) observed a positive association between

yield on the one hand and lint index, seed index and fibre length in *G.hirsutum* cotton on the other.

Singh et al. (1979) subjected 50 varieties of *G.hirsutum* cotton to a path analysis and reported that boll number and boll weight had strong direct effect on seed cotton yield. Boll number and number of sympodia and boll weight and ginning outturn had positive correlations between themselves.

A comparison of path relationship in *G. hirsutum vis a vis G.barbadense* was presented by Giridharan (1979). In *G.hirsutum* species, seed cotton yield per plant was positively correlated with ginning percentage, lint index, number of bolls per plant and kapas weight per boll. Number of bolls per plant, ginning percentage and lint index showed positive inter-correlation among themselves in *G.hirsutum* but such a positive inter-correlation among these three characters did not exist in *G.barbadense* group. The study further disclosed that positive direct effect on seed cotton yield was exerted by seed index, ginning percentage and number of bolls per plant in *G.barbadense* species while the maximum direct effect on seed cotton yield was exerted by number of bolls per plant, ginning percentage and seed index in *G.hirsutum* species. All the yield components showed either high positive or negative indirect effect on seed

cotton yield through lint index and seed index in *G.barbadense* while in *G.hirsutum* all the yield components showed high positive or negative indirect effects on seed cotton yield through ginning percentage, seed index, number of bolls per plant and kapas weight per boll.

Kadambavanasundaram (1980) reported positive correlation between lint index and seed index and lint index and fibre length in *G.hirsutum* cotton. A correlation and path coefficient analysis was carried out by Singh et al. (1981) in *G.hirsutum* cotton. The results revealed that boll number and sympodial number per plant positively and significantly correlated with seed cotton yield. Number of bolls per plant had a high positive direct effect on yield while the other traits contributed indirectly through sympodial number and boll number.

Gill and Singh (1981) from a path analysis involving 62 diverse varieties of *G.hirsutum* cotton, reported that bolls per plant, boll size and ginning outturn had positive direct effects on seed cotton yield. In *G.hirsutum* cotton, Govila and Sharma (1981) noticed a direct and positive effect by boll number, boll weight and lint index on seed cotton yield. In this study ginning percentage and seed index had high positive indirect effects on yield through lint index.

Jehangir (1981) observed that yield had positive association with seed index and fibre length in *G.hirsutum* cotton. He also obtained a negative association between lint index and fibre length and seed index and fibre length.

A study by Dhanda et al. (1984) in *G.hirsutum* cotton revealed a positive correlation between yield and lint index, yield and seed index, lint index and seed index, lint index and fibre length, seed index and fibre length and fibre fineness and fibre maturity. They also observed weak associations between lint index and fibre fineness, seed index and fibre fineness and seed index and maturity coefficient.

The boll number was positively and significantly correlated with seed cotton yield, halo length and days to first flowering but negatively associated with boll weight, ginning percentage, lint index and seed index. There was significant and positive relationship between yield and boll number but yield and boll weight were negatively related (Jagtap and Kolhe, 1984). The same authors in 1986 observed highly significant and positive correlation of seed cotton yield with boll number and boll weight in *G.hirsutum* cotton. Days to flowering was negatively correlated with boll number, boll weight and yield which indicated that early

flowering was favourable for maximum expression of boll number, boll weight and yield of seed cotton.

Vijaykumar and Choudhry (1986) found that seed cotton yield per plant was significantly and positively correlated with boll number and boll weight in *G.hirsutum* cotton. Boll weight was positively and significantly associated with ginning percentage and halo length but showed negative association with boll number. Boll number had significant and negative association with ginning percentage. Studies on correlation in *G.hirsutum* varieties by Nadarajan (1986) indicated the lint yield to be positively correlated with lint index and seed index. Lint index and seed index were highly and positively correlated and they were also found to be positively associated with 2.5 per cent span length. Boll number and boll weight were highly correlated with seed cotton yield in rainfed *G.hirsutum* cotton as observed by Singh et al. (1987).

Ananda Choudary and Hanumantha Rao (1987) recognized a positive correlation between dry matter, kapas weight per boll, harvest index and seed cotton yield in upland cotton. Path coefficient analysis further indicated that plant height, number of monopodia and number of sympodia, dry matter, boll number, kapas weight per boll and harvest index contributed direct and positive effects to

seed cotton yield but ginning percentage and leaf area showed negative direct effects on seed cotton yield.

Tyagi et al. (1988) who made a cause and effect analysis in  $F_3$  and intermated biparental population in *G.hirsutum* cotton, concluded that number of bolls per plant, seed index, lint index, plant height and boll weight had direct effects on seed cotton yield in both the populations. Paramasivam and Udayasoorian (1989) critically analysed the yield components in *G.hirsutum* cotton and reported that yield of seed cotton was positively associated with all yield components. Further partitioning by path analysis revealed that plant height exerted the highest positive direct effect on seed cotton yield. Boll weight and number of bolls also contributed direct positive effects to seed cotton yield. The direct positive effect of sympodia and the indirect positive effects of plant height, boll weight and boll number on yield were mainly responsible in influencing the correlation between boll weight and yield.

Jehangir and Krishnaswami (1990) noticed negative direct effect of ginning percentage in diallel single cross mating and positive and maximum direct effects in diallel selective mating. Similarly, the direct effect of halo length was negative in diallel single cross mating and

diallel intermating system but it was positive in diallel selective mating system.

Seed cotton yield had significant positive correlation with flowers per plant, boll setting, number of bolls per plant, boll weight per boll and total biomass in *G.hirsutum* cotton varieties studied by Vireshwar Singh et al. (1990). The path coefficient analysis revealed that number of bolls per plant and total biomass production per hectare had direct effects on seed cotton yield. Other characters also exerted positive indirect effects on yield through these two characters.

#### 2.4. Studies on Genetic divergence ( $D^2$ )

Genetic divergence between genotypes is usually estimated by  $D^2$  analysis (Mahalanobis, 1928). Mahalanobis  $D^2$  analysis is a powerful biometrical technique which is based on multivariate analysis (Rao, 1952) of quantitative traits. The genotypes or parents are usually grouped into different clusters based on  $D^2$  distance. The genotypes coming in the same cluster are considered to be less divergent than the parents which fall under different clusters.

Siddiq et al. (1974) made a  $D^2$  analysis involving 22 varieties of *G.hirsutum* cotton of diverse geographical origin. They grouped the varieties under seven clusters. The clustering pattern did not correspond with the geographic

origin. Among the different characters studied, plant height, number of monopodia, ginning percentage and halo length contributed maximum towards total genetic divergence.

Giridharan (1979) made a  $D^2$  analysis using 25 parents in *G.hirsutum* species and 25 parents in *G.barbadense* species to extract information on genetic divergence. The individual  $D^2$  analysis resulted in 13 clusters in *G.hirsutum* and 12 clusters in *G.barbadense*. The pooled  $D^2$  analysis however, showed 19 clusters. The clustering pattern indicated that the geographical distribution could not always be related to genetic diversity. In the pooled  $D^2$  analysis, the two tetraploid species got grouped themselves separately in different clusters excepting in two clusters, which brought out the species differentiation to certain extent. Among the different characters studied, boll weight contributed maximum towards the total genetic diversity followed by number of seeds per boll and lint index in individual as well as in pooled  $D^2$  analysis.

The genetic diversity in 28 *G.barbadense* varieties using Mahalanobis  $D^2$  statistics was studied by Amalraj (1982). He reported that seed cotton yield had the highest share of genetic divergence. No correlation was observed between genetic divergence and geographic diversity.

## 2.5. Studies on combining ability and gene action

Combining ability was defined as the relative ability of a genotype to transmit its desirable performance to its hybrid progenies. General combining ability of the parent refers to the average performance of a strain in a series of crosses. Specific combining ability of the hybrid denotes the deviation from the performance predicted on the basis of general combining ability. The concept of combining ability in terms of genetic variation was first proposed by Sprague and Tatum (1942). The literature on combining ability pertaining to the studies in cotton is reviewed hereunder.

Al-Rawi and Kohel (1970) found highly significant general and specific combining ability for all the fibre properties in *G.hirsutum* cotton. The magnitude of GCA variance was two to four times higher than SCA variance indicating the predominance of additive genetic system for yield characters in *G.hirsutum* cotton (Singh and Gupta, 1970). In a line x tester analysis in *G.hirsutum* cotton, Singh et al. (1971) found that variance due to SCA was higher than that for GCA for yield and boll number. The variance due to GCA and SCA were significant for most of the characters in the *G.barbadense* varieties studied by Chandramathi (1973a). High proportion of GCA variance was discernible for plant height, number of fruiting branches

and number of bolls per plant indicating that these characters were governed by additive gene action.

Chinnadurai (1973) detected non-additive gene action for seed cotton yield. The GCA variance was reported to be high for halo length, plant height and days to first flowering (Chinnadurai et al., 1973). The variances due to general and specific combining ability were significant for ginning outturn, seed index, lint index, fibre length, fibre strength and fibre fineness in the genetic material studied by Gupta and Singh (1974). The magnitude of general combining ability variances was however, about four to six times higher than those due to specific combining ability.

The studies by Singh et al. (1976) revealed the importance of additive gene effects for ginning outturn and halo-length and non-additive gene effects for seed cotton yield and boll number, For all the other characters both additive and non-additive genes were important.

Gururaja Rao et al. (1977) observed complementary gene action for ginning percentage, lint index, seed index and fibre weight and over dominance for mean fibre length and fibre strength but there was no indication of gene interaction for seed index and mean fibre length. The study of variability for gossypol content by Yong and Davis (1977)

revealed a large and highly significant general combining ability for this trait. Singh *et al.* (1978) estimated significant combining ability variance for all the characters excepting halo length.

The yield and ginning outturn were governed by additive gene action in *G.hirsutum* cotton studied by Rajesh *et al.* (1979). Sharma (1979) indicated the importance of both additive and non-additive gene action as could be observed from the variances for GCA and SCA.

The yield and its components, boll number and boll weight were reported to be under the influence of non-additive genetic system in the material subjected to genetic analysis by Waldia *et al.* (1979). Both additive and non-additive interactions were found to be important for plant height. Only additive type of genetic interactions were observed for seed/locule in this analysis.

The study of combining ability by Bhandari (1980) revealed that the genetic component of variance for general combining ability (GCA) was important for plant height, number of sympodial and monopodial branches, although for the last character, SCA was also significant. According to Kalsy *et al.* (1981) both GCA and SCA variances were significant for yield, boll number, halo length and seed index which indicated the importance of both additive and

non-additive genetic factors for these characters in *G.hirsutum* cotton.

Gill and Kalsy (1981) detected epistatic gene action for seed cotton yield in *G.hirsutum* cotton. Preponderance of non-additive genetic variance over the additive genetic variance, was evident in the reports of Bhandari et al. (1981) although the latter was also significant for yield, boll number, boll weight, ginning percentage, fibre length, fibre fineness and plant dwarfness in American cotton.

Bains et al. (1982) reported that additive effects were significant for lint yield and seed index in *G.hirsutum* cotton. Ginning outturn was mainly under the control of additive gene action whereas the fibre characters were under the control of dominance and over dominance gene action in *G.barbadense* cotton (Vadne and Thombre, 1982). Jasmel Singh et al. (1982) found that additive genetic component was observed for ginning outturn but both additive and dominance components were significant for lint index and seed index.

Duhoon et al. (1983) encountered significant combining ability effects for all the characters. They reported that additive gene action was relatively more important for all the characters. Patil and Chopde (1983)

brought out the importance of additive and non-additive genetic variances for plant height, ginning percentage and mean halo length. Sanyasi (1983) noticed both additive and non additive gene action for seed index, lint index and ginning outturn in upland cotton. The report by Mohinder Singh et al. (1984) showed that although both GCA and SCA variances were significant for all the traits, non-additive gene effects were more important. However, epistatic variation was also reported to be significant for days to 50 per cent boll opening, yield of seed cotton, number of bolls/plant and seed index by Khajjidoni et al. (1985). For other characters viz., node number, lint index and ginning outturn, dominance component was significant.

Singh and Phundan Singh (1985) recognized the predominance of non-additive genetic variances for bolls/plant. The GCA of yield was found to be influenced by the GCA of its component characters. Preponderance of additive genetic variance was evident for halo length, seed and lint indices and dominance variance was significant for yield/plant, bolls/plant, boll weight, ginning outturn and plant height. Over dominance determined seed cotton yield, bolls/plant, boll weight, ginning outturn and plant height and the rest of the characters were under the control of partial dominance.

Gunaseelan and Krishnaswami (1986) reported that GCA and SCA variances were significant for bolls per plant, locules per boll and boll weight in *G.hirsutum* cotton.

In the study of Jagtap (1986), additive effects were significant for halo length while non-additive effects predominated the expression of bolls per plant, boll weight and yield per plant. Jagtap and Kolhe (1986a) concluded that both additive and dominance variance played a significant role for seed cotton yield, boll number, boll weight, ginning percentage, halo length and days to first flowering in *G.hirsutum* cotton. Additive variance was important for days to 50 per cent boll opening, yield of seed cotton, number of bolls per plant and seed index (Khajjidoni et al., 1986). In contrast, node number, lint index and ginning outturn were under the influence of dominant genes.

The importance of overdominance was demonstrated by Jagtap and Kolhe (1987) for boll number/plant, boll weight, seed cotton yield, ginning percentage and mean halo length and partial over dominance for days to first flowering. The analysis further revealed the significant additive and non-additive gene action for all the six characters.

Mohinder Singh et al. (1987) reported that non-additive genetic effects were more important for fibre

strength and fibre fineness whereas additive genetic effects were essential for fibre length. A special type of gene action involving duplicate epistasis was reported by Thombre et al. (1987) for boll numbers and seed cotton yield. These characters appeared to be under the control of additive, dominance and epistatic gene effects.

Amalraj (1989) recognized that both GCA and SCA variances were significant for all the characters. The GCA:SCA ratios suggested the importance of additive genetic variance for yield, boll number, seeds per boll, halo length and ginning percentage in this study.

The combining ability effects were significant for oil content and other economic traits in cotton (*G.hirsutum*) in the studies of Dani (1989). Green and Culp (1990) in *G.hirsutum* cotton observed significant additive genetic effects for 2.5 per cent span length, 50 per cent span length, uniformity ratio, yarn strength, yield and lint percentage.

The boll number per plant was determined jointly by both additive and non-additive genes while average boll weight was mostly controlled by additive genes (Kadapa and Prajapati, 1990). Nadarajan and Sree Rangasamy (1990) found the importance of additive genes for lint index, seed index,

2.5 per cent span length, uniformity ratio and fibre fineness while lint yield and maturity coefficient were determined jointly by additive and non-additive genes. In the results reported by Pavasia *et al.* (1990), both general and specific combining ability variances were significant for yield and yield components revealing the importance of both additive and non-additive gene action in *G.hirsutum* cotton.

#### 2.5.1. Relationship of combining ability and *per se* performance

Singh and Gupta (1970) did not find any relationship between *per se* performance of the parents and their general combining ability effects for yield characters. But working on the same material, Gupta and Singh (1974) observed strong relationship between the *per se* performance of the parents and their general combining ability effects. They suggested that while for some characters, selection of parents for hybridization programme should be based on their *per se* performance, a critical study of combining ability would be necessary in respect of other traits. Singh *et al.* (1976) showed that the *per se* performance of parents was usually an indication of their combining ability also. Similar reports were also made by Rajesh *et al.* (1979). However, Singh *et al.* (1976a) found that the *per se* performance was not associated with their

combining ability effects. The *per se* performance of male parents was closely associated with general combining ability effects in the studies of Udayakumar Holla (1986), while, this relationship was not discernible in respect of female parents.

## 2.6. Studies on heterosis

The word heterosis was coined by Shull (1908, 1908a, 1948). The superiority of the  $F_1$  hybrid over its parents is expressed as heterosis or hybrid vigour (Gowen, 1952). The concept of heterosis, nature and origin of heterosis, physiology of gene action in hybrids, gene interaction in heterosis, theories of heterosis and utilization of hybrid vigour in developing hybrids were explained by Gowen (1952). A brief review on heterosis in respect of cotton, the crop under study is presented below.

The overall heterosis was significant for all the characters in the studies of Singh *et al.* (1977). The superiority over to the best check was manifested for the yield of seed cotton and the number of bolls. The crosses between highly bred local varieties and genetically diverse genetic stocks were highly heterotic.

Singh et al. (1978) realised heterosis ranging from 40.0 to 129.0 per cent and 4.2 to 30.7 per cent respectively for boll number and boll weight per plant. It was as high as 183.0 per cent for the yield in one of the crosses. In general, hybrid progenies obtained from the crosses involving parents with low phenotypic expression exhibited maximum heterosis.

Bhatade et al. (1979) evaluated intervarietal crosses of Desi cotton for hybrid vigour. Heterosis ranging from 1.4 to 123.9 per cent over better parent was observed for seed cotton yield. The expression varied between 0.2 to 10.4 per cent and 0.9 to 5.7 per cent over mid parental value for ginning percentage and fibre length respectively. Moderate heterosis was noticed for sympodia/plant.

In *arboreum* cottons, high degree of heterotic effect for yield was realised by Govil and Singh (1979). The heterotic expression of yield was associated with high degree of heterosis in the component characters, number of bolls per plant, lint index and ginning outturn. The study of diallel analysis of three *G.hirsutum* and two *G.barbadense* parents by Sharma (1979) on bolls/plant and seed cotton/plant disclosed high heterosis over the top ranking parents. The heterotic effects were observed to be high in case of yield of seed cotton, bolls/plant and boll weight in

the crosses (Waldia et al., 1979). For most of the cases, the heterotic effects were noticed either in boll number or boll weight which in turn reflected by substantial hybrid vigour in yield of seed cotton.

Bhatt and Rao (1981) noticed one intraspecific (*G.hirsutum*) and two interspecific (*G.hirsutum* x *G.barbadense*)  $F_1$  hybrids exhibiting heterosis for fruiting branches, number of bolls, yield of seed cotton and photosynthetic rates. Mid parent and better parent heterosis for seed cotton yield and seven other quantitative characters viz., earliness, flowering, plant height, boll number, dry matter, leaf area and ginning outturn were obtained by Vijendra Das (1982) in interspecific hybrids between cultivars of *G.hirsutum* and *G.barbadense*.

Duhoon et al. (1983) reported that heterosis was high for monopodial and sympodial branches, boll number and yield per plant. A low magnitude of heterosis was observed for halo length. Lather (1985) recorded heterobeltiosis for seed cotton yield in the order of 36.39 to 43.23 per cent. Heterosis for earliness, yield and yield components in twenty crosses of *G.arboreum* x *G.herbaceum* cottons was discernible in the studies by Khajjidoni (1986).

Nadarajan (1986) who studied heterosis for fibre characters in *G.hirsutum* cotton in a line x tester analysis

noticed heterosis for lint yield from -49.6 per cent to 142.4 per cent, for lint index from -12.9 per cent to 120.9 per cent, for seed index from -16.4 per cent to 12.6 per cent, for 2.5 per cent span length from -7.6 per cent to 108.7 per cent, for uniformity ratio from -9.0 per cent to 119.2 per cent, for fibre fineness from -12.2 per cent to 143.9 per cent and for maturity coefficient from -9.4 per cent to 105.7 per cent. Expression of heterosis for all the 11 quantitative characters was evident in the studies of Sangwan and Yadava (1986). Nevertheless, the hybrid vigour was much pronounced for yield, boll weight, bolls per plant and earliness.

Tiwari et al. (1987) reported positive and significant heterosis for bolls per plant, boll weight, ginning outturn and yield in intra specific crosses of upland cotton. Heterosis for yield was accomplished due to increase in boll number per plant. The highest heterosis for yield over the better parent was 219.5 per cent.

The study of Gunaseelan and Krishnaswami (1988) disclosed the expression of heterosis in the inter-racial crosses of *G.hirsutum*. The hybrids which showed maximum heterosis in  $F_1$ , also exhibited maximum inbreeding depression in the  $F_2$  for all the characters.

Interspecific crosses exhibiting high magnitude of useful heterosis for seed cotton yield as compared to the intra-racial hybrids were identified by Ansingkar et al. (1990). Negative heterosis for ginning outturn and halo length was shown by interspecific crosses. Intra racial hybrids of red x red (*G.arboreum* race **bengalense**) varieties also expressed high magnitude of heterosis effect for seed cotton yield. Dwarf x dwarf hybrids displayed high positive heterosis for yield and halo length but for ginning outturn the vigour was in the negative direction. Intra-racial crosses registered substantial heterosis for all the characters.

Bhale and Bhat (1990) found that the hybrids based on genetic male sterility were superior to hybrids involving cytoplasmic male sterile line. Duhoon (1990) in a nine parent diallel crosses of American cotton, noticed high heterobeltiosis for seed cotton yield and boll number per plant and low magnitude of hybrid vigour for boll weight, halo length and ginning percentage.

Green and Culp (1990) evaluated diallel crosses of intra-specific hybrids of upland cotton for heterosis and reported heterosis for some of the fibre properties. Kadapa and Prajapati (1990) encountered heterosis for yield,

earliness and fibre quality in Intra - *G. barbadense* hybrids.

Interspecific crosses of diploid cotton exhibited heterobeltiosis for cotton seed yield, ranging from 21.6 to 208.6 per cent (Phundan Singh and Narayanan, 1990). They suggested that heterosis for yield was mainly due to heterosis for boll number. The naked-seeded character also played an important role in the expression of heterosis in the above study.

The forgoing review goes to show that the studies on combining ability and heterosis in hybrids involving coloured linted cotton varieties are very limited though, an exhaustive work has been accomplished in respect of genetic studies on coloured linted cotton and biometrical investigations on white linted cotton varieties of diploid and tetraploid species of *Gossypium*.

## Materials and Methods

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### **3. MATERIALS AND METHODS**

#### **3.1 MATERIALS**

The experimental materials chosen for this study consisted of ten coloured linted ovule parents viz., Arkansas Green, Texas Green, Brymer Brown, Higgin Botham, Nankeen Brown, Russian Brown, Louisiana Brown, Algerian Brown, Hirsutum Tashkent and Parbhani American and five white linted pollen parents viz., MCU-5, MCU-7, MCU-9, KC-1 and LRA-5166. The selfed seeds of the above parents were obtained from the germplasm collection maintained at the Cotton Breeding Station, School of Genetics, Tamil Nadu Agricultural University, Coimbatore-3. Following the Line x Tester model of Kempthorne (1957), crosses were synthesised using coloured cotton varieties as (female) lines and the white linted standard varieties as (male) testers. The details of the two groups of varieties are presented in Table 1.

#### **3.2. METHODS**

##### **3.2.1. Synthesis of Crosses**

The seeds of the selected parents were sown during winter 1992-93 season (Aug-Feb). Each variety was raised in five rows of 6m length in a crossing block. The spacing adopted was 75 cm between rows and 30 cm between plants in the row, so as to have 20 plants per row. Hand emasculat

Table I. Particulars of parental genotypes used in the investigation.

Genotypes	Sources	Code No.	Special Characters
<b>LINES</b>			
Arkansas Green	USA	C <sub>1</sub>	Very low yield, Green coloured lint Short staple.
Texas Green	USA	C <sub>2</sub>	Low yield, Green Coloured lint, Short Staple
Brymer Brown	USA	C <sub>3</sub>	Poor yield, Brown Coloured lint, Short staple
Higgin Botham	USA	C <sub>4</sub>	Poor yield, Brown Coloured lint, Short staple
Nankeen Brown	USA	C <sub>5</sub>	Poor yield, Brown Coloured lint, Poor fibre quality
Russian Brown	Russia	C <sub>6</sub>	Poor yield, Brown Coloured lint, Poor fibre quality
Lousiana Brown	USA	C <sub>7</sub>	Poor yield, Brown Coloured lint, Poor fibre quality
Algerian Brown	USA	C <sub>8</sub>	Moderate yield, Brown coloured lint, medium staple
Hirsutum Tashkent	Russia	C <sub>9</sub>	Poor yield, Brown Coloured lint, Poor fibre quality
Parbhani American	Surat	C <sub>10</sub>	Poor yield, Brown Coloured lint, Poor fibre quality
<b>TESTERS</b>			
MCU-5	Multiple cross derivative	T <sub>1</sub>	High yielding, high quality and cosmopolitan strain
MCU-7	An Xray irradiated mutant of L1143 EE	T <sub>2</sub>	Short duration and medium staple strain
MCU-9	Derivative of the cross between MCU-5 x MCU-8	T <sub>3</sub>	High yielding and long staple strain
KC-1	Re-selection from SRT-1	T <sub>4</sub>	Jassid resistant and medium staple variety
LRA-5166	Derivative from cross Laxmi x (Reba B-50 x AC 122)	T <sub>5</sub>	High yielding and medium staple variety

in flowers of lines due to open on the next day, was carried out in the evening. The emasculation was performed in such a way as to carefully remove the entire antheriferous column along with the corolla by finger nails without injuring the gynoecium. In the next day, the flowers at their peak of anthesis were collected from the appropriate pollinator parent and the pollen was dusted on to the stigma by gently smearing the anthers on all the sides of the stigma after removing the petals. The emasculation and pollination was continued till sufficient number of crossed bolls were secured in each of the 50 combinations programmed in the experiment.

### 3.2.2. Field layout

The fifty  $F_1$  hybrids involving ten coloured linted varieties and five standard varieties and fifteen parents (10+5) were sown during February, 1993, in an experiment laid out in randomised block design with three replications. Each hybrid/parent was raised in single row plot of 6 m length with a spacing of 75 cm between rows and 30 cm between plants in the row, so as to have 20 plants per row. The recommended agronomic practices and need based plant protection measures were followed to have the best expression of plants in all the varieties.

### 3.2.3. Observations recorded

Five plants out of the total 20 plants in each  $F_1$  hybrid/parent in each replication were randomly selected and tag-labelled for recording observations. The following observations were recorded.

#### 1. Days to first boll bursting

The number of days from sowing to the bursting of the first boll was recorded in five sample plants and the mean worked out.

#### 2. Days to maturity (Crop duration)

The number of days taken from sowing to the date by which maximum number of bolls burst in about 50 per cent of the plants was recorded in the five sample plants and the mean worked out.

#### 3. Plant height

The height of the plant from the cotyledonary node to the tip of the plant at maturity, was recorded in cm. for five sample plants and the mean value calculated.

#### 4. Number of sympodia per plant

Number of sympodial branches i.e., number of fruiting branches produced by each of the sample plants at maturity was counted and the mean arrived at.

#### 5. Number of bolls per plant

Number of matured bolls in the five sample plants was counted at maturity and the mean value computed.

#### 6. Boll weight

Three well burst bolls in each plant were collected and the **kapas** from the bolls was weighed. The weight of **kapas** per boll was worked out. The mean value for the five sample plants was calculated and expressed as boll weight per boll in g.

#### 7. Seed cotton yield

The seed cotton or **kapas** from each sample plant was collected separately, weighed and mean yield of seed cotton per plant was worked out and expressed in g.

#### 8. Ginning outturn

One hundred seeds with fibre (**Kapas** sample) from each single plant were taken and weighed. Then, this sample was ginned by using a hand gin to separate out the lint (fibres) from the seeds. The quantity of lint obtained was weighed and the lint outturn for the **kapas** sample taken was calculated and expressed as ginning outturn in percentage.

#### 9. Lint index

Lint index was determined as the quantity of lint in grams obtained from 100 seeds and was computed using the formula.

$$\text{Lint index} = \frac{\text{Weight of 100 seeds} \times \text{Ginning percentage}}{100 - \text{Ginning percentage}}$$

#### 10. Seed index

Weight of 100 seeds in grams was recorded as seed index.

#### 11. Colour of the lint

The lint colour in five sample plants was graded using the chart developed by Hutchinson and Ramaiah (1938) and the mean worked out.

After evaluating these characters, the kapas samples from the five single plants were pooled, ginned and the lint obtained was given to Central Institute for Research on Cotton Technology, Coimbatore unit for assessing the following fibre characters.

#### 12. 2.5% span length

2.5% span length is the fibre length estimated by the digital fibrograph. This is the length of fibres representing majority of the fibres and expressed in millimeter.

#### 13. Uniformity ratio

This is the ratio between two span lengths, at 50% span and at 2.5% span and it is expressed as percentage. Uniformity ratio was determined as follows.

$$\text{Uniformity ratio} = \frac{50\% \text{ span length}}{2.5\% \text{ span length}} \times 100$$

Uniformity ratio denotes the percentage of longer fibres.

#### 14. Fibre fineness

This is a relative measure of size, diameter and linear density of fibres which denotes the fineness of the fibre. The instrument 'Sheffield micronaire' was used to determine the fineness and expressed in microgram per inch. The micronaire instrument employs the principle of measuring the resistance to air flow through a plug of fibres as an indication of the fineness of those fibres. It was estimated by placing a sample of 3.24 g in the specimen holder and compressing it to a fixed volume. Air at fixed pressure was forced through the plug. The amount of flow is indicated by the position of the float in the vertical tube connected to the compression chamber. Fineness is read directly on the micronaire scale.

#### 15. Maturity coefficient

The unitary expression of fibre maturity usually represented by the percentage of mature, half mature and immature fibres denotes the maturity coefficient.

About 100 fibres were placed on a slide from an aligned end of the sliver with the help of a tweezer in such a manner that the fibres are approximately parallel to one another. The fibres were covered with a coverslip and irrigated with 18 per cent caustic soda (NaOH) solution. The mounted slide was placed on the microscope stage in such a manner that the central portion of the fibres was beneath the objective lens. The fibres were examined one by one by moving the stage of the microscope in the transverse direction. Maturity coefficient was then obtained by using the formula.

$$MC = \frac{M + 0.6 H + 0.4 I}{100}$$

where,

M, H and I refer to the percentage of mature, half mature and immature fibres.

#### 16. Bundle strength

This denotes the fibre strength. This is also known as tensile strength, i.e., the maximum specific stress that is developed in a tensile test to rupture the fibres. The fibre strength was determined by using '1/8' gauge length of the fibres. The stelometer gives the tensile strength and is expressed as tenacity in gram/tex.

### 3.3. Statistical analyses:

#### 3.3.1. Analysis of variance

The mean values arrived from the five sample plants for the different characters were subjected to statistical analysis. Analysis of variance, estimation of standard error and critical difference were done individually for all the characters by adopting the method suggested by Panse and Sukhatme (1964). ANOVA Table was constructed as follows

ANOVA				
Source	d.f.	S.S.	M.S.	Expectation
Replication	r-1	SSr	Mr	
Genotypes	t-1	SSt	Mt	$\sigma^2_e + r\sigma^2_t$
Error	(r-1)(t-1)	SSe	Me	$\sigma^2_e$
Total	rt-1			

The test of significance was carried out by referring to "F" table given by Snedecor and Cochran (1967).

#### 3.3.2. Genotypic and phenotypic variance and coefficient of variability

Genotypic and phenotypic variances, genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were estimated using the mean squares from the ANOVA table for the different characters as given by Singh and Choudhary (1979).

1. Genotypic variance ( $\sigma^2_g$ )

$$\sigma^2_g = \frac{Mt - Me}{r}$$

where,

Mt = Mean squares for varieties,

Me = Error mean squares and

r = Number of replications.

2. Phenotypic variance ( $\sigma^2_p$ )

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

where,

$\sigma^2_g$  = Genotypic variance and

$\sigma^2_e$  = Mean squares due to error.

3. Genotypic coefficient of variability (GCV)

$$GCV = \frac{\sigma_g}{\bar{x}} \times 100$$

where,

$\sigma_g$  = Genotypic standard deviation and

$\bar{x}$  = Grand mean.

4. Phenotypic coefficient of variability (PCV)

$$PCV = \frac{\sigma_p \times 100}{\bar{x}}$$

where,

$\sigma_p$  = phenotypic standard deviation and

$\bar{x}$  = Grand mean.

### 5. Heritability ( $h^2$ )

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

$$\sigma^2_g = \text{Genotypic variance and}$$

$$\sigma^2_p = \text{Phenotypic variance.}$$

### 6. Genetic advance (GA)

$$GA = K\sigma^2_p h^2$$

Where,

$$K = \text{Selection differential,}$$

$$\sigma^2_p = \text{Phenotypic variance and}$$

$$h^2 = \text{Heritability.}$$

### 3.3.3. Correlation coefficient

Genotypic correlation was worked out as per method suggested by Goulden (1959) and Singh and Choudhary (1979) in order to find out the relationship between yield and yield components in the parents. The variance and covariance components were utilised to calculate the correlation coefficients by applying the following formula.

$$r_{xy} = \frac{\text{Cov. (x, y)}}{v(x) \times v(y)}$$

Where,

$$r_{xy} = \text{Correlation coefficient between characters x and y,}$$

$Cov.x,y$  = Covariance between characters x and y,

$v(x)$  = Variance of character x and

$v(y)$  = Variance of character y.

The significance of correlation coefficient was tested by referring to table given by Snedecor and Cochran (1967) at  $(n-2)$  degrees of freedom.

Correlation coefficients were also worked out using lint colour as independent character and fibre quality characters, 2.5% span length, bundle strength, fibre fineness as well as seed cotton yield and ginning outturn as dependent variables.

#### 3.3.4. Path analysis

A Path coefficient analysis was done for yield and the yield components in fifteen parents (10 lines and 5 testers) and in fifty hybrids to find out the direct and indirect effects of different characters on seed cotton yield. By using the genotypic correlation coefficients, path coefficients were arrived at, adopting the procedure of Wright (1921) and Dewey and Lu (1959).

#### 3.3.5. $D^2$ analysis

The data on yield and yield components obtained for the 15 parents (ten lines + five testers) in this experiment were utilised to evaluate the genetic diversity using the Mahalanobis  $D^2$  analysis (Rao, 1952).



In this analysis the generalised distance between any two population is given by the following formula,

$$\Delta^2 = \sum \sum \lambda_{ij} \sigma_i \sigma_j$$

Where,

$\lambda_{ij}$  = Matrix reciprocal to the common dispersion matrix.

$\sigma_i$  = difference between the mean values of the two populations for the  $i$ th character.

The  $D^2$  statistics is estimated using the following formula,

$$D^2 = \sum \sum s_{ij} \sigma_i \sigma_j$$

Where,

$s_{ij}$  = Sample estimate of  $\lambda_{ij}$  and  $\sigma_i \sigma_j$

To work out  $D^2$  statistics, first it is necessary to transform the correlated variables to uncorrelated variables. Transformation was done by using pivotal condensation method (Rao, 1952).

The  $D^2$  value obtained for a pair of population was taken as the calculated  $\chi^2$  value and was tested against the table value of  $\chi^2$  for  $P$  degrees of freedom (where  $P$  is the number of characters studied) to find out the statistical significance.

Grouping of parents into different clusters was done following Tocher's method (Rao, 1952). The criteria of grouping was that any two populations belonging to the same cluster should have smaller  $D^2$  value than those belonging to the other clusters. Starting with two closely associated parents, a third parent having the smallest  $D^2$  value from the first two parents was added. The fourth one was chosen to have the smallest  $D^2$  value from the first three and so on. If at any stage, the average  $D^2$  value of a group from those already included appeared to be high, it was considered that the latter group did not fit in with the former cluster and hence considered to be outside the first cluster. The group of the first cluster was then completed and the rest of the parents were grouped in the same way into different clusters.

After forming the different clusters or group constellations, the average inter and intracluster distances were worked out taking into consideration of all the component  $D^2$  values. The square root of the  $D^2$  value gave the distance (D) between the different clusters.

#### **3.3.5.1. Contribution of individual characters to divergence**

In all the combinations, each character was ranked on the basis of  $d_i = Y_i^j - Y_1^k$  values. Rank one was given to the highest mean difference and last rank P was given to the lowest mean difference, where P was the total number of

characters. Then, the per cent contribution of each character towards divergence was calculated.

The parents grouped together in the same cluster were considered as less divergent than the parents which were grouped in different clusters.

With the help of the intra and intercluster  $D^2$  distances, the cluster diagram was drawn to show the relationship between different populations or groups. Clusters separated by largest or highest  $D^2$  distance was considered to have maximum divergence.

### 3.3.6. Line x tester analysis

A line x tester analysis was carried out to estimate the combining ability effects and variances as proposed by Kempthorne (1957). The mean squares due to different sources of variation and their genetic expectations were estimated as detailed in the ANOVA.

#### ANOVA

Sources of variation	d.f.	S.S	M.S.	Expectation
Replication	$r-1$	$SS_r$	$MSS_r$	
Lines	$l-1$	$SS_l$	$MSS_l = M_l$	$\sigma^2_{e+r} (\text{Cov.F.S} - 2 \text{Cov.H.S.}) + rt (\text{Cov.H.S.})$

Testers	t-1	SS <sub>t</sub>	MSS <sub>t</sub> =M <sub>2</sub>	$\sigma^2 e+r$ (Cov.F.S - 2 Cov.H.S.) + rl (Cov.H.S.)
Line x tester	(l-1) (t-1)	SS <sub>lt</sub>	MSS <sub>lxt</sub> =M <sub>3</sub>	$\sigma^2 e+r$ (Cov.F.S - 2 Cov.H.S.)
Error	(lt-1) (r-1)	SS <sub>e</sub>	MS <sub>e</sub> =M <sub>4</sub>	$\sigma^2 e$
Total	<hr/>			
	rlt-1	<hr/>		

Where,

r = number of replications,

l = number of lines and

t = number of testers.

From the genetic expectations of mean squares, covariance of full sibs (Cov.F.S) and covariance of half sibs (Cov.H.S) were estimated as follows.

$$\text{Cov.F.S.} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4) + 6r \text{ Cov.H.S.} \approx r (l + t) \text{ Cov.H.S.}}{3r}$$

$$\text{Cov.H.S.} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r (l + t)}$$

From the covariance of half sibs and covariance of full sibs, variance due to general combining ability ( $\sigma^2$  GCA) and variance due to specific combining ability ( $\sigma^2$  SCA) were estimated as follows.

$$\sigma^2 \text{ GCA} = \text{Cov.H.S. (Additive) and}$$

$$\sigma^2 \text{ SCA} = \text{Cov.F.S.} - 2 \text{ Cov.H.S. (Non-additive).}$$

General combining ability effects (**gca**) of parents and specific combining ability effects (**sca**) of hybrids were then estimated using the following model.

$$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$$

Where,

$\mu$  = Population mean,

$g_i$  = **gca** effect of *i*th line,

$g_j$  = **gca** effect of *j*th tester,

$S_{ij}$  = **sca** effect of *ij*th hybrid,

$e_{ijk}$  = error associated with *ijk*th observation,

*i* = number of lines,

*j* = number of testers and

*k* = number of replications.

The individual **gca** and **sca** effects were estimated as follows.

$$\text{Mean} = \frac{X_{...}}{ltr}$$

$$\text{gca effect of lines} = g_i = \frac{x_{i...}}{tr} - \frac{x_{...}}{ltr}$$

$$\text{gca effect of testers} = g_j = \frac{x_{.j.}}{lr} - \frac{x_{...}}{ltr}$$

$$\text{sca effect of hybrids} = S_{ij} = \frac{x_{ij.}}{r} - \frac{x_{i..}}{tr} - \frac{x_{.j.}}{lr} + \frac{x_{...}}{ltr}$$

Where,

$x_{...}$  = total of all hybrid combinations,

$x_{i..}$  = total of  $i$ th line over  $t$  testers and  $r$  replications,

$x_{.j.}$  = total of  $j$ th tester over  $l$  lines and  $r$  replications and

$x_{ij.}$  = total of the hybrid between  $i$ th line and  $j$ th tester over  $r$  replications

The standard errors pertaining to **gca** effect of lines, **gca** effect of testers and **sca** effect of hybrids were calculated as detailed below.

$$\text{S.E. } (g_i) \text{ lines} = \sqrt{\frac{\sigma_e^2}{rt}}$$

$$\text{S.E. } (g_j) \text{ testers} = \sqrt{\frac{\sigma_e^2}{rl}}$$

$$\text{S.E. } (S_{ij}) \text{ hybrids} = \sqrt{\frac{\sigma_e^2}{r}}$$

The significance or **gca** effect of lines, **gca** effect of testers and **sca** effect of hybrids was tested against twice the standard error at five per cent level. The ratio of GCA variance/SCA variance was worked out for each character to find out the predominance of additive gene action or non-additive gene action.

### 3.3.7. Heterosis

Three types of heterosis in the hybrids viz.,

1. relative heterosis i.e., heterosis over mid-parental value (di heterosis),
2. heterobeltiosis i.e., heterosis over better parent (dii heterosis) and
3. standard heterosis i.e., heterosis over best parent (diii heterosis) were worked out as suggested by Gowen (1952) for all the characters. Heterosis was estimated as follows.

#### 1. Relative heterosis

Relative heterosis is the superiority of hybrid over its respective mid-parental value. This was estimated using the following formula and expressed in percentage.

$$\text{Relative heterosis (\%)} = \frac{\bar{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$$\begin{aligned} \bar{F}_1 &= \text{Mean of } F_1 \text{ hybrid and} \\ \overline{MP} &= \text{Mean of mid-parental value.} \end{aligned}$$

The significance of heterosis was tested using the respective critical differences (LSD) for the characters.

## 2. Heterobeltiosis

Heterobeltiosis is the superiority of the hybrid over its better parent. This was estimated using the following formula.

$$\text{Heterobeltiosis} = \frac{\bar{F}_1 - \bar{B}_{r.P}}{\bar{B}_{r.P}} \times 100$$

Where,

$\bar{F}_1$  = Mean of  $F_1$  hybrid and

$\bar{B}_{r.P}$  = Mean of better parent for the cross-combination.

The significance of heterosis was tested using the respective critical differences (LSD) for the characters.

## 3. Standard heterosis

Standard heterosis is the superiority of the hybrid over the best parent or standard variety. The best performing parent in each character was considered as the standard variety for calculating standard heterosis. Standard heterosis was estimated using the following formula.

$$\text{Standard heterosis} = \frac{\bar{F}_1 - \bar{B}_{t.P}}{\bar{B}_{t.P}} \times 100$$

Where,

$\bar{F}_1$  = Mean of  $F_1$  hybrid and

$\bar{B}_{t.P}$  = Mean of the best parent among all the parents in each character.

The significance of heterosis was tested using the respective critical differences (LSD) for the characters.

## Experimental Results

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## 4. EXPERIMENTAL RESULTS

The experimental results of the investigations are presented in this chapter.

### 4.1. Mean Performance

The mean performance of parents and hybrids for the 16 characters studied are presented characterwise in Tables 2 and 3.

#### 4.1.1. Days to first boll bursting

Days to first boll bursting ranged from 99.00 in  $C_3$  and  $C_{10}$  to 108.67 in  $C_1$  with a mean of 103.87 among the lines and from 90.33 in  $T_2$  to 107.00 in  $T_3$ . The mean for the testers was 100.73 days. The hybrids varied from 93.67 in  $C_{10} \times T_2$  to 104.33 days in  $C_8 \times T_3$ . The mean duration to first boll bursting in hybrids was 96.97 days.

#### 4.1.2. Days to maturity

Days to maturity was the lowest in  $C_3$  and  $C_{10}$  and highest in  $C_8$ , the values being 128.33 to 138.00 days and the mean was 132.77 days for the lines. It ranged from 130.33 in  $T_2$  to 165.67 in  $T_3$  with a mean of 149.47 among the testers. For hybrids, it varied between 123.00 ( $C_4 \times T_2$ ,  $C_5 \times T_2$ ,  $C_6 \times T_2$  and  $C_{10} \times T_2$ ) and 133.67 ( $C_8 \times T_3$ ) with a mean of 126.17. The hybrids in general were shorter in duration than parents.

Table 2. Mean expression of different characters in the parents

Parents	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympo- dia/ plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)	Colour of lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro- naire)	Maturity coefficient (%)	Bundle stren- gth (g/tex)
<b>(A) Lines (Coloured linted varieties)</b>																
C <sub>1</sub>	108.67	137.67	38.87	9.60	3.60	1.23	4.31	29.30	2.67	6.43	4.40	21.43	47.00	2.75	0.57	20.90
C <sub>2</sub>	103.33	132.67	52.53	10.33	9.53	2.01	18.57	29.29	2.90	7.00	3.53	20.33	47.67	2.75	0.59	23.03
C <sub>3</sub>	99.00	128.33	56.47	11.53	11.27	1.71	18.86	28.79	3.80	9.40	3.40	21.50	44.00	2.63	0.54	19.57
C <sub>4</sub>	105.33	133.67	52.07	12.00	11.47	1.77	19.83	28.54	4.17	10.43	4.53	20.50	47.67	2.89	0.63	19.73
C <sub>5</sub>	102.33	131.33	54.60	12.20	6.67	1.62	10.88	32.89	4.87	9.93	5.73	20.63	46.67	2.84	0.61	19.27
C <sub>6</sub>	101.00	130.33	49.33	11.07	10.67	1.70	17.71	33.08	4.40	8.90	5.47	21.10	44.00	2.82	0.61	19.23
C <sub>7</sub>	107.67	137.00	48.40	11.47	10.40	1.70	17.16	31.10	4.17	9.23	5.00	19.80	46.33	2.93	0.64	19.23
C <sub>8</sub>	111.00	138.00	60.47	12.27	14.53	2.21	32.01	32.56	4.20	8.70	5.40	24.13	43.67	2.58	0.51	19.47
C <sub>9</sub>	101.33	130.33	44.27	11.07	7.47	1.37	10.10	29.01	3.80	9.30	5.47	20.10	44.67	2.99	0.64	18.17
C <sub>10</sub>	99.00	128.33	42.47	10.87	8.00	1.63	13.07	34.63	5.37	10.13	6.00	16.73	50.00	3.55	0.71	15.87
Grand Mean	103.87	132.77	49.95	11.24	9.36	1.70	16.25	30.92	4.04	8.95	4.89	20.63	46.17	2.87	0.61	19.45
<b>(B) Testers (White linted varieties)</b>																
T <sub>1</sub>	103.67	164.67	91.60	19.87	16.67	4.26	70.41	34.28	5.63	10.80	1.00	26.77	46.33	2.89	0.62	24.40
T <sub>2</sub>	90.33	130.33	84.20	18.87	13.13	4.04	52.15	33.13	5.27	10.63	1.00	26.80	48.00	3.17	0.66	23.33
T <sub>3</sub>	107.00	165.67	85.87	18.60	19.40	4.50	86.73	35.05	5.43	10.07	1.00	31.00	44.67	3.19	0.63	23.87
T <sub>4</sub>	97.67	141.00	64.13	15.67	13.73	4.36	58.62	36.15	5.13	9.07	1.00	23.27	48.67	2.80	0.60	25.13
T <sub>5</sub>	105.00	145.67	99.60	20.20	21.80	3.00	65.11	36.70	5.33	9.20	1.00	25.60	48.00	2.85	0.61	25.63
Grand Mean	100.73	149.47	85.08	18.64	16.95	4.03	66.60	35.06	5.36	9.95	1.00	26.69	47.13	2.98	0.62	24.47
SE	0.26	0.31	0.94	0.56	0.48	0.03	0.99	0.04	0.04	0.08	0.13	1.02	1.10	0.15	0.02	0.85
CD	0.75	0.89	2.72	1.63	1.38	0.09	2.86	0.13	0.12	0.24	0.38	2.94	3.18	0.42	0.06	2.46

Table 3. Mean expression of different characters in the hybrids

Hybrids	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympo- dia/ plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)	Colour of lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro- naire)	Maturity coefficient (%)	Bundle strength (g/tex)
C <sub>1</sub> x T <sub>1</sub>	96.33	125.33	49.33	11.47	10.47	1.84	18.47	33.52	2.03	4.03	2.40	23.50	50.33	2.77	0.58	25.53
C <sub>1</sub> x T <sub>2</sub>	94.00	123.67	46.20	11.07	6.27	1.70	11.19	30.60	2.00	4.53	2.40	20.67	48.67	2.90	0.61	21.97
C <sub>1</sub> x T <sub>3</sub>	100.33	129.67	55.73	15.13	13.67	1.96	26.55	35.09	2.67	4.93	2.53	25.60	47.67	2.74	0.56	23.77
C <sub>1</sub> x T <sub>4</sub>	97.00	126.00	69.73	13.13	11.20	1.75	19.47	36.56	3.40	5.90	2.47	23.20	48.00	2.63	0.52	24.60
C <sub>1</sub> x T <sub>5</sub>	96.00	125.00	73.33	15.20	12.73	1.60	20.19	36.02	2.53	4.50	2.47	23.73	47.67	2.70	0.59	23.07
C <sub>2</sub> x T <sub>1</sub>	99.00	128.33	58.13	13.27	12.27	2.38	28.76	35.74	2.97	5.33	2.53	25.97	47.67	2.81	0.61	23.73
C <sub>2</sub> x T <sub>2</sub>	98.00	127.00	60.20	14.73	12.13	2.26	27.27	33.23	2.60	5.23	2.53	24.90	49.33	2.83	0.60	22.07
C <sub>2</sub> x T <sub>3</sub>	99.33	128.67	59.13	16.87	14.47	2.47	35.39	35.82	2.40	4.30	2.60	26.30	49.00	2.77	0.59	23.60
C <sub>2</sub> x T <sub>4</sub>	99.00	128.00	66.80	13.33	10.80	2.37	25.43	35.72	2.50	4.50	2.27	23.20	47.33	2.80	0.61	23.20
C <sub>2</sub> x T <sub>5</sub>	99.00	128.67	77.47	14.53	14.27	2.10	29.75	36.16	3.00	5.30	2.47	23.77	51.00	3.50	0.70	23.73
C <sub>3</sub> x T <sub>1</sub>	97.33	126.00	58.93	15.27	16.07	2.20	35.13	33.45	2.83	5.63	2.53	25.37	48.00	2.86	0.60	22.87
C <sub>3</sub> x T <sub>2</sub>	95.33	124.00	56.53	13.40	14.47	2.10	30.21	31.82	2.33	5.00	2.33	25.63	47.33	3.02	0.63	22.07
C <sub>3</sub> x T <sub>3</sub>	97.00	126.67	61.73	16.20	16.47	2.30	37.27	33.70	2.37	4.67	2.47	24.97	45.67	2.67	0.54	21.87
C <sub>3</sub> x T <sub>4</sub>	97.33	126.00	64.27	14.60	16.27	2.14	34.73	33.77	2.60	5.10	2.27	23.00	46.33	2.87	0.62	19.90
C <sub>3</sub> x T <sub>5</sub>	96.00	125.67	66.73	16.40	20.47	2.00	40.20	35.54	2.87	5.20	2.47	25.73	45.33	2.97	0.63	22.43
C <sub>4</sub> x T <sub>1</sub>	95.33	124.00	62.40	16.13	16.67	2.27	37.79	33.59	2.80	5.53	3.60	25.27	43.67	2.74	0.56	22.17
C <sub>4</sub> x T <sub>2</sub>	94.00	123.00	65.20	13.73	15.93	2.10	32.71	31.99	3.23	6.87	3.33	23.53	47.67	3.11	0.67	23.07

(Contd.)

Table 3. (Contd.)

Hybrids	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympo- dia/plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)	Colour of the lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro- naire)	Maturity coefficient (%)	Bundle strength (g/tex)
C <sub>4</sub> x T <sub>3</sub>	96.33	125.67	54.53	13.20	20.60	2.40	49.11	34.24	2.10	4.03	2.60	24.83	43.00	2.64	0.52	21.33
C <sub>4</sub> x T <sub>4</sub>	95.00	124.00	69.40	14.80	15.53	2.25	34.78	35.57	2.80	5.07	3.60	23.20	45.67	2.99	0.63	21.47
C <sub>4</sub> x T <sub>5</sub>	96.33	125.33	74.53	17.00	22.07	2.10	45.24	34.72	2.50	4.70	3.40	23.60	43.67	2.79	0.58	22.47
C <sub>5</sub> x T <sub>1</sub>	96.67	126.67	54.20	16.00	12.60	2.33	29.05	34.69	2.83	5.33	4.40	24.53	46.33	2.80	0.60	22.73
C <sub>5</sub> x T <sub>2</sub>	94.00	123.00	58.53	11.07	9.47	2.24	20.99	32.43	2.40	5.00	5.47	23.00	47.67	2.88	0.62	22.53
C <sub>5</sub> x T <sub>3</sub>	98.33	127.67	51.20	12.27	13.80	2.40	32.57	34.58	2.47	4.67	4.60	23.50	43.67	2.66	0.54	21.80
C <sub>5</sub> x T <sub>4</sub>	95.33	124.67	71.60	16.67	17.07	2.82	46.67	33.33	2.43	4.87	3.53	23.20	47.33	2.94	0.63	21.53
C <sub>5</sub> x T <sub>5</sub>	95.00	124.00	74.13	15.93	21.60	2.20	46.27	32.81	2.10	4.30	3.47	23.90	45.00	2.96	0.63	20.63
C <sub>6</sub> x T <sub>1</sub>	97.00	126.67	64.47	15.53	13.93	2.68	36.30	33.73	2.87	5.63	4.20	25.13	44.33	2.79	0.60	20.30
C <sub>6</sub> x T <sub>2</sub>	94.00	123.00	61.67	14.00	10.07	2.56	25.59	32.91	2.60	5.30	3.47	24.57	47.33	2.94	0.62	23.13
C <sub>6</sub> x T <sub>3</sub>	96.00	125.67	55.47	13.67	15.73	2.80	42.70	35.14	2.60	4.80	4.47	22.17	44.33	2.78	0.59	18.60
C <sub>6</sub> x T <sub>4</sub>	95.00	124.00	66.40	10.93	12.27	2.42	29.47	34.95	2.87	5.33	4.53	24.00	45.00	2.72	0.58	22.37
C <sub>6</sub> x T <sub>5</sub>	96.00	125.00	69.67	16.13	17.60	2.40	40.79	35.23	3.10	5.70	3.40	23.17	44.00	2.75	0.59	19.43
C <sub>7</sub> x T <sub>1</sub>	97.00	126.67	63.53	16.07	15.80	2.30	36.07	34.48	3.00	5.70	3.47	25.20	48.67	3.28	0.68	20.67
C <sub>7</sub> x T <sub>2</sub>	95.00	124.67	52.40	13.40	11.87	2.19	25.69	33.58	3.03	6.00	3.53	23.53	47.00	2.94	0.64	21.10
C <sub>7</sub> x T <sub>3</sub>	99.33	128.67	53.13	13.80	16.33	2.76	44.64	35.59	2.10	3.80	3.20	23.37	45.00	2.73	0.58	19.53
C <sub>7</sub> x T <sub>4</sub>	96.00	125.00	68.33	13.53	13.73	2.13	29.17	35.30	3.00	5.50	3.47	22.77	47.33	2.85	0.63	20.50

(Contd.)

Table 3. (Contd.)

Hybrids	Days to first boll bursting duration)	Days to maturity (crop duration)	Plant height (cm)	No. of sympo- dia/ plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/ plant)	Seed ginning outturn (%)	Lint index (g/100 seeds)	Colour of the lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro- naire)	Maturity coeffic- lent (%)	Bundle stren- gth (g/tex)
C <sub>7</sub> x T <sub>5</sub>	96.67	125.67	70.40	<b>17.00</b>	16.33	2.00	32.68	35.97	3.03	3.53	24.53	45.00	2.83	0.62	22.13
C <sub>8</sub> x T <sub>1</sub>	101.33	130.67	65.40	16.40	17.40	2.28	39.63	33.96	2.80	2.53	<b>28.70</b>	46.33	2.60	0.52	24.27
C <sub>8</sub> x T <sub>2</sub>	96.00	124.00	64.00	14.60	14.73	2.23	32.69	32.89	2.50	2.60	26.60	44.00	2.63	0.54	22.37
C <sub>8</sub> x T <sub>3</sub>	<b>104.33</b>	<b>133.67</b>	62.47	15.47	19.00	2.30	43.51	34.78	2.93	<b>2.27</b>	28.10	43.33	<b>2.49</b>	<b>0.48</b>	21.97
C <sub>8</sub> x T <sub>4</sub>	97.00	125.00	72.67	14.33	16.07	2.22	35.43	36.74	3.23	2.33	27.20	45.33	2.64	0.56	24.10
C <sub>8</sub> x T <sub>5</sub>	97.00	126.33	75.33	16.07	20.27	2.10	41.78	36.62	2.60	2.40	27.57	46.33	2.62	0.54	24.57
C <sub>9</sub> x T <sub>1</sub>	99.33	128.67	57.80	14.53	12.60	2.56	31.95	34.25	2.90	3.60	24.70	47.33	2.76	0.59	21.97
C <sub>9</sub> x T <sub>2</sub>	97.33	126.67	49.53	12.13	9.33	2.21	20.42	32.40	2.10	2.53	24.03	46.00	3.04	0.66	21.83
C <sub>9</sub> x T <sub>3</sub>	100.67	130.67	63.87	14.60	13.67	2.60	34.81	35.44	2.57	3.53	25.10	44.33	2.65	0.54	21.97
C <sub>9</sub> x T <sub>4</sub>	100.00	129.67	65.00	12.20	13.07	2.04	26.35	35.94	2.77	2.40	23.60	46.33	2.79	0.62	22.63
C <sub>9</sub> x T <sub>5</sub>	98.67	128.00	72.27	15.13	14.67	2.30	33.27	36.34	2.80	2.53	24.27	45.33	2.96	0.64	22.63
C <sub>10</sub> x T <sub>1</sub>	95.00	124.33	53.73	13.40	13.47	2.35	31.37	33.59	2.80	3.40	21.77	45.33	3.21	0.68	<b>17.33</b>
C <sub>10</sub> x T <sub>2</sub>	<b>93.67</b>	<b>123.00</b>	52.60	12.33	12.07	2.12	25.43	32.18	2.80	2.53	21.90	47.67	<b>3.64</b>	<b>0.73</b>	17.67
C <sub>10</sub> x T <sub>3</sub>	96.67	126.00	55.53	15.27	15.80	2.52	39.25	33.59	2.77	4.40	21.33	46.00	3.08	0.66	18.73
C <sub>10</sub> x T <sub>4</sub>	96.00	125.00	65.47	14.40	11.20	2.09	23.18	34.37	2.87	3.60	21.00	48.67	3.36	0.68	18.83
C <sub>10</sub> x T <sub>5</sub>	96.33	125.33	64.67	15.80	16.40	2.00	32.54	<b>36.79</b>	2.60	3.53	23.00	45.00	2.93	0.67	20.30
Grand Mean	96.97	126.17	62.52	14.44	14.82	2.25	32.60	34.43	2.68	3.12	24.23	46.37	2.87	0.60	21.86
SE	0.22	0.19	1.21	0.48	0.47	0.03	0.95	0.20	0.13	0.17	0.73	0.98	0.11	0.03	0.92
CD	0.62	0.53	3.41	1.35	1.33	0.07	2.66	0.56	0.35	0.47	2.05	2.74	0.30	0.07	2.60

#### 4.1.3. Plant height

Plant height ranged from 38.87 cm in  $C_1$  to 60.47 cm in  $C_8$ . The mean plant height of lines was 49.95 cm. For the testers, the mean was 85.08 and the range was 64.13 to 99.60.  $T_4$  and  $T_5$  were the shortest and tallest tester genotypes. The plant height ranged from 46.20 cm to 77.47 cm in hybrids with  $C_1 \times T_2$  and  $C_2 \times T_5$  recording the lowest and highest values respectively. The mean was 62.52 cm for the hybrids.

#### 4.1.4. Number of sympodia per plant

Number of sympodia per plant ranged from 9.60 in  $C_1$  to 12.27 in  $C_8$  and the mean was 11.24 among the lines. In the testers, it varied between 15.67 and 20.20 in  $T_4$  and  $T_5$  respectively. The mean number of sympodia per plant in tester was 18.64. The range in the hybrids was from 10.93 in  $C_6 \times T_4$  to 17.00 in crosses  $C_4 \times T_5$  and  $C_7 \times T_5$ . The mean number of sympodia in the hybrids was 14.44.

#### 4.1.5. Number of bolls per plant

The number of bolls per plant displayed a variation in boll number from 3.60 in  $C_1$  to 14.53 in  $C_8$  among the lines. The mean was 9.36. In testers, this varied from 13.13 in  $T_2$  to 21.80 in  $T_5$  and the testers had a mean boll number of 16.95. The range for this character in the

hybrids was from 6.27 in  $C_1 \times T_2$  to 22.07 in  $C_4 \times T_5$ . The mean number of bolls per plant in the hybrids was 14.82.

#### 4.1.6. Boll weight

Boll weight was the lowest in  $C_1$  and highest in  $C_8$ , the values being 1.23 g and 2.21 g respectively. A mean boll weight of 1.70 g was recorded for the lines. It ranged from 3.00 g in  $T_5$  to 4.50 g in  $T_3$  among the testers. The mean boll weight of testers was 4.03 g. The hybrids were intermediate with a range of 1.60 g to 2.82 g in  $C_1 \times T_5$  and  $C_5 \times T_4$  respectively, and the average was 2.25 g.

#### 4.1.7. Seed cotton yield

Seed cotton yield varied from 4.31 g in  $C_1$  to 32.01 g in  $C_8$  with a mean of 16.25 g among the lines and from 52.15 g in  $T_2$  to 86.73 g in  $T_3$  with a mean of 66.60 g among the testers. The hybrids showed a variation from 11.19g in  $C_1 \times T_2$  to 49.11 g in  $C_4 \times T_3$ . The mean of 32.60 g noticed in the hybrids was intermediate to the female and male parental values.

#### 4.1.8. Ginning outturn

Ginning outturn was the lowest in  $C_4$  and highest in  $C_{10}$  among the lines, the values being 28.54 and 34.63 per cent respectively for these genotypes. The mean value for the lines was 30.92 per cent. The minimum and maximum values of ginning percentage in testers were 33.13 per cent in  $T_2$

and 36.70 per cent in  $T_5$ . For the testers, the mean was 35.06 percentage. The hybrids had a mean expression of 34.43 per cent and the range was from 30.60 per cent to 36.79 per cent. The lowest and highest values were registered by  $C_1 \times T_2$  and  $C_{10} \times T_5$  respectively.

#### 4.1.9. Lint index

The mean lint index for lines, testers and hybrids were 4.04 g, 5.36 g and 2.68 g respectively. The range was between 2.67 g and 5.37 g in the lines, 5.13 g and 5.63 g in testers and 2.00 g and 3.40 g in hybrids.  $C_1$  (line),  $T_4$  (tester) and the hybrid  $C_1 \times T_2$  registered minimum values whereas  $C_{10}$  (line),  $T_1$  (tester) and  $C_1 \times T_4$  (hybrid) recorded maximum values.

#### 4.1.10. Seed index

The variation in seed index was between 6.43 g in  $C_1$  and 10.43 g in  $C_4$  among the lines, between 9.07 g in  $T_4$  and 10.80 g in  $T_1$  in the testers and from 3.80 g in  $C_7 \times T_3$  to 6.87 g in  $C_4 \times T_2$  in the hybrids. The mean values for lines, testers and hybrids were 8.95 g, 9.95 g and 5.10 g respectively.

#### 4.1.11. Colour of the lint

The lint colour assumed a range from 3.40 in  $C_3$  to 6.00 in  $C_{10}$  with a mean of 4.89 among the lines. All testers

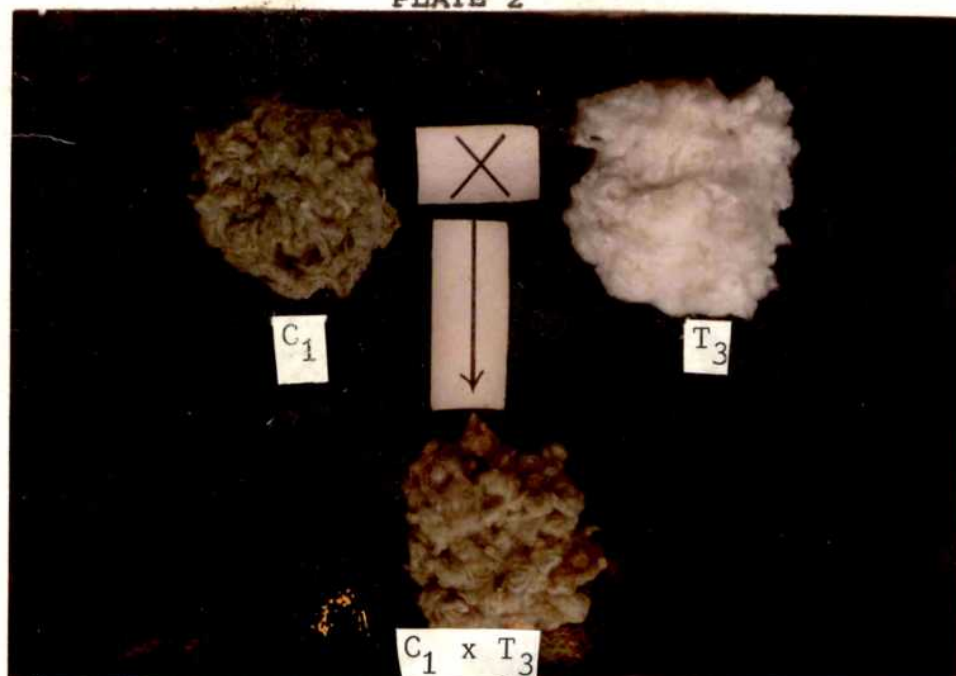
PLATE 1

Lint colour grades - Hutchinson and  
Ramaiah (1938) Colour Chart

## PLATE 2 to 11

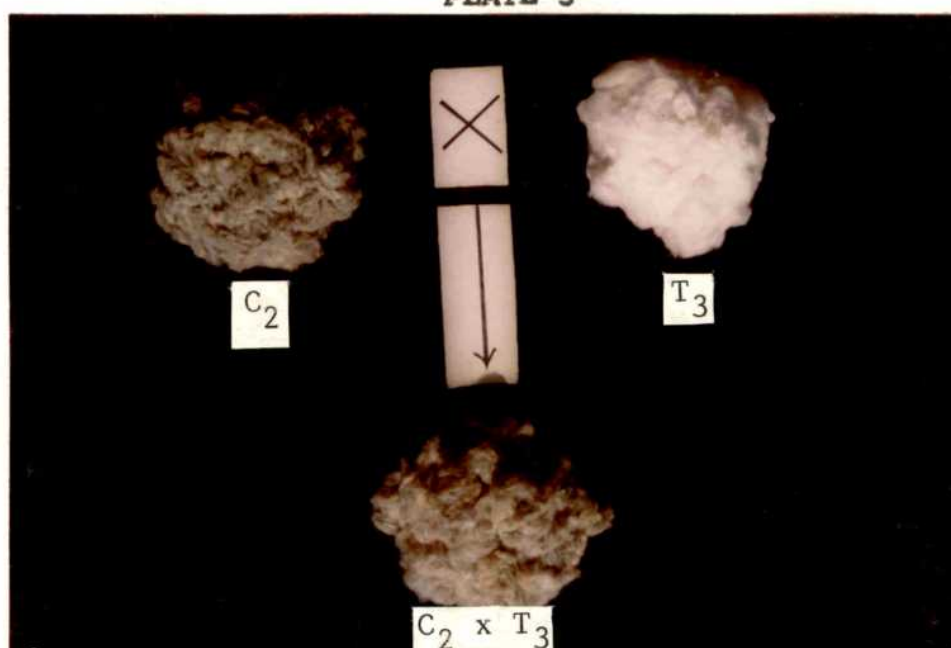
Lint colour of parents and their hybrids

## PLATE 2



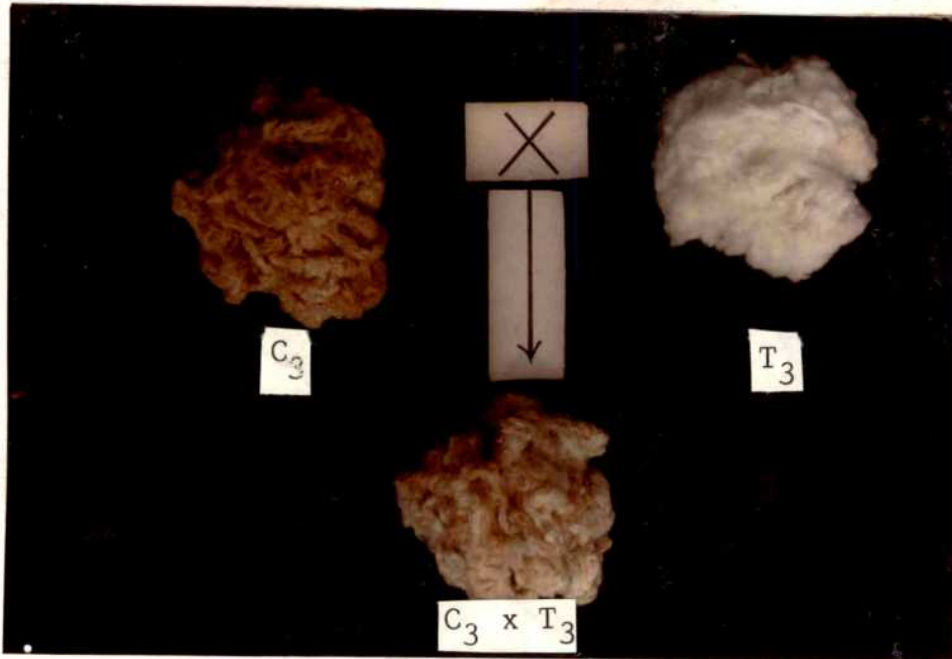
C<sub>1</sub> = Arkansas Green                      T<sub>3</sub> = MCU 9  
 C<sub>1</sub> x T<sub>3</sub> = Arkansas Green x MCU 9 hybrid

## PLATE 3



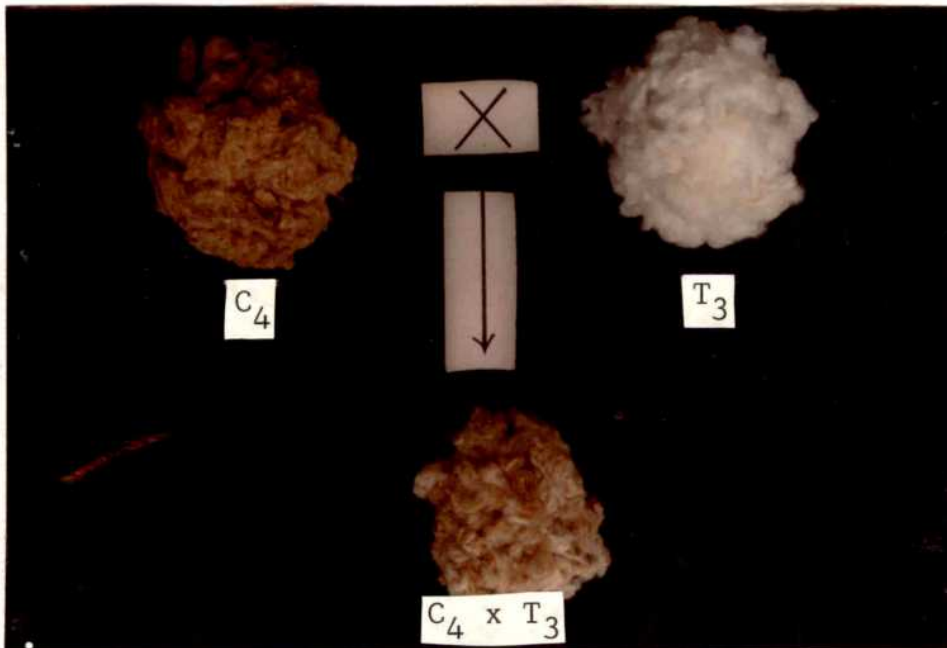
C<sub>2</sub> = Texas Green                              T<sub>3</sub> = MCU 9  
 C<sub>2</sub> x T<sub>3</sub> = Texas Green x MCU 9 hybrid

PLATE 4



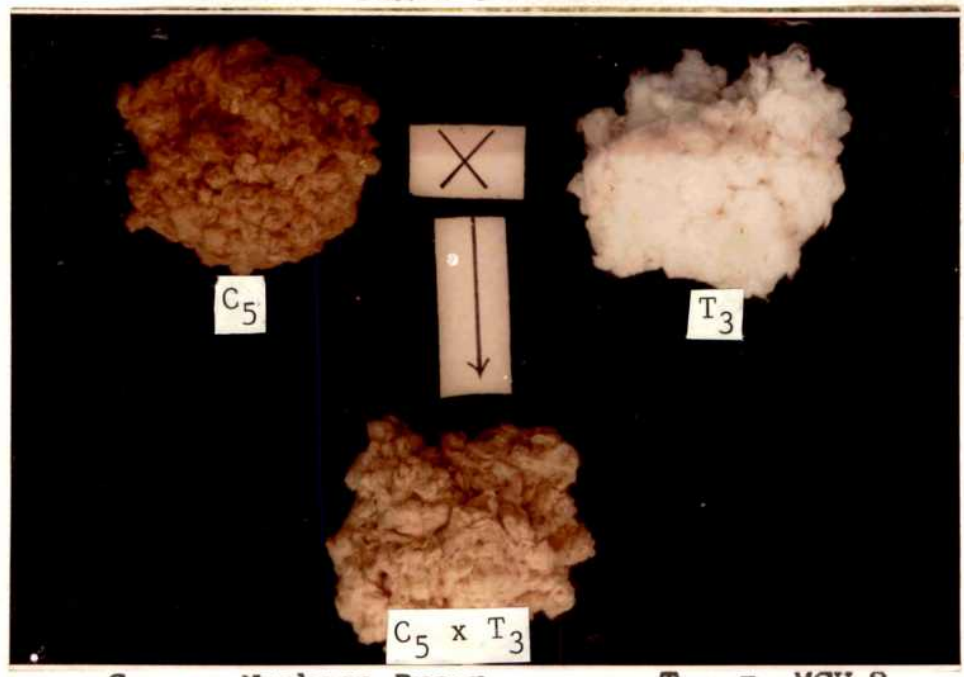
$C_3$  = Brymer Brown       $T_3$  = MCU 9  
 $C_3 \times T_3$  = Brymer Brown x MCU 9 hybrid

PLATE 5



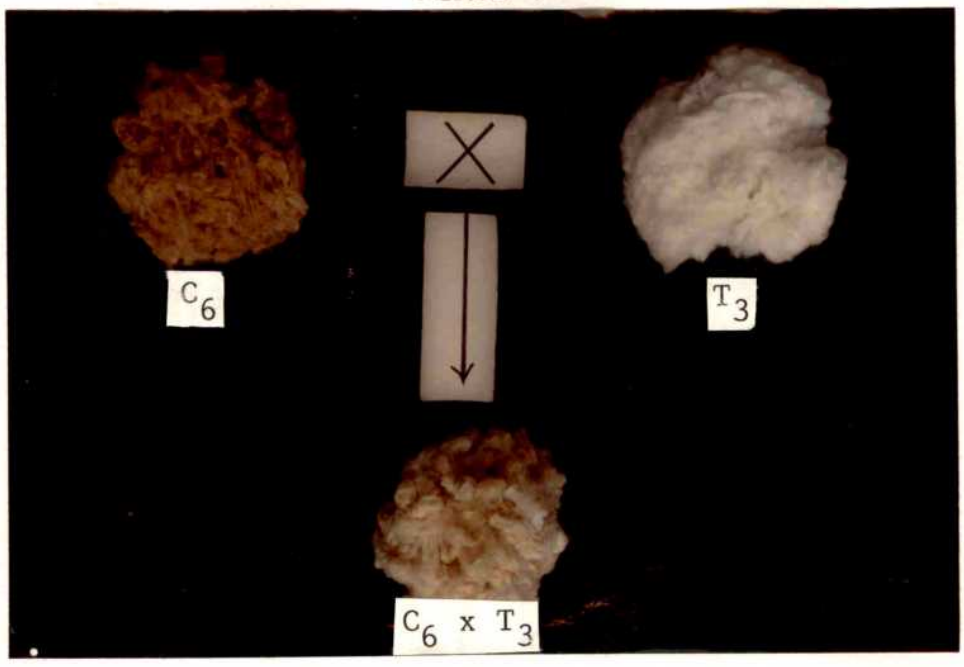
$C_4$  = Higgin Botham       $T_3$  = MCU 9  
 $C_4 \times T_3$  = Higgin Botham x MCU 9 hybrid

PLATE 6



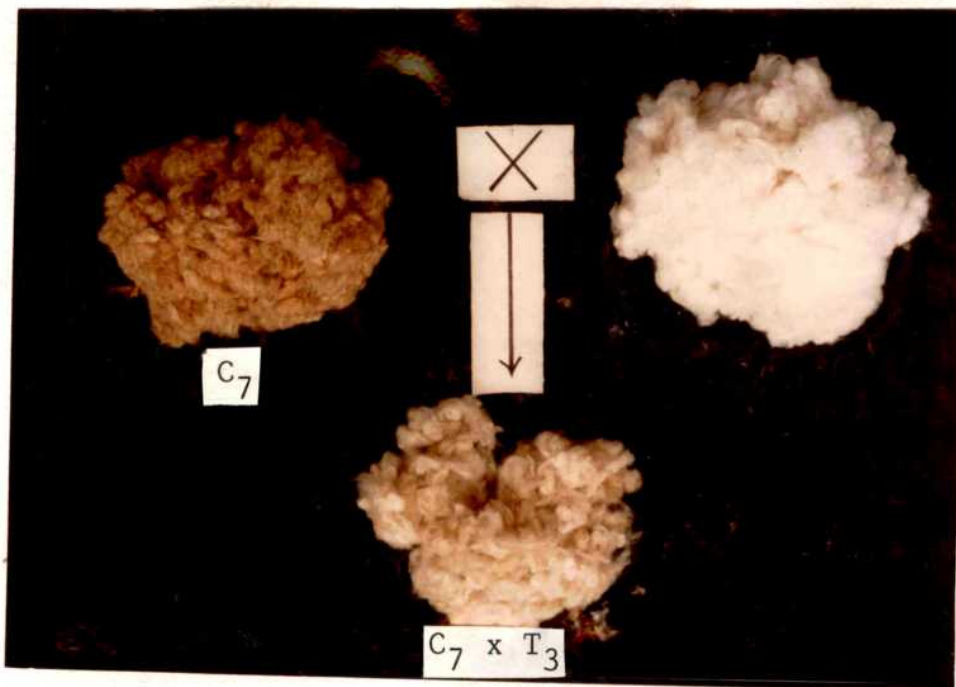
$C_5$  = Nankeen Brown                       $T_3$  = MCU 9  
 $C_5 \times T_3$  = Nankeen Brown x MCU 9 hybrid

PLATE 7



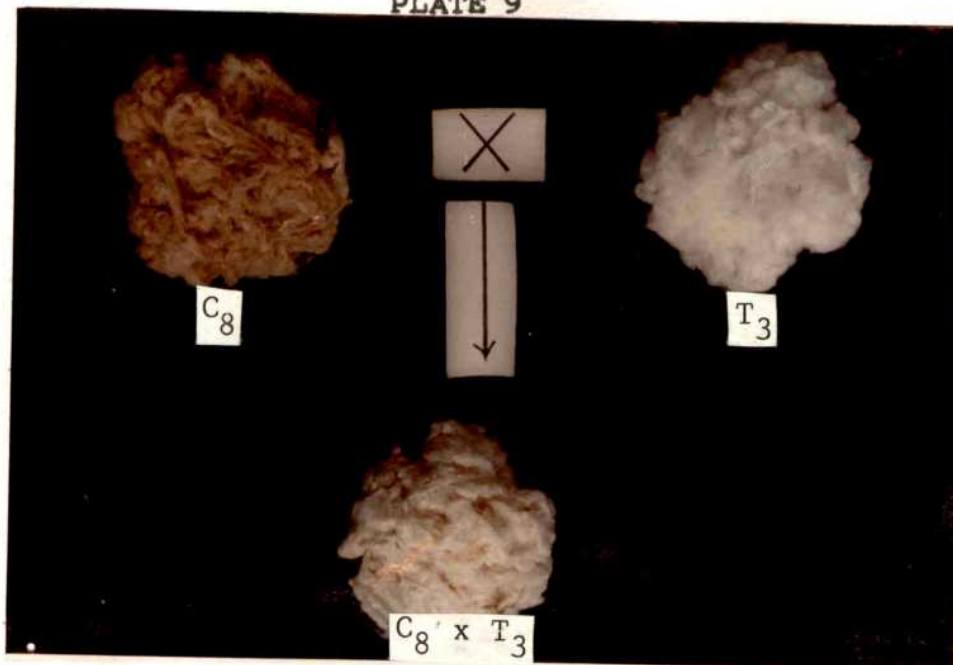
$C_6$  = Russian Brown                       $T_3$  = MCU 9  
 $C_6 \times T_3$  = Russian Brown x MCU 9 hybrid

PLATE 8



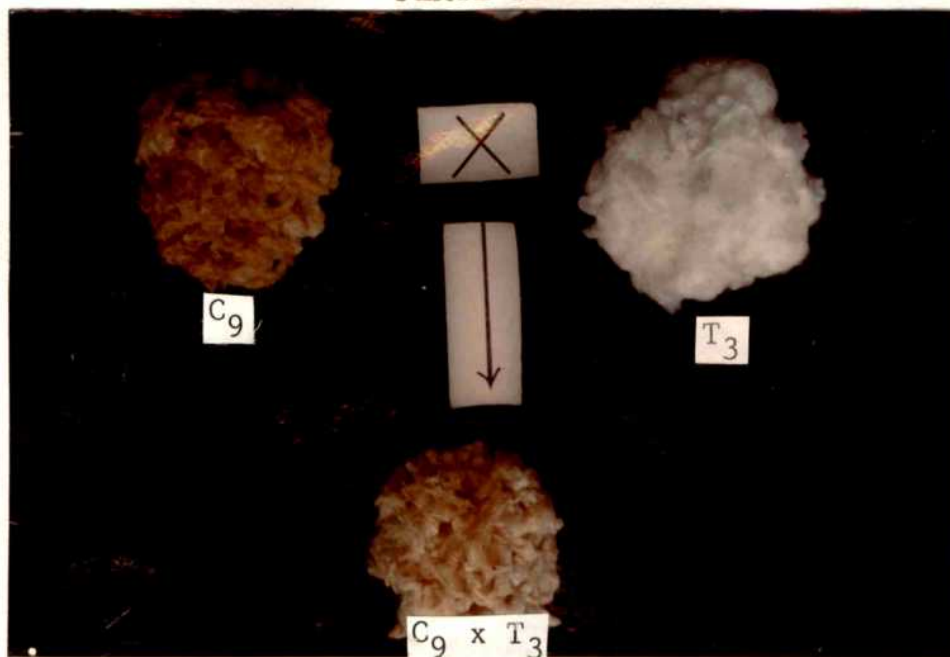
C<sub>7</sub> = Louisiana Brown      T<sub>3</sub> = MCU 9  
C<sub>7</sub> x T<sub>3</sub> = Louisiana Brown x MCU 9 hybrid

PLATE 9



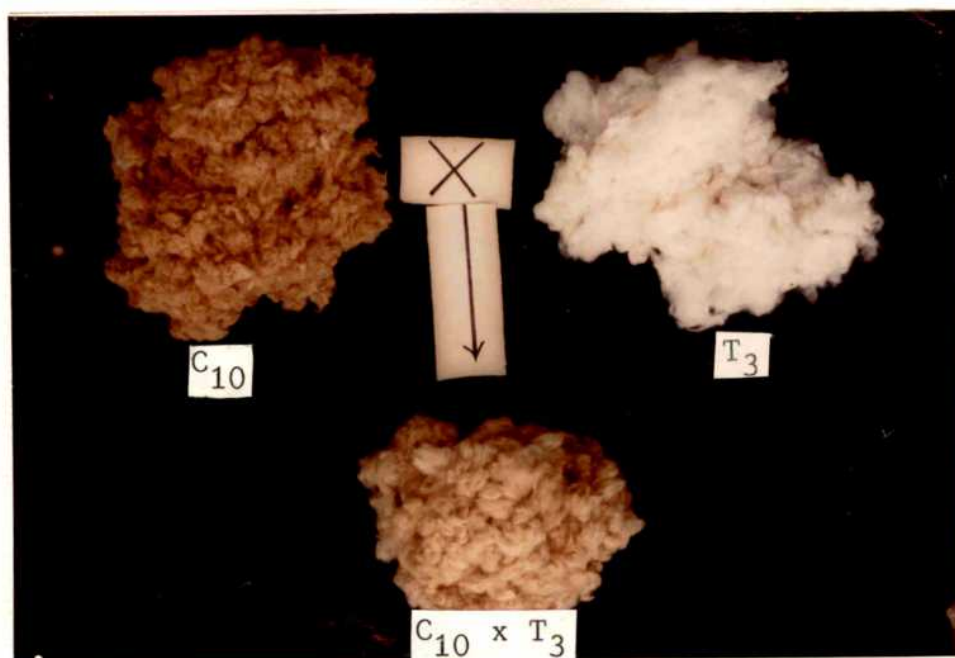
C<sub>8</sub> = Algerian Brown      T<sub>3</sub> = MCU 9  
C<sub>8</sub> x T<sub>3</sub> = Algerian Brown x MCU 9 hybrid

## PLATE 10



$C_9$  = Hirsutum Tashkent       $T_3$  = MCU 9  
 $C_9 \times T_3$  = Hirsutum Tashkent x MCU 9 hybrid

## PLATE 11



$C_{10}$  = Parbhani American       $T_3$  = MCU 9  
 $C_{10} \times T_3$  = Parbhani American x MCU 9 hybrid

were white linted and were graded 1. Grade of lint colour in the hybrids varied between 2.27 in three hybrids,  $C_2 \times T_4$ ,  $C_3 \times T_4$  and  $C_8 \times T_3$  and 5.47 in  $C_5 \times T_2$ . The mean of lint colour grade in hybrids was 3.12, which was midway between the white linted testers to colour linted parental lines (Tables 2 and 3; Plates 1 to 11).

#### 4.1.12. 2.5 % span length

The length at 2.5 % span ranged from 16.73 mm in  $C_{10}$  to 24.13 mm in  $C_8$  with a mean of 20.63 mm among the lines and from 23.27 mm in  $T_4$  to 31.00 mm in  $T_3$  among the testers. The mean for the testers was 26.69 mm. The hybrids varied from 20.67 mm in  $C_1 \times T_2$  to 28.70 mm in  $C_8 \times T_1$ . The mean 2.5 % span length in hybrids was 24.23 mm.

#### 4.1.13. Uniformity ratio

The line  $C_8$  exhibited the minimum uniformity ratio of 43.67 per cent. The maximum uniformity ratio of 50.0 per cent was observed in  $C_{10}$ . The mean was 46.17 per cent for the lines. In the testers, it varied between 44.67 per cent and 48.67 per cent in  $T_3$  and  $T_4$  respectively. The mean of uniformity ratio in the testers was 47.13 per cent. The hybrids showed a range of 43.00 per cent in  $C_4 \times T_3$  to 51.00 per cent in  $C_2 \times T_5$  for the uniformity ratio. The mean of uniformity ratio in the hybrids was 46.37 per cent which was intermediate between the two parental groups.

#### 4.1.14. Fibre fineness

The fibre fineness in the lines ranged from 2.58 micronaire in  $C_8$  to 3.55 micronaire in  $C_{10}$ . The mean was 2.87 micronaire. In the testers, this varied from 2.80 in  $T_4$  to 3.19 micronaire in  $T_3$  and the mean was 2.98 micronaire. The range for this character in the hybrids was from 2.49 to 3.64 micronaire, the lowest and the highest values were encountered in  $C_8 \times T_3$  and  $C_{10} \times T_2$ , respectively. The average fibre fineness in the hybrids was 2.87 micronaire.

#### 4.1.15. Maturity coefficient

The maturity coefficient varied from 0.51 per cent in  $C_8$  to 0.71 per cent in  $C_{10}$  with a mean of 0.61 per cent among the lines. The testers had a range of 0.60 per cent to 0.66 per cent. The average for the testers was 0.62 per cent. The minimum and maximum values were registered by  $T_4$  and  $T_2$  respectively. The hybrids showed a variation from 0.48 per cent in  $C_8 \times T_3$  to 0.73 per cent in  $C_{10} \times T_2$ . The mean fibre maturity coefficient in the hybrids was 0.60 per cent.

#### 4.1.16. Bundle strength

The bundle strength had a range of 15.87 g/tex in  $C_{10}$  to 23.03 g/tex in  $C_2$  in the lines and from 23.33 g/tex in  $T_2$  to 25.63 g/tex in  $T_5$  in the testers. The mean values were 19.45 g/tex and 24.47 g/tex for the line and testers

respectively. The hybrids ranged from 17.33 g/tex in  $C_{10} \times T_1$  to 25.53 g/tex in  $C_1 \times T_1$  in respect of bundle strength and the mean was 21.86 g/tex.

#### 4.2. Analysis of variance

The data on days to first boll bursting, days to maturity (crop duration), plant height, number of sympodia per plant, number of bolls per plant, boll weight, seed cotton yield, ginning outturn, lint index, seed index, colour of the lint (grades), 2.5% span length, uniformity ratio, fibre fineness, maturity coefficient and bundle strength, were found to be statistically significant at one percent level for both parents and hybrids (Table 4).

#### 4.3. Variability in Parents

The genotypic variance was the highest for seed cotton yield followed by plant height and days to maturity, the values being 687.70, 371.10 and 142.67 respectively, for the three characters in the order mentioned. Maturity coefficient and fibre fineness had minimum genotypic variance of 0.002 and 0.04 respectively. Genotypic variance was almost equal to the phenotypic variance for all the characters as seen from the estimates of GCV and PCV. In parents, heritability was the highest in ginning outturn (99.93%) closely followed by boll weight (99.81%) and days to maturity (99.80%). Genetic advance was very low for all

Table 4. Analysis of variance for different characters in parents and hybrids

Source	df	Days to first boll bursting	Plant height (cm)	No. of sympo- dia/ plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Colour of lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro- naire)	Maturity coefficient (%)	Bundle stren- gth (g/tex)		
Replications	2	0.16	1.06	4.90	1.25	2.95	0.002	10.13	-0.002	0.010	0.04	0.02	5.77	14.49	0.47	0.01	0.38
Genotypes	14	79.61**	428.29**	1115.95**	43.24**	70.69**	4.36**	2066.03**	23.49**	2.56**	4.52**	12.39**	39.44**	11.09**	0.18**	0.006**	25.14**
Error	28	0.20	0.28	2.66	0.95	0.68	0.003	2.92	0.006	0.005	0.02	0.05	3.09	3.61	0.06	0.001	2.17
<b>Parents</b>																	
Replications	2	0.63	4.13	25.47	8.54	0.18	0.003	0.93	0.10	0.02	0.05	0.005	3.50	0.61	0.03	0.002	13.45
Genotypes	49	13.77**	15.57**	178.38**	8.13**	32.38**	0.20**	203.39**	6.37**	0.32**	1.04**	1.82**	8.83**	10.48**	0.16**	0.008**	9.65**
Error	98	0.15	0.11	4.42	0.69	0.67	0.002	2.70	0.12	0.05	0.16	0.08	1.60	2.86	0.03	0.002	2.57
<b>Hybrids</b>																	

\* Significant at 5% level

\*\* Significant at 1% level

the characters except seed cotton yield, plant height and days to maturity which registered values of 53.91, 39.54 and 24.58 per cent genetic advance respectively (Table 5).

#### **4.4. Variability in hybrids**

The hybrids were less variable than parents as seen from the genotypic and phenotypic variances. The genotypic variance was the highest for seed cotton yield (66.90) followed by plant height (57.99) and number of bolls per plant (10.57). In hybrids also, the GCV and PCV were more or less equal. Days to maturity, boll weight and days to first boll bursting recording 97.96, 97.19 and 96.92 were some of the characters recording high heritability estimates in the hybrids. Heritability values in hybrids were relatively lesser than parents except uniformity ratio and fibre fineness. Low genetic advance was evident in all the characters but seed cotton yield and plant height were exceptions with fairly high genetic advance values (Table 5).

A combination of high heritability and high genetic advance was encountered in the characters, seed cotton yield and plant height in both parents and the hybrids. Nevertheless, the magnitude of both the estimates was lesser in hybrids than parents.

Table 5: Phenotypic and genotypic variances, heritability and genetic advance in parents and hybrids

Genetic Parameters	Days to first boll bursting	Days to maturity	Plant height	No. of sympodia/plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/plant)	Seed ginning outturn (%)	Lint index (g/100 seeds)	Colour of lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro-naire)	Maturity coefficient (%)	Bundle strength (g/tex)
<b>Parents</b>															
Genotypic variance	26.47	142.67	371.10	14.09	23.34	1.45	687.70	7.83	0.85	4.11	12.12	2.49	0.04	0.002	7.66
Phenotypic variance	26.67	142.95	373.75	15.05	24.02	1.46	690.62	7.83	0.86	4.17	15.21	6.10	0.10	0.003	9.83
GCV (%)	5.00	8.63	31.24	27.39	40.63	48.72	79.38	8.66	20.61	56.41	15.37	3.40	6.70	6.74	13.10
PCV (%)	5.02	8.64	31.35	28.30	41.22	48.77	79.55	8.66	20.68	56.76	17.22	5.31	10.93	8.96	14.84
Heritability (%)	99.24	99.80	99.29	93.66	97.16	99.81	99.58	99.93	99.38	98.76	79.67	40.87	37.54	56.70	77.93
Genetic advance as percentage of mean	10.27	17.77	64.13	54.60	82.51	100.27	163.19	17.84	42.33	115.48	28.26	4.47	8.45	10.46	23.82
<b>Hybrids</b>															
Genotypic variance	4.54	5.15	57.99	2.48	10.57	0.07	66.90	2.08	0.09	0.58	2.41	2.54	0.04	0.002	2.36
Phenotypic variance	4.68	5.26	62.41	3.17	11.24	0.07	69.60	2.20	0.14	0.66	4.01	5.40	0.07	0.004	4.93
GCV (%)	2.20	1.80	12.18	10.90	22.25	11.50	25.09	4.19	11.24	24.33	6.41	3.44	7.05	7.26	7.03
PCV (%)	2.23	1.82	12.64	12.33	22.94	11.67	25.59	4.31	13.89	26.05	8.27	5.01	9.53	10.50	10.15
Heritability (%)	96.92	97.96	92.92	78.16	94.05	97.19	96.12	94.57	65.45	87.28	60.14	47.05	54.72	47.82	47.92
Genetic advance as percentage of mean	4.46	3.67	24.19	19.85	44.44	23.36	50.68	8.40	18.72	46.83	10.24	4.86	10.74	10.34	10.02

#### **4.5. Path coefficient analysis**

A path coefficient analysis was done with the data pertaining to parents and hybrids separately to find out the direct and indirect effects of different yield components on seed cotton yield and also to evaluate the relative importance of different traits in selection. The analysis was done only for yield and its component characters and the quality parameters were excluded (Figures 1 and 2).

##### **4.5.1. Parents**

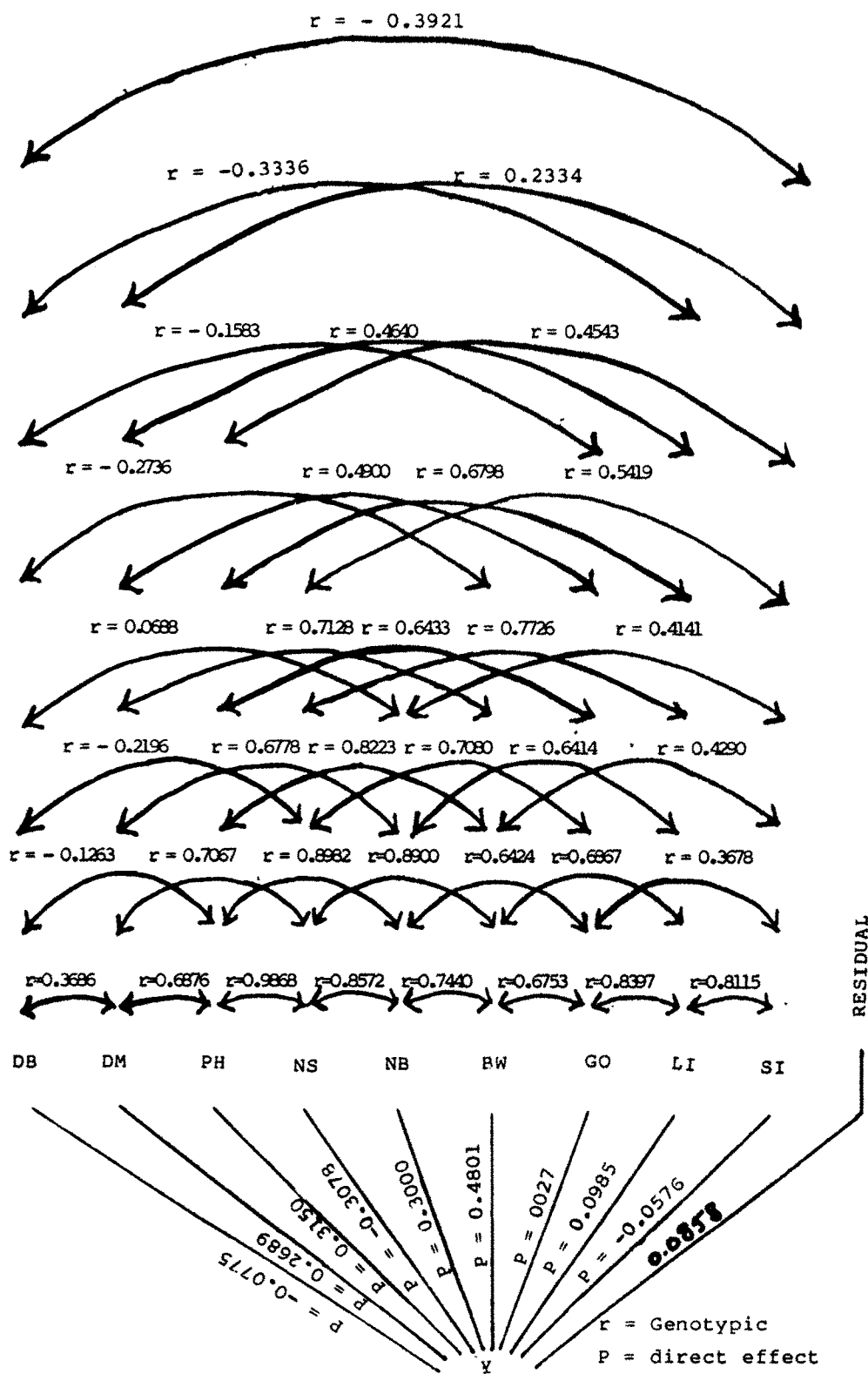
###### **4.5.1.1. Direct effects**

In parents, boll weight exerted the maximum positive direct effect of 0.4801 on seed cotton yield. Three other characters which had positive and direct influence on seed cotton yield were plant height (0.3150), number of bolls per plant (0.3000) and days to maturity (0.2689). In the negative direction, the influence of number of sympodia per plant was high. Other characters had negligible influence (Table 6).

###### **4.5.1.2. Indirect effects**

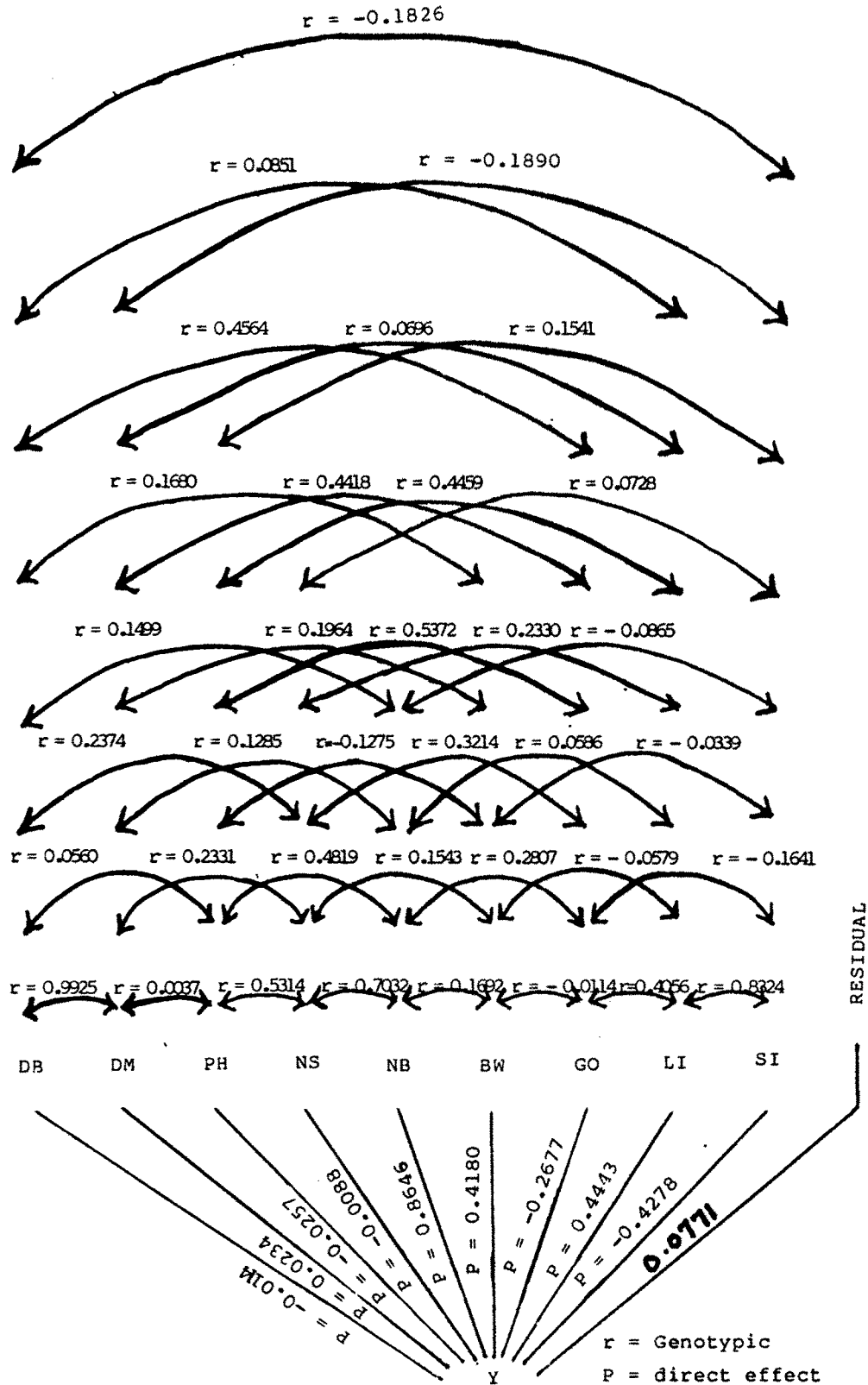
Days to maturity showed high positive indirect effect on seed cotton yield through boll weight (0.3422), plant height (0.2166) and number of bolls per plant (0.2033). Its influence on yield through number of sympodia was negative and high, the value being -0.2175.

FIG. 1 PATH DIAGRAM FOR PARENTS



DB-Days to first boll bursting, DM- Days to maturity, PH-Plant height  
 NS-No. of sympodia per plant, NB-No. of bolls per plant, BW-Boll weight  
 GO-Ginning outturn, LI-Lint index, SI-Seed index, Y-Seed Cotton Yield.

FIG. 2 PATH DIAGRAM FOR HYBRIDS



DB-Days to first boll bursting, DM-Days to maturity, PH-Plant height  
 NS-No. of sympodia per plant, NB-No of bolls per plant, BW-Boll weight  
 GO-Ginning outturn, LI-Lint index, SI-Seed index, Y-Seed Cotton Yield.

Table 6. Direct and indirect effects of different characters on seed cotton yield in parents

Characters	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympodia/plant	No. of bolls/plant	Boll weight (g)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)	Correlation with seed cotton yield (g/plant)
Days to first boll bursting	-0.0775	0.0991	-0.0398	0.0676	0.0206	-0.1313	-0.0004	-0.0328	0.0226	0.0720
Days to maturity (crop duration)	-0.0286	<u>0.2689</u>	0.2166	-0.2175	0.2033	0.3422	0.0013	0.0457	-0.0134	0.8185
Plant height (cm)	0.0098	0.1849	<u>0.3150</u>	-0.3037	0.2695	0.3948	0.0017	0.0669	-0.0262	0.9127
No. of sympodia/plant	0.0170	0.1900	0.3108	<u>-0.3078</u>	0.2571	0.4273	0.0019	0.0761	-0.0312	0.9413
No. of bolls/plant	-0.0053	0.1822	0.2829	-0.2638	<u>0.3000</u>	0.3572	0.0017	0.0632	-0.0238	0.8942
Boll weight (g)	0.0212	0.1917	0.2590	-0.2739	0.2232	<u>0.4801</u>	0.0018	0.0676	-0.0247	0.9460
Ginning outturn (%)	0.0123	0.1318	0.2026	-0.2179	0.1927	0.3242	<u>0.0027</u>	0.0827	-0.0212	0.7099
Lint index (g/100 seeds)	0.0259	0.1248	0.2141	-0.2378	0.1924	0.3297	0.0022	<u>0.0985</u>	-0.0467	0.7030
Seed index (g/100 seeds)	0.0304	0.0628	0.1431	-0.1668	0.1242	0.2060	0.0010	0.0799	<u>-0.0576</u>	0.4230

Residual effect = 0.0858

Diagonal values indicate direct effect

Plant height showed high positive indirect effect on seed cotton yield through boll weight, number of bolls per plant and days to maturity, with the estimates of 0.3948, 0.2695 and 0.1849 respectively for these three characters in the order mentioned. It showed high negative indirect effect of -0.3037 on seed cotton yield via number of sympodia per plant.

Number of sympodia per plant exerted high positive indirect effect on seed cotton yield through boll weight (0.4273), plant height (0.3108), number of bolls per plant (0.2571) and also through days to maturity, although its direct effect was negative and moderate.

Number of bolls per plant showed high positive indirect effect on seed cotton yield through boll weight, number of bolls per plant, plant height and days to maturity. The values estimated for these characters were 0.3572, 0.3000, 0.2829 and 0.1822 respectively. Its main negative indirect influence was through number of sympodia per plant, the value being -0.2638.

Boll weight showed high positive indirect effect on seed cotton yield through plant height (0.2590), number of bolls per plant (0.2232) and days to maturity (0.1917),

while its influence through number of sympodia per plant was -0.2739 which was negative and high.

Ginning outturn showed high positive indirect effect on seed cotton yield through boll weight (0.3242), plant height (0.2026), number of bolls per plant (0.1927) and days to maturity with an estimate of 0.1318. It showed high negative indirect effect on number of sympodia per plant with an estimate of -0.2179.

The influence of lint index on yield through boll weight (0.3297) and plant height (0.2141) was positive and high whereas its indirect effect via number of bolls per plant (0.1924) and days to maturity (0.1248) was moderate and positive. Lint index exerted high negative indirect effect of -0.2378 on seed cotton yield through number of sympodia per plant.

Seed index showed high positive indirect effect on seed cotton yield through boll weight (0.2060), plant height (0.1431) and number of bolls per plant (0.1242). On the other hand, it showed high negative indirect effect of -0.1668 on seed cotton yield through number of sympodia per plant.

Generalising the results on path relationship in parents, it can be seen that, the number of sympodia per

plant directly or indirectly influenced on the yield in the negative direction. The direct effect of days to maturity, plant height, number of bolls per plant and boll weight was positive and the indirect effects of other characters through these characters were also positive. The three characters viz., ginning outturn, lint index and seed index did not have appreciable influence on seed yield. The residual effect was very low and the estimate was 0.0858 (Table 6).

#### **4.5.2. Hybrids**

##### **4.5.2.1. Direct effects**

In hybrids, the maximum positive direct effect of 0.8646 on seed cotton yield was exerted by number of bolls per plant. The other characters that influenced directly, the yield were lint index (0.4443) and boll weight (0.4180). Days to maturity had negligible positive direct effect on yield with the value of 0.0234. All the other characters had negative direct effect on seed cotton yield. Particularly, the effect of the seed index and ginning outturn are negative and high with the values of -0.4278 and -0.2677 respectively (Table 7).

##### **4.5.2.2. Indirect effects**

Days to first boll bursting showed moderate positive indirect effect on seed cotton yield through number

Table 7. Direct and indirect effects of different characters on seed cotton yield in hybrids

Characters	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympodia/plant	No. of bolls/plant	Boll weight (g)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)	Correlation with seed cotton yield (g/plant)
Days to first boll bursting	<u>-0.0114</u>	0.0232	-0.0014	-0.0021	0.1296	0.0702	-0.1221	0.0378	0.0781	0.2019
Days to maturity (crop duration)	-0.0113	<u>0.0234</u>	-0.0001	-0.0021	0.1111	0.0821	-0.1182	0.0309	0.0808	0.1966
Plant height (cm)	-0.0006	0.0001	<u>-0.0257</u>	-0.0047	0.4166	-0.0533	-0.1438	0.1981	-0.0659	0.3208
No. of sympodia/plant	-0.0027	0.0055	-0.0137	<u>-0.0088</u>	0.6080	0.0645	-0.0860	0.1035	-0.0311	0.6391
No. of bolls/plant	-0.0017	0.0030	-0.0124	-0.0062	<u>0.8646</u>	0.0707	-0.0751	0.0260	0.0370	0.9059
Boll weight (g)	-0.0019	0.0046	0.0033	-0.0014	0.1463	<u>0.4180</u>	0.0031	-0.0257	0.0145	0.5607
Ginning outturn (%)	-0.0052	0.0103	-0.0138	-0.0028	0.2427	-0.0048	<u>-0.2677</u>	0.1802	0.0702	0.2092
Lint index (g/100 seeds)	-0.0010	0.0016	-0.0115	-0.0021	0.0507	-0.0242	-0.1086	<u>0.4443</u>	-0.3561	-0.0068
Seed index (g/100 seeds)	0.0021	-0.0044	-0.0040	-0.0006	-0.0748	-0.0142	0.0439	0.3699	<u>-0.4278</u>	-0.1099

Residual effect = 0.0771  
 Diagonal values indicate direct effect

of bolls per plant (0.1296) and moderate indirect and negative effect of -0.1221 on seed cotton yield through ginning outturn. Its influence through all other characters were negligible.

Days to maturity exerted moderate positive indirect effect of 0.1111 on seed cotton yield through number of bolls per plant and negative effect of -0.1182 through ginning outturn. The indirect effect of this character on seed cotton yield through other characters were negligible.

Plant height exerted positive high indirect effect on seed cotton yield through number of bolls per plant and lint index. The estimates of these indirect influence were 0.4166 and 0.1981. Its effect on seed cotton yield via ginning outturn was negative and moderate, the estimate being -0.1438. It did not have any appreciable influence through other characters on yield.

Number of sympodia per plant showed high positive indirect effect on seed cotton yield via number of bolls per plant with a value of 0.6080. Through lint index also, the indirect effect of number of sympodia was positive but of lesser magnitude. Its indirect effects on seed cotton yield through other characters were negligible.

The number of bolls per plant did not have appreciable indirect effect either positively or negatively through other characters on seed cotton yield. Thus, the direct effect of this character was more or less equal to the correlation value.

Boll weight exerted high positive indirect effect of 0.1463 on seed cotton yield through number of bolls per plant. Its indirect effects on seed cotton yield through other characters was very meagre.

Ginning outturn showed high positive indirect effect on seed cotton yield through number of bolls per plant (0.2427) and also via lint index (0.1802). The indirect effects of ginning outturn through other characters was not very conspicuous.

There was no positive influence of lint index on seed cotton yield through other characters. The only significant indirect effect of this character on seed cotton yield was through seed index. The estimate of -0.3561 observed for this relationship was high and negative.

Seed index showed high positive indirect effect of 0.3699 on seed cotton yield via lint index. Through other characters, it exerted only negligible influence.

Summarising the path relationship in hybrids, it can be noticed that the number of bolls and lint index were the most important characters which influence the yield directly or indirectly. The other important character which influence the yield was boll weight which had high direct effect. The residual effect estimated was 0.0771 which was very small in this analysis (Table 7).

#### **4.6. Association Studies**

The results on correlation studies in the parents and hybrids are furnished in Table 8 & 9.

##### **4.6.1. Parents**

Days to maturity, plant height, number of sympodia per plant, number of bolls per plant, boll weight, ginning outturn and lint index had highly significant and positive correlation with seed cotton yield at the genotypic and phenotypic level. The values for these character pairs were 0.8185 and 0.8159, 0.9127 and 0.9079, 0.9413 and 0.9107, 0.8942 and 0.8891, 0.9460 and 0.9435, 0.7099 and 0.7079 and 0.7030 and 0.6980 respectively.

Days to first boll bursting had no relationship with any of the characters. A positive correlation existed between days to maturity on the one hand and plant height, number of sympodia per plant, number of bolls per plant, boll weight and ginning outturn on the other, both

Table 8. Genotypic and phenotypic correlation coefficients between different characters in the parents

Characters	Days to maturity (crop duration)	Plant height (cm)	No. of sympodia/plant	No. of bolls/plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)
Days to first boll	G 0.3686	-0.1263	-0.2196	0.0688	-0.2736	-0.0720	-0.1583	-0.3336	-0.3921
bursting	P 0.3672	-0.1273	-0.2050	0.0703	-0.2722	-0.0701	-0.1580	-0.3328	-0.3902
Days to maturity (crop duration)	G 0.6876**	0.7067**	0.6778**	0.7128**	0.8185**	0.4900*	0.4640	0.2334	
(crop duration)	P 0.6848**	0.6836**	0.6674**	0.7113**	0.8159**	0.4894*	0.4622	0.2317	
Plant height (cm)	G 0.9868**	0.8982**	0.8223**	0.9127**	0.6433**	0.6798**	0.4543		
	P 0.9468**	0.8846**	0.8187**	0.9079**	0.6413**	0.6758**	0.4504		
No. of sympodia/plant	G 0.8572**	0.8900**	0.9413**	0.7080**	0.7726**	0.5419*			
	P 0.8215**	0.8609**	0.9107**	0.6830**	0.7448**	0.5212*			
No. of bolls/plant	G 0.7440**	0.8942**	0.6424**	0.6414**	0.4141				
	P 0.7315**	0.8891**	0.6324**	0.6288**	0.4037				
Boll weight (g)	G 0.9460**	0.6753**	0.6867**	0.4290					
	P 0.9435**	0.6745**	0.6834**	0.4249					
Seed cotton yield (g/plant)	G 0.7099**	0.7030**	0.4230						
	P 0.7079**	0.6980**	0.4172						
Ginning outturn (%)	G 0.8397**	0.3678							
	P 0.8379**	0.3665							
Lint index (g/100 seeds)	G 0.8115**								
	P 0.8125**								

G = Genotypic correlation coefficient P = Phenotypic correlation coefficient

\* Significant at 5% level

\*\* Significant at 1% level

Table 9. Genotypic and phenotypic correlation coefficients between different characters in the hybrids

Characters	Days to maturity (crop duration)	Plant height (cm)	No. of sympodia/plant	No. of bolls/plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)
Days to first boll	G 0.9925**	0.0560	0.2374	0.1499	0.1680	0.2019	0.4564**	0.0851	-0.1826
bursting	P 0.9694**	0.0479	0.2123	0.1458	0.1616	0.1963	0.4413**	0.0727	-0.1403
Days to maturity (crop duration)	G 0.0037	0.0037	0.2331	0.1285	0.1964	0.1966	0.4418**	0.0696	-0.1890
(crop duration)	P 0.0040	0.0040	0.1947	0.1159	0.1926	0.1849	0.4272**	0.0533	-0.1531
Plant height (cm)	G 0.5314**	0.5314**	0.4819**	-0.1275	0.3208*	0.3208*	0.5372**	0.4459**	0.1541
	P 0.4803**	0.4803**	0.4585**	-0.1135	0.3110*	0.3110*	0.4957**	0.3278*	0.1005
No. of sympodia/plant	G 0.7032**	0.7032**	0.7032**	0.1543	0.6391**	0.6391**	0.3214*	0.2330	0.0728
	P 0.6250**	0.6250**	0.6250**	0.1261	0.5703**	0.5703**	0.2979*	0.1803	0.0542
No. of bolls/plant	G 0.1692	0.1692	0.1692	0.1692	0.9059**	0.9059**	0.2807*	0.0586	-0.0865
	P 0.1620	0.1620	0.1620	0.1620	0.9052**	0.9052**	0.2608	0.0485	-0.0640
Boll weight (g)	G 0.5607**	0.5607**	0.5607**	-0.0114	0.5607**	0.5607**	-0.0114	-0.0579	-0.0339
	P 0.5505**	0.5505**	0.5505**	-0.0182	0.5505**	0.5505**	-0.0182	-0.0622	-0.0405
Seed cotton yield (g/plant)	G 0.2092	0.2092	0.2092	0.2092	0.2092	0.2092	0.2092	-0.0068	-0.1099
	P 0.1944	0.1944	0.1944	0.1944	0.1944	0.1944	0.1944	-0.0121	-0.0925
Ginning outturn (%)	G 0.4056**	0.4056**	0.4056**	-0.1641	0.4056**	0.4056**	-0.1641	0.4056**	-0.1641
	P 0.3619**	0.3619**	0.3619**	-0.1097	0.3619**	0.3619**	-0.1097	0.3619**	-0.1097
Lint index (g/100 seeds)	G 0.8324**	0.8324**	0.8324**	0.8324**	0.8324**	0.8324**	0.8324**	0.8324**	0.8324**
	P 0.8845**	0.8845**	0.8845**	0.8845**	0.8845**	0.8845**	0.8845**	0.8845**	0.8845**

G = Genotypic correlation coefficient P = Phenotypic correlation coefficient  
 \*Significant at 5% level \*\*Significant at 1% level

genotypically and phenotypically, the estimates being 0.6876 and 0.6848, 0.7067 and 0.6836, 0.6778 and 0.6674, 0.7128 and 0.7113 and 0.4900 and 0.4894 respectively.

Plant height had a positive correlation with number of sympodia per plant, number of bolls per plant, boll weight, ginning outturn and lint index both genotypically and phenotypically, the values of 0.9868 and 0.9468, 0.8982 and 0.8846, 0.8223 and 0.8187, 0.6433 and 0.6413 and 0.6798 and 0.6758 respectively were significant at 1 per cent level.

The correlations between number of sympodia and all the other characters, number of bolls per plant, boll weight, ginning outturn, lint index and seed index were positive and highly significant. The correlation coefficient estimated for these character pairs were, 0.8572 and 0.8215, 0.8900 and 0.8609, 0.7080 and 0.6830, 0.7726 and 0.7448 and 0.5419 and 0.5212 respectively. Similarly number of bolls per plant were also found related with all the other characters positively except seed index. The values were significant at 1 % level.

Ginning outturn had high correlation with all the other characters except seed index and days to first boll bursting. Lint index had high positive correlation

coefficient with seed index while such an association was not discernible between ginning outturn and seed index.

In general, all the characters had a positive phenotypic and genotypic association with yield except days to first boll bursting and seed index. The inter correlations among the yield components were also significant and positive both at genotypic and phenotypic level in most of the cases.

#### 4.6.2. Hybrids

The genotypic and phenotypic correlations of yield with its component characters plant height, number of sympodia per plant, number of bolls per plant and boll weight were positive and high. The values were 0.3208 and 0.3110, 0.6391 and 0.5703, 0.9059 and 0.9052 and 0.5607 and 0.5505 for the characters in the order mentioned. However, there was no correlation between yield and days to first boll bursting, days to maturity, ginning outturn, lint index and seed index either at genotypic or phenotypic level or both.

High and positive association existed between days to first boll bursting and days to maturity. Days to first boll bursting also exhibited a positive correlation coefficient of 0.4564 and 0.4413 with ginning outturn at genotypic and phenotypic level.

Days to maturity had a high correlation coefficient with ginning outturn apart from days to first boll bursting both at genotypic and phenotypic level.

A positive association was evident between plant height on the one hand and number of sympodia per plant, number of bolls per plant, ginning outturn and lint index on the other both genotypically and phenotypically. The values for these character pairs were 0.5314 and 0.4803, 0.4819 and 0.4585, 0.5372 and 0.4957 and 0.4459 and 0.3278 respectively.

Number of sympodia per plant was positively correlated with other yield components plant height, number of bolls per plant and ginning outturn both genotypically and phenotypically, while, it had no marked relationship with days to first boll bursting, days to maturity, boll weight, lint index and seed index.

Number of bolls per plant had positive correlations with plant height and number of sympodia per plant both genotypically and phenotypically, while, it had positive correlation of 0.2807 with ginning outturn at genotypic level only.

Boll weight did not have any association with other yield attributes at the genotypic and phenotypic levels.

The correlation between ginning outturn and all the characters except boll weight and seed index was positive and significant at genotypic level. However, the phenotypic correlation between number of bolls per plant and ginning outturn was not significant. The positive relationship between lint index on the one hand, and plant height and ginning outturn on the other was significant with the coefficients of 0.4459 and 0.3278 and 0.4056 and 0.3619 respectively.

In summary, it can be seen that the relationship of yield with its components and also the inter se associations among the yield components were different in parents and hybrids, lesser relationship being evident in respect of hybrids than in the parental genotypes between character pairs.

#### **4.7. Parallelism between lint colour and fibre quality and yield**

##### **4.7.1. Parental lines**

Colour of the lint had a positive correlation with fibre fineness and ginning outturn at genotypic level. The values were 0.5884 and 0.7807 respectively. It had a

positive correlation with ginning outturn at phenotypic level also and it was negatively associated with bundle strength both at genotypic and phenotypic level. The values being -0.8618 and -0.6054 respectively (Table 10).

#### 4.7.2. Hybrids

Colour of the lint had negative correlation with 2.5% span length and bundle strength both at genotypic and phenotypic level, the values being -0.4164 and -0.2807 and -0.4426 and -0.3026 respectively, while its association with other quality traits was not significant (Table 10).

#### 4.8. $D^2$ analysis

The genetic divergence in the 15 parental genotypes was estimated using Mahalanobis  $D^2$  statistics involving the ten characters viz., days to first boll bursting, days to maturity, plant height, number of sympodia per plant, number of bolls per plant, boll weight, seed cotton yield, ginning outturn, lint index and seed index and the results are presented in Tables 11 to 14. Based on  $D^2$  values, the 15 parents came under five clusters (Table 11). Among the five clusters, cluster I had six genotypes and was the largest. In cluster II, there were four genotypes, while cluster III and IV comprised two genotypes each. Cluster V was the smallest including only one genotype.

Table 10. Genotypic and phenotypic correlation coefficients between lint colour and different characters in the parents (lines) and hybrids

Characters	2.5% span length (mm)	Fibre fineness (micronaire)	Bundle strength (g/tex)	Ginning outturn (%)	Seed cotton yield (g/plant)
<b>Lines</b>					
Colour of the	G -0.3152	0.5884*	-0.8618**	0.7807**	-0.0927
lint (grade)	P -0.2227	0.4916	-0.6054*	0.7453**	-0.0694
<b>Hybrids</b>					
Colour of the	G -0.4164**	0.0596	-0.4426**	-0.1060	0.1108
lint (grade)	P -0.2807*	0.0621	-0.3026*	-0.1039	0.1047

G = Genotypic correlation coefficients      P = Phenotypic correlation coefficients  
 \* Significant at 5 % level                      \*\* Significant at 1 % level

Table 11. Varietal composition of different clusters

Cluster number	No. of parents	Constituent genotypes	Geographical origin
I	6	Arkansas Green	USA
		Texas Green	USA
		Brymer Brown	USA
		Higgin Botham	USA
		Lousiana Brown	USA
		Hirsutum Tashkent	Russia
II	4	Nankeen Brown	USA
		Russian Brown	Russia
		Algerian Brown	USA
		Parbhani American	Surat, India
III	2	MCU-5	Tamil Nadu, India
		MCU-9	Tamil Nadu, India
IV	2	KC-1	Tamil Nadu, India
		LRA - 5166	Tamil Nadu, India
V	1	MCU-7	Tamil Nadu, India

#### 4.8.1. Average inter and intra cluster distance

The inter and intra cluster distances (D values) for the different clusters are furnished in Table 12 and depicted in Figure 3.

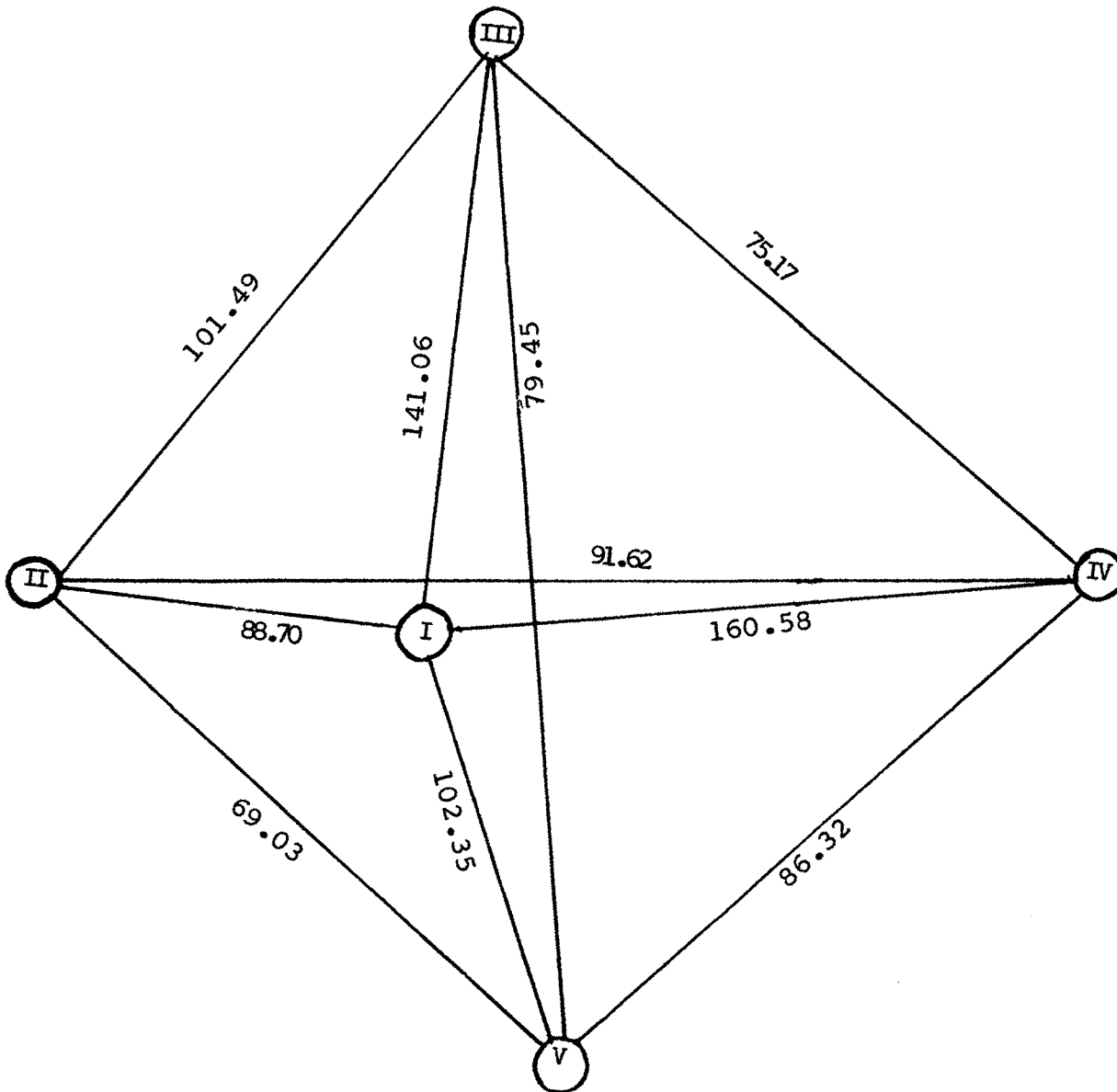
The intra cluster distance ranged from 0.00 in cluster I to 48.25 for cluster IV. The inter cluster distances had a range of 69.03 to 160.58. The maximum inter cluster distance of 160.58 was noticed between the cluster I and IV followed 141.06 between the clusters I and III. The clusters II and V recorded the minimum inter cluster distance of 69.03 (Table 12).

#### 4.8.2. Contribution to genetic divergence

Contribution of each character to the genetic divergence presented in Table 13 indicated that ginning outturn contributed the most accounting for 39.05 per cent of the total divergence. This was closely followed by seed index with 35.24 per cent. Days to maturity also had a moderate contribution of 13.33 per cent. These three characters put together contributed 87.62 per cent to the total genetic diversity. Plant height and lint index had the lowest share while seed cotton yield and number of sympodia per plant did not contribute anything.

The mean values for different clusters were worked for all the ten characters (Table 14). The clusters

FIG. 3 CLUSTER DIAGRAM SHOWING INTER CLUSTER DISTANCES IN PARENTS (Not to scale)



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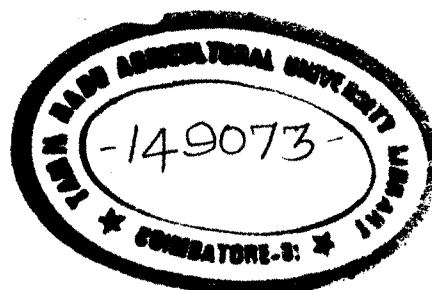


Table 12. Inter and intra cluster distances (D) (and  $D^2$  values in brackets) in cotton genotypes chosen for study

Cluster	I	II	III	IV	V
I	43.71 (1910.65)	88.70 (7867.75)	141.06 (19897.73)	160.58 (25785.78)	102.35 (10474.80)
II		40.87 (1670.34)	101.49 (10299.77)	91.62 (8394.18)	69.03 (4765.83)
III			22.79 (519.32)	75.17 (5649.93)	79.45 (6313.02)
IV				48.25 (2328.03)	86.32 (7450.95)
V					0.00 (0.00)

Table 13. Percentage contribution of different characters to the total genetic divergence in parents

Characters	No. of first ranks	Percentage of contribution to genetic divergence
Ginning outturn (%)	41	39.05
Seed index (g/100 seeds)	37	35.24
Days to maturity (Crop duration)	14	13.33
Days to first boll bursting	6	5.72
Number of bolls/plant	3	2.86
Boll weight (g)	2	1.90
Plant height (cm)	1	0.95
Lint index (g/100 seeds)	1	0.95
Seed cotton yield (g/plant)	0	0
Number of sympodia/plant	0	0
Total		100.00

Table 14. Mean values of different clusters for different characters

Group	No. of geno- types	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympodia/ plant	No. of bolls/ plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)
I	6	104.22	133.28	48.77	11.00	8.96	1.63	14.81	29.34	3.59	8.63
II	4	103.33	132.00	51.72	11.60	9.97	1.79	18.42	33.29	4.71	9.42
III	2	105.34	165.17	88.74	19.24	18.04	4.38	78.57	34.67	5.53	10.44
IV	2	101.34	143.34	81.87	17.94	17.77	3.68	61.87	36.43	5.23	9.14
V	1	90.33	130.33	84.20	18.87	13.13	4.04	52.15	33.13	5.27	10.63
CD		0.75	0.89	2.72	1.63	1.38	0.09	2.86	0.13	0.12	0.24

distinctly differed from each other in respect of most of the characters.

#### 4.9. Line x tester analysis

The results of combining ability analysis and heterosis extracted from Line x tester analysis are presented in Tables 15 to 48.

The variance of different characters were found to be statistically significant in respect of parents, hybrids and lines. The variance due to parents Vs hybrids component was significant for all characters except seed cotton yield, uniformity ratio, fibre fineness and maturity coefficient. The variance due to testers was significant for all the characters except bundle strength. The variance due to line x tester was significant for all the characters except 2.5% span length, uniformity ratio, maturity coefficient and bundle strength (Table 15).

##### 4.9.1. Days to first boll bursting

Among the coloured linted cotton lines, the **gca** was positive in  $C_2$ ,  $C_8$  and  $C_9$ , the values being 1.8933, 2.1600 and 2.2267 while in all other coloured linted varieties it was negative. The **gca** of  $C_7$  (-0.1733) was not significant. Out of the five testers, the **gca** was positive

Table 15. Analysis of variances for different characters

Source	df	Days to first boll bursting	Days to maturity (crop duration)	Plant height (cm)	No. of sympto-plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield (g/plant)	Ginning outturn (%)	Lint index (g/100 seeds)	Seed index (g/100 seeds)	Colour of lint (grade)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micro-naire)	Maturity coefficient (%)	Bundle strength (g/tex)
Replications	2	0.75	5.00	28.78	9.54	1.41	0.001	5.57	0.09	0.01	0.03	-0.0002	2.23	6.23	0.20	0.004	12.34
Parents	14	79.62**	428.28**	1115.95**	43.24**	70.69**	4.36**	2066.03**	23.49**	2.56**	4.52**	12.39**	39.44**	11.09**	0.18**	0.006**	25.14**
Hybrids	49	13.77**	15.57**	178.37**	8.13**	32.38**	0.20**	203.40**	6.37**	0.32**	1.04**	1.82**	8.83**	10.48**	0.16**	0.008**	9.65**
Parents vs Hybrids	1	1184.13**	5118.50**	25.44**	18.75**	257.19**	1.77**	6.59	157.06**	111.60**	605.07**	7.70**	86.55**	0.50	0.06	0.002	18.91**
Lines	9	35.15**	36.11**	124.00**	6.76**	79.80**	0.64**	529.70**	5.45**	0.25**	0.75**	7.21**	33.06**	28.97**	0.41**	0.02**	35.93**
Testers	4	53.81**	67.5**	1441.11**	35.45**	156.54**	0.61**	812.02**	47.98**	0.66**	2.68**	0.55**	11.20**	20.84**	0.29**	0.02**	3.53
Lines x Testers	36	3.98**	4.67**	51.66**	5.43**	6.73**	0.05**	54.19**	1.98**	0.30**	0.93**	0.61**	2.51	4.71	0.08*	0.002	3.76
Error	128	0.15	0.15	3.99	0.74	0.69	0.002	2.79	0.09	0.04	0.13	0.08	2.01	3.12	0.04	0.002	2.46
GCA		1.80	2.10	32.48	0.70	4.95	0.03	27.41	1.10	0.007	0.04	0.15	0.0009	0.90	0.01	0.0009	0.71
SCA		1.27	1.51	15.89	1.56	2.02	0.02	17.13	0.63	0.09	0.27	0.18	0.0001	0.53	0.01	0.0001	0.43
GCA/SCA		1.41	1.39	2.04	0.45	2.46	1.61	1.60	1.75	0.08	0.13	0.82	7.60	1.69	1.03	7.60	1.64

\* Significant at 5% level

\*\* Significant at 1% level

in  $T_1$  and  $T_3$ , the estimates being 0.4600 and 1.8600. All the other testers exhibited negative **gca** (Table 16).

Fifteen out of 50 hybrids possessed positive **sca** for this trait. The values were negative in 15 hybrids.  $C_1$  and  $C_8$  produced three hybrids each with negative **sca** while there were two hybrids in each of the combinations involving  $C_4$  and  $C_{10}$  with **sca** values.

Among the combinations involving different testers, five hybrids with  $T_3$ , three each with  $T_1$  and  $T_5$  and two in each involving  $T_2$  and  $T_4$  recorded negative **sca** effects (Table 16). The variance due to GCA was higher than that of SCA (Table 15).

Heterosis in hybrids over their mid-parental values ranged from -10.19 per cent in  $C_8 \times T_5$  to 1.56 per cent in  $C_9 \times T_2$ . Four hybrids recorded positive heterosis while 46 hybrids were negatively heterotic. Heterobeltiosis of hybrids over the respective better parental values had a range from -13.51 per cent in  $C_8 \times T_2$  to -1.32 per cent in  $C_9 \times T_4$ . All the hybrids recorded only negative heterosis over their better parent for days to first boll bursting. Standard heterosis ranged between -12.46 per cent in  $C_{10} \times T_2$  and -2.49 in  $C_8 \times T_3$  (Table 17). All hybrids exhibited negative heterosis when compared against the standard parent ( $T_3$ ).

Table 16. Gca and sca effects of parents and hybrids for days to first boll bursting

Testers Lines	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
C <sub>1</sub>	-0.8600**	-0.8933**	1.7400**	0.4733*	-0.4600*	-0.2400*
C <sub>2</sub>	-0.3267	0.9733**	-1.3933**	0.3400	0.4067	1.8933**
C <sub>3</sub>	0.2733	0.5733*	-1.4600**	0.9400**	-0.3267	-0.3733**
C <sub>4</sub>	-0.5267*	0.4400	-0.9267**	-0.1933	1.2067**	-1.5733**
C <sub>5</sub>	0.3400	-0.0267	0.6067**	-0.3267	-0.5933**	-1.1067**
C <sub>6</sub>	0.9400**	0.2400	-1.4600**	-0.3933	0.6733**	-1.3733**
C <sub>7</sub>	-0.2600	0.0400	0.6733**	-0.5933**	0.1400	-0.1733
C <sub>8</sub>	1.7400**	-1.2933**	3.3400**	-1.9267**	-1.8600**	2.1600**
C <sub>9</sub>	-0.3267	-0.0267	-0.3933	1.0067**	-0.2600	2.2267**
C <sub>10</sub>	-0.9933**	-0.0267	-0.7267**	0.6733**	1.0733**	-1.4400**
Gca effects of testers	0.4600**	-1.8400**	1.8600**	-0.2067**	-0.2733**	

SE of lines : 0.1011 SE of testers : 0.0715 SE of hybrids : 0.2261

\*Significant at 5% level

\*\*Significant at 1% level

Table 17. Expression of heterosis in cotton hybrids (percentage) - Days to first boll bursting

Testers	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	dl	d11	d111	di	d11	d111	d1	d11	d111	d1	d11	d111	d1	d11	d111
C <sub>1</sub>	-9.26**	-11.35**	-9.97**	-5.53**	-13.50**	-12.15**	-6.96**	-7.67**	-6.23**	-5.98**	-10.74**	-9.35**	-10.14**	-11.66**	-10.28**
C <sub>2</sub>	-4.35**	-4.50**	-7.48**	1.20**	-5.16**	-8.41**	-5.55**	-7.17**	-7.17**	-1.49**	-4.19**	-7.48**	-4.96**	-5.71**	-7.48**
C <sub>3</sub>	-3.95**	-6.11**	-9.03**	0.70**	-3.70**	-10.90**	-5.83**	-9.35**	-9.35**	-1.02**	-1.68**	-9.03**	-5.88**	-8.57**	-10.28**
C <sub>4</sub>	-8.77**	-9.49**	-10.90**	-3.92**	-10.76**	-12.15**	-9.26**	-9.97**	-9.97**	-6.40**	-9.81**	-11.21**	-8.40**	-8.54**	-9.97**
C <sub>5</sub>	-6.15**	-6.75**	-9.66**	-2.42**	-8.14**	-12.15**	-6.05**	-8.10**	-8.10**	-4.67**	-6.84**	-10.90**	-8.36**	-9.52**	-11.21**
C <sub>6</sub>	-5.21**	-6.43**	-9.35**	-1.74**	-6.93**	-12.15**	-7.69**	-10.28**	-10.28**	-4.36**	-5.94**	-11.21**	-6.80**	-8.57**	-10.28**
C <sub>7</sub>	-8.20**	-9.91**	-9.35**	-4.04**	-11.76**	-11.21**	-7.45**	-7.74**	-7.17**	-6.49**	-10.84**	-10.28**	-9.09**	-10.22**	-9.66**
C <sub>8</sub>	-5.59**	-8.71**	-5.30**	-4.64**	-13.51**	-10.28**	-4.28**	-6.01**	-2.49**	-7.03**	-12.61**	-9.35**	-10.19**	-12.61**	-9.35**
C <sub>9</sub>	-3.09**	-4.18**	-7.17**	1.56**	-3.95**	-9.03**	-3.36**	-5.92**	-5.92**	0.50**	-1.32**	-6.54**	-4.36**	-6.03**	-7.79**
C <sub>10</sub>	-6.25**	-8.36**	-11.21**	-1.06**	-5.39**	-12.46**	-6.15**	-9.66**	-9.66**	-2.37**	-3.03**	-10.28**	-5.56**	-8.25**	-9.97**

\* Significant at 5% level

\*\* Significant at 1% level

#### 4.9.2. Days to maturity

Three out of 10 coloured lited genotypes exhibited positive **gca** effects of 1.9600 ( $C_2$ ), 1.7600 ( $C_8$ ) and 2.5600 ( $C_9$ ) for days to maturity, while the other seven showed negative estimates. The negative **gca** of -0.0400 observed in  $C_7$  was negligible and not significant.  $T_1$  and  $T_3$  were general combiners in the positive direction for days to maturity and  $T_2$ ,  $T_4$  and  $T_5$  had negative values of -1.9733, -0.4400 and -0.2733 respectively (Table 18).

Among the hybrids, sixteen combinations had negative **sca** effect and 15 possessed positive **gca**. Among different testers,  $T_3$  produced a maximum of five hybrids with negative **sca** values while there were four hybrids with negative estimate of **sca** in the combinations involving  $T_5$ . Line  $C_8$  among the coloured lited types produced a maximum of three hybrids ( $C_8 \times T_2$ ,  $C_8 \times T_4$  and  $C_8 \times T_5$ ) with negative **sca** while there were two hybrids in each of the combinations involving  $C_1$ ,  $C_4$ ,  $C_9$  and  $C_{10}$  (Table 18). The variance due to GCA was higher than that of SCA (Table 15).

Heterotic expression in hybrids over their mid-parental values varied from -17.09 per cent in  $C_1 \times T_1$  to -2.81 per cent in  $C_9 \times T_2$ . All the hybrids were negatively heterotic over their respective mid-parental value. The heterosis in hybrids when estimated over their respective

Table 18. *Gca* and *sca* effects of parents and hybrids for days to maturity  
(crop duration)

Testers	Sca effects of Hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-1.1600**	-0.2933	1.6067**	0.5067*	-0.6600**	-0.2400*
C <sub>2</sub>	-0.3600	0.8400**	-1.5933**	0.3067	0.8067**	1.9600**
C <sub>3</sub>	-0.2267	0.3067	-1.1267**	0.7733**	0.2733	-0.5067**
C <sub>4</sub>	-0.9600**	0.5733**	-0.8600**	0.0400	1.2067**	-1.7733**
C <sub>5</sub>	0.9067**	-0.2267	0.3400	-0.0933	-0.9267**	-0.9733**
C <sub>6</sub>	1.2400**	0.1067	-1.3267**	-0.4267	0.4067	-1.3067**
C <sub>7</sub>	-0.0267	0.5067*	0.4067	-0.6933**	-0.1933	-0.0400
C <sub>8</sub>	2.1733**	-1.9600**	3.6067**	-2.4933**	-1.3267**	1.7600**
C <sub>9</sub>	-0.6267**	-0.0933	-0.1933	1.3733**	-0.4600*	2.5600**
C <sub>10</sub>	-0.9600**	0.2400	-0.8600**	0.7067**	0.8733**	-1.4400**
<b>Gca effects of testers</b>	0.5600**	-1.9733**	2.1267**	-0.4400**	-0.2733**	

SE of lines : 0.0983 SE of testers : 0.0695 SE of hybrids : 0.2199

\*Significant at 5% level

\*\*Significant at 1% level

Table 19. Expression of heterosis in cotton hybrids (percentage) - Days to maturity (crop duration)

Testers	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	d1	d1f1	d1f1f1	d1	d1f1	d1f1f1	d1	d1f1	d1f1f1	d1	d1f1	d1f1f1	d1	d1f1	d1f1f1
C <sub>1</sub>	-17.09**	-23.89**	-24.35**	-7.71**	-10.17**	-25.35**	-14.51**	-21.73**	-21.73**	-9.57**	-10.64**	-23.94**	-11.76**	-14.19**	-24.55**
C <sub>2</sub>	-13.68**	-22.06**	-22.54**	-3.42**	-4.27**	-23.34**	-13.74**	-22.33**	-22.33**	-6.46**	-9.22**	-22.74**	-7.54**	-11.67**	-22.33**
C <sub>3</sub>	-13.99**	-23.48**	-23.94**	-4.12**	-4.86**	-25.16**	-13.83**	-23.54**	-23.54**	-6.44**	-10.64**	-23.94**	-8.27**	-13.73**	-24.14**
C <sub>4</sub>	-16.87**	-24.70**	-25.15**	-6.82**	-7.98**	-25.75**	-16.04**	-24.14**	-24.14**	-9.71**	-12.06**	-25.16**	-10.26**	-13.96**	-24.35**
C <sub>5</sub>	-14.41**	-23.08**	-23.54**	-5.99**	-6.35**	-25.75**	-14.03**	-22.94**	-22.94**	-8.45**	-11.58**	-24.75**	-10.47**	-14.87**	-25.15**
C <sub>6</sub>	-14.12**	-23.08**	-23.54**	-5.63**	-5.63**	-25.75**	-15.09**	-24.14**	-24.14**	-8.60**	-12.06**	-25.15**	-9.42**	-14.19**	-24.55**
C <sub>7</sub>	-16.02**	-23.08**	-23.54**	-6.73**	-9.00**	-24.75**	-14.98**	-22.33**	-22.33**	-10.07**	-11.35**	-24.55**	-11.08**	-13.73**	-24.14**
C <sub>8</sub>	-13.66**	-20.65**	-21.13**	-7.58**	-10.14**	-25.15**	-11.96**	-19.32**	-19.32**	-10.39**	-11.35**	-24.55**	-10.93**	-13.27**	-23.74**
C <sub>9</sub>	-12.77**	-21.86**	-22.33**	-2.81**	-2.81**	-23.54**	-11.71**	-21.13**	-21.13**	-4.42**	-8.04**	-21.73**	-7.25**	-12.13**	-22.74**
C <sub>10</sub>	-15.13**	-24.49**	-24.95**	-4.90**	-5.63**	-25.75**	-14.29**	-23.94**	-23.94**	-7.18**	-11.35**	-24.55**	-8.52**	-13.96**	-24.35**

\* = Significant at 5% level \*\* Significant at 1% level

better parental values, was found to range from -24.70 per cent to -2.81 per cent with the hybrids  $C_4 \times T_1$  and  $C_9 \times T_2$  recording the lowest and highest values. All hybrids recorded negative heterosis over their better parent. When the estimate was based on the standard check, a minimum of -25.75 per cent and a maximum of -19.32 per cent hybrid vigour was discernible. The hybrids  $C_4 \times T_2$ ,  $C_5 \times T_2$ ,  $C_6 \times T_2$  and  $C_{10} \times T_2$  registered the lowest values while the hybrid  $C_8 \times T_3$  was the highly heterotic hybrid (Table 19).

#### 4.9.3. Plant height

Four lines  $C_2$ ,  $C_4$ ,  $C_6$  and  $C_8$  exhibited positive gca, two lines  $C_1$  and  $C_{10}$  had negative gca and the remaining four lines did not have significant gca values. Positive gca values were evident in two testers  $T_4$  and  $T_5$  which registered 5.4507 and 9.3373 respectively. Testers  $T_1$ ,  $T_2$  and  $T_3$  possessed negative gca values (Table 20).

The sca effects presented in Table 20 reveals that 13 hybrids had positive sca. The values were negative in 16 hybrids. There were three hybrids with positive sca in each of the combinations involving  $T_2$ ,  $T_3$  and  $T_5$  as testers whereas, two hybrids in each involving  $T_1$  and  $T_4$ , exhibited positive sca (Table 20). The variance due to GCA was higher than that of SCA (Table 15).

Table 20. Gca and sca effects of parents and hybrids for plant height

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-5.8107**	-6.8373**	2.1027	5.4160**	5.1293**	-3.6493**
C <sub>2</sub>	-2.4907*	1.6827	0.0227	-2.9974**	3.7827**	1.8307**
C <sub>3</sub>	1.0160	0.7227	5.3293**	-2.8240*	-4.2440**	-0.8760
C <sub>4</sub>	0.9093	5.8160**	-5.4440**	-1.2640	-0.0173	2.6973**
C <sub>5</sub>	-4.0107**	2.4293*	-5.4973**	4.2160**	2.8627*	-0.5827
C <sub>6</sub>	4.6560**	3.9627**	-2.8307*	-2.5840*	-3.2040**	1.0173*
C <sub>7</sub>	5.6960**	-3.3307**	-3.1907**	1.3227	-0.4973	-0.9560
C <sub>8</sub>	1.1493	1.8560	-0.2707	-0.7573	-1.9773	5.4573**
C <sub>9</sub>	-0.1707	-6.3307**	7.4093**	-2.1440	1.2360	-0.8227
C <sub>10</sub>	-0.9440	0.0293	2.3693*	1.6160	-3.0707**	-4.1160**
<b>Gca effects of testers</b>	-3.7227**	-5.8293**	-5.2360**	5.4507**	9.3373**	

SE of lines : 0.5160 SE of testers : 0.3648 SE of hybrids : 1.1537

\* Significant at 5% level

\*\* Significant at 1% level

Table 21. Expression of heterosis in cotton hybrids (percentage) - Plant height

Testers	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	-24.37**	-46.14**	-42.55**	-24.92**	-45.13**	-46.20**	-10.64**	-35.09**	-35.09**	35.40**	8.73**	-18.79**	5.92**	-26.37**	-14.60**
C <sub>2</sub>	-19.33**	-36.54**	-32.30**	-11.95**	-28.50**	-29.89**	-14.55**	-31.13**	-31.13**	14.51**	4.16	-22.20**	1.84	-22.22**	-9.78**
C <sub>3</sub>	-20.40**	-35.66**	-31.37**	-19.62**	-32.86**	-34.16**	-13.26**	-28.11**	-28.11**	6.58**	0.21**	-25.16**	-14.48**	-33.00**	-22.28**
C <sub>4</sub>	-13.13**	-31.88**	-27.33**	-4.31*	-22.57**	-24.07**	-20.93**	-36.49**	-36.49**	19.45**	8.21**	-19.18**	-1.71	-25.17**	-13.20**
C <sub>5</sub>	-25.85**	-40.83**	-36.88**	-15.66**	-30.48**	-31.83**	-27.10**	-40.37**	-40.37**	20.61**	11.64**	-16.61**	-3.85**	-25.57**	-13.66**
C <sub>6</sub>	-8.51**	-29.62**	-24.92**	-7.64**	-26.76**	-28.18**	-17.95**	-35.40**	-35.40**	17.04**	3.53	-22.67**	-6.45**	-30.05**	-18.87**
C <sub>7</sub>	-9.24**	-30.64**	-26.01**	-20.97**	-37.77**	-38.98**	-20.85**	-38.12**	-38.12**	21.45**	6.55*	-20.42**	-4.86**	-29.32**	-18.01**
C <sub>8</sub>	-13.99**	-28.60**	-23.83**	-11.52**	-23.99**	-25.47**	-14.62**	-27.25**	-27.25**	16.64**	13.31**	-15.37**	-5.87**	-24.36**	-12.27**
C <sub>9</sub>	-14.92**	-36.90**	-32.69**	-22.89**	-41.17**	-42.31**	-1.84	-25.62**	-25.62**	19.93**	1.35	-24.30**	0.46	-27.44**	-15.84**
C <sub>10</sub>	-19.84**	-41.34**	-37.42**	-16.95**	-37.53**	-38.74**	-13.45**	-35.33**	-35.33**	22.83**	2.08	-23.76**	-8.96**	-35.07**	-24.69**

\* Significant at 5% level

\*\* Significant at 1% level

Heterosis of hybrids over their mid-parental values ranged from -27.10 per cent in  $C_5 \times T_3$  to 35.40 per cent in  $C_1 \times T_4$ . Thirty five hybrids recorded negative heterosis and positive estimates of heterosis was evident in 11 hybrids. Better parental heterosis ranged from -46.14 per cent in  $C_1 \times T_1$  to 13.31 per cent in  $C_8 \times T_4$  in the hybrids. Forty hybrids recorded negative heterosis and six hybrids were positively heterotic over their respective better parent. Standard heterosis varied between -46.20 per cent in  $C_1 \times T_2$  and -9.78 per cent in  $C_2 \times T_5$ . All hybrids recorded only negative heterotic expression when estimated against the standard variety (Table 21).

#### 4.9.4. Number of sympodia per plant

Three coloured linted lines  $C_3$ ,  $C_4$  and  $C_8$  had positive *gca* effects of 0.7307 ( $C_3$ ), 0.5307 ( $C_4$ ) and 0.9307 ( $C_8$ ) and two testers,  $T_1$  and  $T_5$  had positive *gca* for this trait.  $C_1$ ,  $C_9$  among the lines and  $T_2$  and  $T_4$  of the testers were negative general combiners (Table 22).

The *sca* values were positive in seven hybrids  $C_5 \times T_1$ ,  $C_6 \times T_1$ ,  $C_2 \times T_2$ ,  $C_6 \times T_2$ ,  $C_1 \times T_3$ ,  $C_2 \times T_3$  and  $C_5 \times T_4$  while the estimates were negative in nine hybrids.  $T_1$ ,  $T_2$  and  $T_3$  produced two hybrids having positive *sca* in each of their combinations. Also a maximum of three hybrids with negative *sca* were noticed among the ten hybrids involving

Table 22. Gca and sca effects of parents and hybrids for number of sympodia per plant

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-2.0973**	-0.7373	1.7293**	0.5827	0.5227	-1.2427**
C <sub>2</sub>	-1.6440**	1.5827**	2.1160**	-0.5640	-1.4907**	0.1040
C <sub>3</sub>	-0.2707	-0.3773	0.8227	0.0760	-0.2507	0.7307**
C <sub>4</sub>	0.7960	0.1560	-1.9773**	0.4760	0.5493	0.5307*
C <sub>5</sub>	1.2493*	-1.9240**	-2.3240**	2.9293**	0.0693	-0.0560
C <sub>6</sub>	1.1160*	1.3427**	-0.5907	-2.4707**	0.6027	-0.3893
C <sub>7</sub>	0.9427	0.0360	-1.1640*	-0.5773	0.7627	0.3173
C <sub>8</sub>	0.6627	0.6227	-0.1107	-0.3907	-0.7840	0.9307**
C <sub>9</sub>	0.4493	-0.1907	0.6760	-0.8707	-0.0640	-0.7227**
C <sub>10</sub>	-1.2040*	-0.5107	0.8227	0.8093	0.0827	-0.2027
<b>Gca effects of testers</b>	0.3640*	-1.3960**	0.2040	-0.6493**	1.4773**	

SE of lines : 0.2226    SE of testers : 0.1574    SE of hybrids : 0.4977

\* Significant at 5% level

\*\* Significant at 1% level

Table 23. Expression of heterosis in cotton hybrids (percentage) - Number of sympodia per plant

Testers	T <sub>1</sub>				T <sub>2</sub>				T <sub>3</sub>				T <sub>4</sub>				T <sub>5</sub>			
	df	dff	dfff	dfff	df	dff	dfff	dfff	df	dff	dfff	dfff	df	dff	dfff	dfff	df	dff	dfff	dfff
C <sub>1</sub>	-22.17**	-42.28**	-38.35**	-22.25**	-41.34**	-40.50**	7.33*	-18.64**	-18.64**	3.96	-16.17**	-29.39**	2.01	-24.75**	-18.28**					
C <sub>2</sub>	-12.14**	-33.22**	-28.67**	0.91	-21.91**	-20.79**	16.59**	-9.32**	-9.32**	2.56	-14.89**	-28.32**	-4.80	-28.05**	-21.86**					
C <sub>3</sub>	-2.76	-23.15**	-17.92**	-11.84**	-28.98**	-27.96**	7.52*	-12.90**	-12.90**	7.35	-6.81	-21.51**	3.36	-18.81**	-11.83**					
C <sub>4</sub>	1.26	-18.79**	-13.26**	-11.02**	-27.21**	-26.16**	-13.73**	-29.03**	-29.03**	6.99	-5.53	-20.43**	5.59	-15.84**	-8.60**					
C <sub>5</sub>	-0.21	-19.46**	-13.98**	-28.76**	-41.34**	-40.50**	-20.35**	-34.05**	-34.05**	19.62**	6.38	-10.39**	-1.65	-21.12**	-14.34**					
C <sub>6</sub>	0.43	-21.81**	-16.49**	-6.46	-25.80**	-24.73**	-7.87*	-26.52**	-26.52**	-18.20**	-30.21**	-41.22**	3.20	-20.13**	-13.26**					
C <sub>7</sub>	2.55	-19.13**	-13.62**	-11.65**	-28.98**	-27.96**	-8.20*	-25.81**	-25.81**	-0.25	-13.62**	-27.24**	7.37*	-15.84**	-8.60**					
C <sub>8</sub>	2.07	-17.45**	-11.83**	-6.21	-22.61**	-21.51**	0.22	-16.85**	-16.85**	2.63	-8.51	-22.94**	-1.03**	-20.46**	-13.62**					
C <sub>9</sub>	-6.03	-26.85**	-21.86**	-18.93**	-35.69**	-34.77**	-1.57	-21.51**	-21.51**	-8.73*	-22.13**	-34.41**	-3.20	-25.08**	-18.64**					
C <sub>10</sub>	-12.80**	-32.55**	-27.96**	-17.04**	-34.63**	-33.69**	3.62	-17.92**	-17.92**	8.54*	-8.09	-22.58**	1.72	-21.78**	-15.05**					

\* Significant at 5% level

\*\* Significant at 1% level

each  $T_1$  and  $T_3$  as testers. Out of the ten combinations involving each of the different coloured linted lines,  $C_2$ ,  $C_5$  and  $C_6$ , two hybrids were found to possess positive sca (Table 22). The variance due to SCA was higher than that of GCA (Table 15).

The hybrid vigour in hybrids over the mid-parental values was found to range between -28.76 per cent in  $C_5 \times T_2$  to 19.62 per cent in  $C_5 \times T_4$ . In all six hybrids recorded positive heterosis while 17 had negative heterosis over the mid-parent. The hybrid vigour estimated over their better parental values had a range between -42.28 per cent in  $C_1 \times T_1$  and 6.38 per cent in  $C_5 \times T_4$ . A total of 45 hybrids was negatively heterotic. Standard heterosis ranging between -41.22 per cent in  $C_6 \times T_4$  to -8.60 per cent in  $C_4 \times T_5$  and  $C_7 \times T_5$  was noticed in the hybrids for number of sympodia per plant. None of the hybrids exceeded the check variety and all were negatively heterotic (Table 23).

#### 4.9.5. Number of bolls per plant

Three coloured linted genotypes  $C_3$ ,  $C_4$  and  $C_8$  exhibited positive gca effects of 2.1320, 3.5453 and 2.8787 respectively and five had negative gca values. Positive gca effects of 1.3387 and 3.0253 was noticed in two testers,  $T_3$  and  $T_5$  respectively and  $T_1$ ,  $T_2$  and  $T_4$  showed negative

estimates of -0.4880, -2.9813 and -0.8947 respectively (Table 24).

The sca was positive in nine hybrids. These included one hybrid involving  $T_1$  and one having  $T_5$  as testers, two each with  $T_2$ ,  $T_3$  and three involving  $T_4$  as testers. Negative sca was noticed in 13 combinations, out of which four had  $T_5$  as the tester. The frequency of hybrids with negative sca was higher in combinations with  $C_5$  as line, than those involving other coloured linted varieties (Table 24). The variance due to GCA was higher than that of SCA (Table 15).

The heterosis of hybrids over their mid-parental values was found to vary from -25.10 per cent to 67.32 per cent, the combinations  $C_1 \times T_2$  and  $C_5 \times T_4$  registering the lowest and the highest values. 27 hybrids recorded positive heterosis and three were negatively heterotic. The hybrids  $C_1 \times T_2$  registered the lowest heterobeltiosis of -52.28 per cent and the heterobeltiosis was the highest in  $C_5 \times T_4$  which recorded 24.27 per cent. Positive heterosis over the respective parent, was evident in six hybrids while 30 hybrids expressed negative heterosis. Heterosis estimated over the standard parent varied from -67.70 per cent ( $C_1 \times T_2$ ) to 13.75 per cent ( $C_4 \times T_5$ ). Two hybrids,  $C_4 \times T_5$  and  $C_5 \times T_5$  recorded positive standard heterosis, the expression

Table 24. Gca and sca effects of parents and hybrids for number of bolls per plant

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	0.0880	-1.6187**	1.4613**	1.2280*	-1.1587*	-3.7480**
C <sub>2</sub>	-0.0320	2.3280**	0.3413	-1.0920*	-1.5453**	-1.8280**
C <sub>3</sub>	-0.1920	0.7013	-1.6187**	0.4147	0.6947	2.1320**
C <sub>4</sub>	-1.0053*	0.7547	1.1013*	-1.7320**	0.8813	3.5453**
C <sub>5</sub>	-1.8187**	-2.4587**	-2.4453**	3.0547**	3.6680**	0.2920
C <sub>6</sub>	0.5013	-0.8720	0.4747	-0.7587	0.6547	-0.6947**
C <sub>7</sub>	1.4747**	0.0347	0.1813	-0.1853	-1.5053**	0.1987
C <sub>8</sub>	0.3947	0.2213	0.1680	-0.5320	-0.2520	2.8787**
C <sub>9</sub>	0.4213	-0.3520	-0.3387	1.2947**	-1.0253*	-1.9480**
C <sub>10</sub>	0.1680	1.2613**	0.6747	-1.6920**	-0.4120	-0.8280**
<b>Gca effects of testers</b>	-0.4880**	-2.9813**	1.3387**	-0.8947**	3.0253**	

SE of lines : 0.2142 SE of testers : 0.1515 SE of hybrids : 0.4790

\*Significant at 5% level

\*\*Significant at 1% level

Table 25. Expression of heterosis in cotton hybrids (percentage) - Number of bolls per plant

Testers	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	3.29	-37.20**	-46.05**	-25.10**	-52.28**	-67.70**	18.84**	-29.55**	-29.55**	29.23**	-18.45**	-42.27**	0.26	-41.59**	-34.36**
C <sub>2</sub>	-6.36	-26.40**	-36.77**	7.06	-7.61	-37.46**	0	-25.43**	-25.43**	-7.16	-21.36**	-44.33**	-8.94**	-34.56**	-26.46**
C <sub>3</sub>	15.04**	-3.60	-17.18**	18.58**	10.15*	-25.43**	7.39*	-15.12**	-15.12**	30.13**	18.45**	-16.15**	23.79**	-6.12*	5.50
C <sub>4</sub>	18.48**	0	-14.09**	29.54**	21.32**	-17.87**	33.48**	6.19	6.19	23.28**	13.11**	-19.93**	32.67**	1.22	13.75**
C <sub>5</sub>	8.00	-24.40**	-35.05**	-4.38	-27.92**	-51.20**	5.88	-28.87**	-28.87**	67.32**	24.27**	-12.03**	51.76**	-0.92	11.34**
C <sub>6</sub>	1.95	-16.40**	-28.18**	-15.41**	-23.35**	-48.11**	4.66	-18.90**	-18.90**	0.55	-10.68*	-36.77**	8.42**	-19.27**	-9.28**
C <sub>7</sub>	16.75**	-5.20	-18.56**	0.85	-9.64	-38.83**	9.62**	-15.81**	-15.81**	13.81**	0	-29.21**	1.45	-25.08**	-15.81**
C <sub>8</sub>	11.54**	4.40	-10.31**	6.51	1.38	-24.05**	11.98**	-2.06	-2.06	13.68**	10.55*	-17.18**	11.56**	-7.03*	4.47
C <sub>9</sub>	4.42	-24.40**	-35.05**	-9.39	-28.93**	-51.89**	1.74	-29.55**	-29.55**	23.27**	-4.85	-32.65**	0.23	-32.72**	-24.40**
C <sub>10</sub>	9.19*	-19.20**	-30.58**	14.20**	-8.12	-37.80**	15.33**	-18.56**	-18.56**	3.07	-18.45**	-42.27**	10.07**	-24.77**	-15.46**

\* Significant at 5% level

\*\* Significant at 1% level

being 13.75 and 11.34 per cent respectively for these two hybrids. Negative standard heterosis was discernible in 44 hybrids (Table 25).

#### 4.9.6. Boll weight

For boll weight, five lines,  $C_2$ ,  $C_5$ ,  $C_6$ ,  $C_7$  and  $C_9$  were found to possess positive and four lines had negative gca values. Among the testers,  $T_1$  and  $T_3$  showed positive gca values of 0.0696 and 0.2023 respectively, whereas the other testers  $T_2$ ,  $T_4$  and  $T_5$  exhibited negative values of -0.0784, -0.0251 and -0.1684 respectively (Table 26).

The sca effects presented in Table 26 disclosed that 11 hybrids had positive sca values. The values were negative in ten hybrids.  $T_3$  and  $T_4$  as testers, produced a maximum of three hybrids, each possessing positive sca. Similarly coloured linted line  $C_9$  produced three hybrids ( $C_9 \times T_1$ ,  $C_9 \times T_3$  and  $C_9 \times T_5$ ) with positive specific combining ability. These hybrids recorded sca values of 0.1491, 0.0564 and 0.1271 respectively for boll weight. The variance due to GCA was higher than that of SCA (Table 15).

Minimum and maximum heterosis over the mid-parental value were recorded in  $C_1 \times T_4$  and  $C_9 \times T_5$  respectively and the corresponding values were -37.23 and 5.34 per cent for the two hybrids. Negative heterosis over their respective mid parent was noticed in 44 hybrids while none of the

Table 26. Gca and sca effects of parents and hybrids for boll weight

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-0.0003	0.0077	-0.0129	0.0077	-0.0023	-0.4777**
C <sub>2</sub>	-0.0043	0.0237	-0.0503	0.0771**	-0.0463	0.0663**
C <sub>3</sub>	-0.0176	0.0304	-0.0503	0.0171	0.0204	-0.1004**
C <sub>4</sub>	-0.0269	-0.0456	-0.0263	0.0544*	0.0444	-0.0244*
C <sub>5</sub>	-0.1403**	-0.0789**	-0.1996**	0.4477**	-0.0289	0.1489**
C <sub>6</sub>	0.0384	0.0664*	0.0257	-0.1269**	-0.0036	0.3236**
C <sub>7</sub>	-0.0456	-0.0109	0.2817**	-0.1176**	-0.1076**	0.0276*
C <sub>8</sub>	-0.0149	0.0797**	-0.1276**	0.0197	0.0431	-0.0231
C <sub>9</sub>	0.1491**	-0.0563*	0.0564*	-0.2763**	0.1271**	0.0929**
C <sub>10</sub>	0.0624*	-0.0163	0.1031**	-0.1029**	-0.0463	-0.0337**
<b>Gca effects of testers</b>	0.0696**	-0.0784**	0.2023**	-0.0251**	-0.1684**	

SE of lines : 0.0119 SE of testers : 0.0084 SE of hybrids : 0.0267

\*Significant at 5% level

\*\*Significant at 1% level

Table 27. Expression of heterosis in cotton hybrids (percentage) - Boll weight

Lines	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	-32.93**	-56.81**	-59.11**	-35.44**	-57.92**	-62.22**	-31.55**	-56.44**	-59.79**	-37.23**	-59.79**	-61.04**	-24.29**	-46.67**	-64.44**
C <sub>2</sub>	-24.12**	-44.13**	-47.11**	-25.33**	-44.06**	-49.78**	-24.26**	-45.19**	-45.72**	-25.73**	-45.72**	-47.41**	-16.22**	-30.00**	-53.33**
C <sub>3</sub>	-26.34**	-48.36**	-51.11**	-27.00**	-48.02**	-53.33**	-25.97**	-48.89**	-50.92**	-29.53**	-50.92**	-52.44**	-15.13**	-33.33**	-55.56**
C <sub>4</sub>	-24.78**	-46.79**	-49.63**	-27.67**	-48.02**	-53.33**	-23.40**	-46.67**	-48.32**	-26.44**	-48.32**	-49.93**	-11.89**	-30.00**	-53.33**
C <sub>5</sub>	-20.86**	-45.38**	-48.30**	-20.85**	-44.55**	-50.22**	-21.57**	-46.67**	-35.32**	-5.69	-35.32**	-37.33**	-4.76	-26.67**	-51.11**
C <sub>6</sub>	-10.07**	-37.09**	-40.44**	-10.80**	-36.63**	-43.11**	-9.68	-37.78**	-44.50**	-20.13**	-44.50**	-46.22**	2.13	-20.00**	-46.67**
C <sub>7</sub>	-22.82**	-46.01**	-48.89**	-23.81**	-45.87**	-51.41**	-10.97**	-38.67**	-51.07**	-29.59**	-51.07**	-52.59**	-14.89**	-33.33**	-55.56**
C <sub>8</sub>	-29.56**	-46.48**	-49.33**	-28.78**	-44.88**	-50.52**	-31.48**	-48.89**	-49.08**	-32.45**	-49.08**	-50.67**	-19.44**	-30.00**	-53.33**
C <sub>9</sub>	-9.00	-39.91**	-43.11**	-18.37**	-45.38**	-50.96**	-11.36**	-42.22**	-53.21**	-28.75**	-53.21**	-54.67**	5.34	-23.33**	-48.89**
C <sub>10</sub>	-20.36**	-44.91**	-47.85**	-25.26**	-47.52**	-52.89**	-17.83**	-44.00**	-52.14**	-30.37**	-52.14**	-53.63**	-13.67**	-33.33**	-55.56**

\* Significant at 5% level

\*\* Significant at 1% level

hybrids were heterotic in the positive direction. All the hybrids registered only negative heterobeltiosis which ranged from -59.79 per cent in  $C_1 \times T_4$  to -20.00 per cent in  $C_6 \times T_5$ . Likewise, standard heterosis was also in the negative direction in all the hybrids, the combinations  $C_1 \times T_5$  and  $C_5 \times T_4$  recording minimum and maximum expressions of -64.44 and -37.33 per cent (Table 27).

#### 4.9.7. Seed cotton yield

Six coloured linted lines  $C_3, C_4, C_5, C_6, C_7$  and  $C_8$  proved to be general combiners exhibiting positive gca. Among the testers,  $T_3$  and  $T_5$  were the general combiners in the positive side, the values being 5.9816 and 3.6729 respectively while  $T_4$  and  $T_2$  had negative gca values (Table 28).

In all, 12 hybrids, including two each involving  $T_1, T_4$  and  $T_5$  and three involving each  $T_2$  and  $T_3$  as testers were found to possess positive sca values. The sca was negative in 13 hybrids out of which the maximum number of four, involved  $T_4$  as tester parent (Table 28). The variance due to GCA was higher than that of SCA (Table 15).

Heterosis in hybrids based on mid-parental values had a range of -60.37 per cent to 34.31 per cent. The combinations  $C_1 \times T_2$  and  $C_5 \times T_4$  were the hybrids

Table 28. Gca and sca effects of parents and hybrids for seed cotton yield

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-0.5523	-0.6069	1.3931	2.4244*	-2.6583**	-13.4257**
C <sub>2</sub>	-0.4136	5.3317**	0.0851	-1.7636	-3.2396*	-3.2777**
C <sub>3</sub>	-0.2323	2.0797*	-4.2203**	1.3511	1.0217	2.9076**
C <sub>4</sub>	-1.9923*	0.1597	3.2064**	-3.0156**	1.6417	7.3276**
C <sub>5</sub>	-5.9096**	-6.7443**	-8.5243**	13.6937**	7.4844**	2.5116**
C <sub>6</sub>	1.4757	-1.9989*	1.7477	-3.3676**	2.1431*	2.3729**
C <sub>7</sub>	2.5624**	-0.5789	5.0077**	-2.3476*	-4.6436**	1.0529*
C <sub>8</sub>	1.1651	1.4637	-1.0829	-1.0449	-0.5009	6.0103**
C <sub>9</sub>	2.7384**	-1.5629	-0.5296	-0.8849	0.2391	-3.2364**
C <sub>10</sub>	1.1584	2.4571*	2.9171**	-5.0449**	-1.4876	-2.2431**
<b>Gca effects of testers</b>	-0.1464	-7.3784**	5.9816**	-2.1297**	3.6729**	

SE of lines : 0.4313 SE of testers : 0.3050 SE of hybrids : 0.9644

\*Significant at 5% level

\*\* Significant at 1% level

Table 29. Expression of heterosis in cotton hybrids (percentage) - Seed cotton yield

Lines	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	-50.56**	-73.76**	-78.70**	-60.37**	-78.55**	-87.10**	-41.68**	-69.39**	-69.39**	-38.14**	-66.79**	-77.55**	-41.84**	-68.99**	-76.72**
C <sub>2</sub>	-35.36**	-59.16**	-66.84**	-22.86**	-47.70**	-68.55**	-32.78**	-59.20**	-59.20**	-34.12**	-56.62**	-70.68**	-28.88**	-54.30**	-65.69**
C <sub>3</sub>	-21.31**	-50.11**	-59.50**	-14.92**	-42.07**	-65.17**	-29.41**	-57.03**	-57.03**	-10.36**	-40.76**	-59.96**	-4.25	-38.26**	-53.65**
C <sub>4</sub>	-16.25**	-46.34**	-56.43**	-9.12**	-37.28**	-62.29**	-7.82**	-43.37**	-43.37**	-11.34**	-40.67**	-59.90**	6.52**	-30.51**	-47.84**
C <sub>5</sub>	-28.52**	-58.74**	-66.50**	-33.40**	-59.75**	-75.80**	-33.27**	-62.45**	-62.45**	+34.31**	-20.38**	-46.18**	21.78**	-28.94**	-46.65**
C <sub>6</sub>	-17.61**	-48.45**	-58.14**	-26.72**	-50.92**	-70.49**	-18.23**	-50.76**	-50.76**	-22.77**	-49.72**	-66.02**	-1.50	-37.35**	-52.97**
C <sub>7</sub>	-17.63**	-48.78**	-58.41**	-25.86**	-50.73**	-70.37**	-14.06**	-48.53**	-48.53**	-23.01**	-50.23**	-66.36**	-20.55**	-49.81**	-62.32**
C <sub>8</sub>	-22.62**	-43.72**	-54.31**	-22.31**	-37.31**	-62.30**	-26.72**	-49.83**	-49.83**	-21.81**	-39.55**	-59.14**	-13.96**	-35.83**	-51.83**
C <sub>9</sub>	-20.63**	-54.62**	-63.16**	-34.39**	-60.84**	-76.45**	-28.09**	-59.86**	-59.86**	-23.32**	-55.06**	-69.62**	-11.51**	-48.89**	-61.63**
C <sub>10</sub>	-24.85**	-55.45**	-63.83**	-22.00**	-51.23**	-70.67**	-21.33**	-54.74**	-54.74**	-35.33**	-60.46**	-73.27**	-16.75**	-50.02**	-62.48**

\* Significant at 5% level

\*\* Significant at 1% level

registering the lowest and the highest expressions. Only three hybrids,  $C_5 \times T_4$ ,  $C_4 \times T_5$ , and  $C_5 \times T_5$  recorded positive heterosis ranging from 6.52 to 34.31 per cent while it was negative in as many as 45 hybrids out of the total 50. None of the hybrids registered positive heterobeltiosis and standard heterosis. On the other hand, all of them were negatively heterotic (Table 29).

#### 4.9.8. Ginning outturn

Four coloured linted varieties among the lines viz.,  $C_2$ ,  $C_7$ ,  $C_8$  and  $C_9$  and three testers  $T_3$ ,  $T_4$  and  $T_5$  showed positive **gca** effects. Four coloured linted varieties  $C_3$ ,  $C_4$ ,  $C_5$  and  $C_{10}$  and testers,  $T_1$  and  $T_2$  were found to possess negative values for this estimate (Table 30).

Among the hybrids, 15 were positive specific combiners for ginning outturn. These included four having  $T_5$  as testers, three each involving  $T_2$ ,  $T_3$  and  $T_4$  as testers and two with  $T_1$  as the tester parent. Fifteen hybrids had negative **sca** values. Out of these, five had  $T_4$  as tester. Three of the hybrids in each, with  $C_1$  and  $C_5$  as line had positive values of **sca** (Table 30). The variance due to GCA was higher than that of SCA (Table 15).

Heterosis of hybrids over their mid-parental values varied between -5.69 per cent in  $C_5 \times T_5$  and 12.44 per cent in  $C_2 \times T_1$ . In all, 37 hybrids recorded positive

Table 30. Gca and sca effects of parents and hybrids for ginning outturn

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-0.5094**	-1.7297**	0.3599*	1.4106**	0.4686**	-0.0709
C <sub>2</sub>	0.7352**	-0.0784	0.1212	-0.4114*	-0.3667*	0.9044**
C <sub>3</sub>	0.1213	0.1909	-0.3227	-0.6821**	0.6926**	-0.7749**
C <sub>4</sub>	-0.1048	-0.0084	-0.1488	0.7519**	-0.4901**	-0.4056**
C <sub>5</sub>	1.4519**	0.8849**	0.6446**	-1.0347**	-1.9467**	-0.8589**
C <sub>6</sub>	-0.3341	0.5456**	0.3786*	-0.2374	-0.3527*	-0.0396
C <sub>7</sub>	-0.1748	0.6216**	0.2412	-0.4814**	-0.2067	0.5544**
C <sub>8</sub>	-0.7074**	-0.0811	-0.5881**	0.9426**	0.4339*	0.5704**
C <sub>9</sub>	-0.2954	-0.4491*	0.2006	0.2713	0.2726	0.4451**
C <sub>10</sub>	-0.1827	0.1036	-0.8867**	-0.5294**	1.4953**	-0.3243**
<b>Gca effects of testers</b>	-0.3286**	-2.0249**	0.3688**	0.7947**	1.1901**	

SE of lines : 0.0784 SE of testers : 0.0555 SE of hybrids : 0.1754

\* Significant at 5% level

\*\* Significant at 1% level

Table 31. Expression of heterosis in cotton hybrids (percentage) - Ginning outturn

Lines	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	5.43**	-2.23**	-4.37**	-1.96**	-7.62**	-12.69**	9.04**	0.10	0.10	11.72**	1.14	4.32**	9.14**	-1.85**	2.76**
C <sub>2</sub>	12.44**	4.25**	1.97**	6.48**	0.31	-5.19**	11.36**	2.21**	2.21**	9.16**	-1.20	1.90**	9.59**	-1.47*	3.16**
C <sub>3</sub>	6.06**	-2.44**	-4.57**	2.79**	-3.94**	-9.22**	5.58**	-3.85**	-3.85**	4.00**	-6.59**	-3.66**	8.54**	-3.16**	1.39*
C <sub>4</sub>	6.94**	-2.02**	-4.17**	3.76**	-3.43**	-8.73**	7.71**	-2.30**	-2.30**	9.98**	-1.60*	1.48*	6.46**	-5.38**	-0.93
C <sub>5</sub>	3.30**	1.20	-1.02	-1.75**	-2.10**	-7.48**	1.81**	-1.33	-1.33	-3.44**	-7.80**	-4.91**	-5.69**	-10.58**	-6.38**
C <sub>6</sub>	0.13	-1.62*	-3.78**	-0.59	-0.65	-6.11**	3.14**	0.25	0.25	0.95	-3.33**	-0.29	0.96	-4.01**	0.50
C <sub>7</sub>	5.48**	0.57	-1.63*	4.57**	1.37	-4.19**	7.62**	1.55*	1.55*	4.98**	-2.36**	0.70	6.11**	-1.99**	2.62**
C <sub>8</sub>	1.62**	-0.93	-3.10**	0.15	-0.70	-6.15**	2.88**	-0.77	-0.77	6.93**	1.62*	4.81**	5.76**	-0.20	4.49**
C <sub>9</sub>	8.23**	-0.10	-2.28**	4.29**	-2.19**	-7.56**	10.66**	1.12	1.12	10.32**	-0.58	2.54**	10.61**	-0.98	3.67**
C <sub>10</sub>	-2.50**	-2.98**	-4.16**	-5.00**	-7.06**	-8.18**	-3.59**	-4.17**	-4.17**	-2.88**	-4.92**	-1.94**	3.16**	0.25	4.96**

\* Significant at 5% level

\*\* Significant at 1% level

heterosis and eight exhibited negative heterosis over the mid-parent. Heterobeltiosis ranged from -10.58 per cent in  $C_5 \times T_5$  to 4.25 per cent in  $C_2 \times T_1$ . Four hybrids,  $C_2 \times T_1$ ,  $C_2 \times T_3$ ,  $C_7 \times T_3$  and  $C_8 \times T_4$  were positively heterotic while it was negative in 27 hybrids. Standard heterosis was found to vary from -12.69 per cent in  $C_1 \times T_2$  to 4.96 per cent in  $C_{10} \times T_5$ . Positive heterosis was noticed in 15 hybrids. The expression, however, was negative in 25 hybrids (Table 31).

#### 4.9.9. Lint index

The *gca* effect was positive in three parental lines,  $C_6$  (0.1267),  $C_7$  (0.1533) and  $C_8$  (0.1333) while it was negative in  $C_1$  and  $C_5$ . Among the testers,  $T_1$  and  $T_4$  were general combiners in the positive direction, the values were 0.1033 and 0.1667 respectively while  $T_2$  and  $T_3$  were negative in their general combining ability (Table 32).

Three hybrids having  $T_5$  as tester, two each involving  $T_4$ ,  $T_3$  and  $T_2$  as testers and one with  $T_1$  were found to possess positive *sca* values. The values were negative in eight hybrids out of the 50. Among the coloured lines,  $C_1$  and  $C_8$  produced each two hybrids with positive *sca* (Table 32). The variance due to SCA was higher than that of GCA (Table 15).

Table 32. Gca and sca effects of parents and hybrids for lint index.

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-0.5967**	-0.4067**	0.3233**	0.7067**	-0.0267	-0.1533**
C <sub>2</sub>	0.1700	0.0267	-0.1100	-0.3600	0.2733*	0.0133
C <sub>3</sub>	0.1300	-0.1467	-0.0500	-0.1667	0.2333*	0.0800
C <sub>4</sub>	0.0100	0.6667**	-0.4033**	-0.0533	-0.2200	0.0067
C <sub>5</sub>	0.2833*	0.0733	0.2033	-0.1800	-0.3800**	-0.2333**
C <sub>6</sub>	-0.0433	-0.0867	-0.0233	-0.1067	0.2600*	0.1267*
C <sub>7</sub>	0.0633	0.3200**	-0.5500**	-	0.1667	0.1533**
C <sub>8</sub>	-0.1167	-0.1933	0.3033**	0.2533*	-0.2467*	0.1333*
C <sub>9</sub>	0.1700	-0.4067**	0.1233	-0.0267	0.1400	-0.0533
C <sub>10</sub>	-0.0700	0.1533	0.1833	-0.0667	-0.2000	0.0867
<b>Gca effects of testers</b>	0.1033**	-0.1200**	-0.1833**	0.1667**	0.0333	
SE of lines : 0.0504    SE of testers : 0.0356    SE of hybrids : 0.1126						
- = negligible    * Significant at 5% level    ** Significant at 1% level						



All the hybrids recorded negative values of heterosis based on all the three criteria, mid-parental value, better parental value and the standard parental value (Table 33).

#### 4.9.10. Seed index

The gca for seed index was positive in two coloured linted varieties ( $C_6$  and  $C_{10}$ ) whereas it was negative in three lines,  $C_1$ ,  $C_5$  and  $C_9$ . Two tester parents,  $T_1$  and  $T_2$  had positive gca effects of 0.2720 and 0.2287 respectively and two testers  $T_3$  and  $T_5$  possessed negative values (Table 34).

Nine hybrids exhibited positive sca values, with the distribution of one, two, three, one and two combinations for  $T_1$ ,  $T_2$ ,  $T_3$ ,  $T_4$  and  $T_5$  tester parents respectively. In eight hybrids, the sca was negative. Among the coloured linted lines,  $C_1$  produced two hybrids,  $C_1 \times T_3$  and  $C_1 \times T_4$ , with significantly higher sca while  $C_2$ ,  $C_4$ ,  $C_6$ ,  $C_7$ ,  $C_8$ ,  $C_9$  and  $C_{10}$  had one combination each, exhibiting positive sca (Table 34). The variance due to SCA was higher than that of GCA (Table 15).

For this character also, the heterotic expression estimated over parental average, better parental value and standard parent was negative and significant. The magnitude

Table 34. Gca and sca effects of parents and hybrids for seed index

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-1.0187**	-0.4753*	0.5713**	0.9980**	-0.0753	-0.3213**
C <sub>2</sub>	0.1280	0.0713	-0.2153	-0.5553**	0.5713**	-0.1680
C <sub>3</sub>	0.2413	-0.3487	-0.0353	-0.1420	0.2847	0.0187
C <sub>4</sub>	0.0213	1.3980**	-0.7887**	-0.2953	-0.3353	0.1387
C <sub>5</sub>	0.2280	-0.0620	0.2513	-0.0887	-0.3287	-0.2680**
C <sub>6</sub>	0.0080	-0.2820	-0.1353	-0.1420	0.5513**	0.2520**
C <sub>7</sub>	0.1480	0.4913*	-1.0620**	0.0980	0.3247	0.1787
C <sub>8</sub>	-0.0587	-0.3487	0.6980**	0.2247	-0.5153*	0.1187
C <sub>9</sub>	0.4080*	-0.7487**	0.1980	-0.0753	0.2180	-0.2147*
C <sub>10</sub>	-0.1053	0.3047	0.5180*	-0.0220	-0.6953**	0.2653**
<b>Gca effects of testers</b>	0.2720**	0.2287**	-0.4180**	0.1220	-0.2047**	
SE of lines	: 0.0928	SE of testers	: 0.0656	SE of hybrids	: 0.2076	
	*Significant at 5% level			**Significant at 1% level		

Table 35. Expression of heterosis in cotton hybrids (percentage) - Seed Index

Testers	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	-53.19**	-62.65**	-59.93**	-46.88**	-57.37**	-54.97**	-40.20**	-50.99**	-50.99**	-23.87**	-34.93**	-41.39**	-42.43**	-51.09**	-55.30**
C <sub>2</sub>	-40.07**	-50.62**	-47.02**	-40.64**	-50.78**	-48.01**	-49.61**	-57.28**	-57.28**	-43.98**	-50.37**	-55.30**	-34.57**	-42.39**	-47.35**
C <sub>3</sub>	-44.22**	-47.84**	-44.04**	-50.08**	-52.98**	-50.33**	-52.05**	-53.64**	-53.64**	-44.77**	-45.74**	-49.34**	-44.09**	-44.69**	-48.34**
C <sub>4</sub>	-47.88**	-48.77**	-45.03**	-34.81**	-35.42**	-31.79**	-60.65**	-61.34**	-59.93**	-48.03**	-51.44**	-49.67**	-52.12**	-54.95**	-53.31**
C <sub>5</sub>	-48.55**	-50.62**	-47.02**	-51.38**	-52.98**	-50.33**	-53.33**	-53.64**	-53.64**	-48.77**	-51.01**	-51.66**	-55.05**	-56.71**	-57.28**
C <sub>6</sub>	-42.81**	-47.84**	-44.04**	-45.73**	-50.16**	-47.35**	-49.38**	-52.32**	-52.32**	-40.63**	-41.18**	-47.02**	-37.02**	-38.04**	-43.38**
C <sub>7</sub>	-43.09**	-47.22**	-43.38**	-39.60**	-43.57**	-40.40**	-60.62**	-62.25**	-62.25**	-39.89**	-40.43**	-45.36**	-41.41**	-41.52**	-46.36**
C <sub>8</sub>	-44.27**	-49.69**	-46.03**	-47.24**	-52.04**	-49.34**	-41.39**	-45.36**	-45.36**	-37.34**	-38.60**	-44.70**	-49.72**	-51.09**	-55.30**
C <sub>9</sub>	-44.61**	-48.46**	-44.70**	-56.19**	-58.93**	-56.62**	-51.80**	-53.64**	-53.64**	-46.28**	-46.95**	-50.99**	-47.03**	-47.31**	-51.32**
C <sub>10</sub>	-47.13**	-48.77**	-45.03**	-43.18**	-44.51**	-41.39**	-45.87**	-46.05**	-45.70**	-43.06**	-46.05**	-45.70**	-53.79**	-55.92**	-55.63**

\* Significant at 5% level

\*\* Significant at 1% level

of expression was larger in the negative side when it was estimated on better parental value (Table 35).

#### 4.9.11. Colour of the lint

Among the coloured linted cotton lines, the **gca** was positive in  $C_4$ ,  $C_5$ ,  $C_6$ ,  $C_7$  and  $C_{10}$  while in all other coloured linted varieties it was negative. The testers  $T_1$  and  $T_3$  displayed positive **gca** effects of 0.1427 and 0.1427 respectively while  $T_5$  registered a negative value of -0.1573 (Table 36).

Six out of the 50 hybrids possessed positive **sca** for this trait. The values were negative in nine hybrids. Each of the coloured linted lines  $C_5$ ,  $C_6$  and  $C_9$  produced two hybrids showing negative **sca**.  $C_9$  produced two hybrids ( $C_9 \times T_1$  and  $C_9 \times T_3$ ) with positive **sca** effects of 0.5373 and 0.4707 respectively. Among the combinations involving different testers, three hybrids with  $T_2$ , two each with  $T_3$ ,  $T_4$  and  $T_5$  recorded negative **sca** effects (Table 36). The variance due to SCA was higher than that of GCA (Table 15).

Heterosis of hybrids over their midparental values ranged from -29.17 per cent in  $C_8 \times T_3$  to 62.38 per cent in  $C_5 \times T_2$ . In all, 17 hybrids recorded positive heterosis while nine combinations were negatively heterotic. Heterobeltiosis of hybrids over the respective better parental values was found to range from -58.02 per cent in

Table 36. Gca and sca effects of parents and hybrids for colour of the lint

Lines	Sca effects of hybrids					gca effects of lines
	Testers T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
C <sub>1</sub>	-0.1960	-0.0027	-0.0627	0.0907	0.1707	-0.6707**
C <sub>2</sub>	-0.0893	0.1040	-0.0227	-0.1360	0.1440	-0.6440**
C <sub>3</sub>	-0.0227	-0.0293	-0.0893	-0.0693	0.2107	-0.7107**
C <sub>4</sub>	0.1507	0.0773	-0.8493**	0.3707*	0.2507	0.1827*
C <sub>5</sub>	-0.0360	1.2240**	0.1640	-0.6827**	-0.6693**	1.1693**
C <sub>6</sub>	0.0440	-0.4960**	0.3107	0.5973**	-0.4560**	0.8893**
C <sub>7</sub>	-0.1160	0.1440	-0.3827*	0.1040	0.2507	0.3160**
C <sub>8</sub>	-0.0360	0.2240	-0.3027	-0.0160	0.1307	-0.6973**
C <sub>9</sub>	0.5373**	-0.3360*	0.4707**	-0.4427**	-0.2293	-0.2040**
C <sub>10</sub>	-0.2360	-0.9093**	0.7640**	0.1840	0.1973	0.3693**
gca effects of testers	0.1427**	-0.0507	0.1427**	-0.0773	-0.1573**	

SE of lines : 0.0713 SE of testers : 0.0504 SE of hybrids : 0.1594

\* Significant at 5 % level      \*\* Significant at 1 % level

Table 37. Expression of heterosis in cotton hybrids (percentage) - Colour of the lint

Lines	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	-11.11	-45.45**	140.00**	-11.11	-45.45**	140.00**	-6.18	-42.42**	153.33**	-8.64	-43.94**	146.67**	-8.64	-43.94**	146.67**
C <sub>2</sub>	11.76	-28.30**	153.33**	11.76	-28.30**	153.33**	14.71*	-26.42**	160.00**	-	-35.85**	126.67**	8.82	-30.19**	146.67**
C <sub>3</sub>	15.15*	-25.49**	153.33**	6.06	-31.37**	133.00**	12.12	-27.45**	146.67**	3.03	-33.33**	126.67**	12.12	-27.45**	146.67**
C <sub>4</sub>	30.12**	-20.59**	260.00**	20.48*	-26.47**	233.33**	-6.02	-42.65**	160.00**	30.12**	-20.59**	260.00**	22.89**	-25.00**	240.00**
C <sub>5</sub>	30.69**	-23.26**	340.00**	62.38**	-4.65	446.67**	36.63**	-19.77**	360.00**	4.95	-38.37**	253.33**	2.97	-39.53**	246.67**
C <sub>6</sub>	29.90**	-23.17**	320.00**	7.22	-36.59**	246.67**	38.14**	-18.29**	346.67**	40.21**	-17.07**	353.33**	5.15	-37.80**	240.00**
C <sub>7</sub>	15.56**	-30.67**	246.67**	17.78**	-29.33**	253.33**	6.67	-36.00**	220.00**	15.56**	-30.67**	246.67**	17.78**	-29.33**	253.33**
C <sub>8</sub>	-20.83**	-53.09**	153.33**	-18.75**	-51.85**	160.00**	-29.17**	-58.02**	126.67**	-27.08**	-56.79**	133.33**	-25.00**	-55.56**	140.00**
C <sub>9</sub>	11.34*	-34.15**	260.00**	-21.65**	-53.66**	153.33**	9.28	-35.37**	253.00**	-25.77**	-56.10**	140.00**	-21.65**	-53.66**	153.33**
C <sub>10</sub>	-2.86	-43.33**	240.00**	-27.62**	-57.78**	153.33**	25.71**	-26.67**	340.00**	2.86	-40.00**	260.00**	0.95	-41.11**	253.33**

\* Significant at 5% level

\*\* Significant at 1% level

- Negligible heterosis

$C_8 \times T_3$  to -4.65 per cent  $C_5 \times T_2$ . A total of 49 hybrids recorded negative heterosis over their respective better parent. Standard heterosis ranged between 126.67 per cent ( $C_8 \times T_3$ ,  $C_3 \times T_4$  and  $C_2 \times T_4$ ) and 446.67 per cent ( $C_5 \times T_2$ ). All hybrids exhibited positive standard heterosis (Table 37).

#### 4.9.12. 2.5 % span length

The line  $C_8$  possessed positive *gca* effect of 3.4053 for 2.5 per cent span length and the two lines  $C_1$  and  $C_{10}$  had negative *gca* estimates. Among the testers,  $T_1$  showed positive *gca* value of 0.7853 whereas  $T_4$  exhibited negative value (Table 38).

The *sca* effects presented in table 38 disclosed that only one hybrid,  $C_1 \times T_3$  had positive *sca* value of 1.9613. The values were negative in two hybrids,  $C_1 \times T_2$  and  $C_6 \times T_3$ . The variance due to GCA was higher than that of SCA (Table 15).

Heterosis for 2.5% span length in hybrids based on mid-parental values had a range of -14.91 per cent in  $C_6 \times T_3$  to 14.77 per cent in  $C_8 \times T_4$ . Ten hybrids recorded positive heterosis and five had negative heterosis over the mid parental value. Heterobeltiosis ranged between -31.18 per cent in  $C_{10} \times T_3$  and 12.71 per cent in  $C_8 \times T_4$ . Only one

Table 38. *Gca* and *sca* effects of parents and hybrids for 2.5% span length

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	-0.6253	-2.2820**	1.9613*	0.6513	0.2947	-0.8880*
C <sub>2</sub>	0.3547	0.4647	1.1747	-0.8353	-1.1587	0.5987
C <sub>3</sub>	-0.3587	1.0847	-0.2720	-1.1487	0.6947	0.7120
C <sub>4</sub>	0.3947	-0.1620	0.4480	-0.0953	-0.5853	-0.1413
C <sub>5</sub>	0.1213	-0.2353	-0.4253	0.3647	0.1747	-0.6013
C <sub>6</sub>	0.5413	1.1513	-1.9387*	0.9847	-0.7387	-0.4213
C <sub>7</sub>	0.5347	0.0447	-0.8120	-0.3220	0.5547	-0.3480
C <sub>8</sub>	0.2813	-0.6420	0.1680	0.3580	-0.1653	3.4053**
C <sub>9</sub>	-0.4253	0.0847	0.4613	0.0513	-0.1720	0.1120
C <sub>10</sub>	-0.8187	0.4913	-0.7653	-0.0087	1.1013	-2.4280**
<b>Gca effects of testers</b>	0.7853**	-0.3913	0.2987	-0.7913**	0.0987	

SE of lines : 0.3661    SE of testers : 0.2589    SE of hybrids : 0.8186

\* Significant at 5% level

\*\* Significant at 1% level

Table 39. Expression of heterosis in cotton hybrids (percentage) - 2.5% span length

Lines	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	-2.49	-12.20**	-24.19**	-14.31**	-22.89**	-33.33**	-2.35	-17.42**	-17.42**	3.80	-0.29	-25.16**	0.92	-7.29	-23.44**
C <sub>2</sub>	10.26**	-2.99	-16.24**	5.66	-7.09	-19.68**	2.47	-15.16**	-15.16**	6.42	-0.29	-25.16**	3.48	-7.16	-23.33**
C <sub>3</sub>	5.11	-5.23	-18.17**	6.14	-4.35	-17.31**	-4.89	-19.46**	-19.46**	2.76	-1.15	-25.81**	9.27*	0.52	-16.99**
C <sub>4</sub>	6.91	-5.60	-18.49**	-0.49	-12.19**	-24.09**	-3.56	-19.89**	-19.89**	6.02	-0.29	-25.16**	2.39	-7.81	-23.87**
C <sub>5</sub>	3.52	-8.34	-20.86**	-3.02	-14.18**	-25.81**	-8.97**	-24.19**	-24.19**	5.69	-0.29	-25.16**	3.39	-6.64	-22.90**
C <sub>6</sub>	5.01	-6.10	-18.92**	2.57	-8.33	-20.75**	-14.91**	-28.49**	-28.49**	8.19*	3.15	-22.58**	-0.79	-9.51*	-25.27**
C <sub>7</sub>	8.23*	-5.85	-18.71**	1.00	-12.19**	-24.09**	-8.01*	-24.62**	-24.62**	5.73	-2.15	-26.56**	8.08*	-4.17	-20.86**
C <sub>8</sub>	12.77**	7.22	-7.42*	4.45	-0.75	-14.19**	1.93	-9.35*	-9.35*	14.77**	12.71**	-12.26**	10.86**	7.68	-11.08**
C <sub>9</sub>	5.41	-7.72	-20.32**	2.49	-10.32*	-22.47**	-1.76	-19.03**	-19.03**	8.84*	1.43	-23.87**	6.20	-5.21	-21.72**
C <sub>10</sub>	0.08	-18.68**	-29.78**	0.61	-18.28**	-29.35**	-10.61**	-31.18**	-31.18**	5.00	-9.74	-32.26**	8.66*	-10.16*	-25.81**

\* Significant at 5% level

\*\* Significant at 1% level

hybrid,  $C_8 \times T_4$  recorded positive heterosis of 12.71 per cent for this trait while 20 hybrids were negatively heterotic over their better parental values. Standard heterosis was found to vary from -33.33 per cent in  $C_1 \times T_2$  to -7.42 per cent in  $C_8 \times T_1$ . All hybrids showed negative heterosis over the standard parental value (Table 39)

#### 4.9.13. Uniformity ratio

Two coloured linted genotypes,  $C_1$ ,  $C_2$  exhibited positive **gca** values of 2.1000 and 2.5000 respectively and three lines,  $C_4$ ,  $C_6$  and  $C_8$  had negative **gca** values. Positive **gca** was noticed in  $T_2$  (0.9000) and  $T_3$  showed negative estimate of -1.1667 among the testers. The **sca** was positive in two hybrids ( $C_4 \times T_2$  and  $C_2 \times T_5$ ), the values being 2.0333 and 2.6667 respectively (Table 40). The variance due to GCA was higher than that of SCA (Table 15).

Heterosis over mid parental value displayed a range of -8.71 per cent in  $C_4 \times T_5$  to 7.86 per cent in  $C_1 \times T_1$ . Five hybrids exhibited positive heterosis and eight registered negative values over their respective mid parental value. Heterobeltiosis ranged from -10.00 per cent in  $C_{10} \times T_5$  to 7.09 per cent in  $C_1 \times T_1$ . Positive heterosis was registered by two hybrids ( $C_1 \times T_1$  and  $C_2 \times T_5$ ) while 14 were heterotic in the negative direction. The standard heterosis was found to vary from -3.73 per cent in  $C_4 \times T_3$

Table 40. Gca and sca effects of parents and hybrids for uniformity ratio

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	1.4333	-0.7000	0.3667	-0.8333	-0.2667	2.1000**
C <sub>2</sub>	-1.6333	-0.4333	1.3000	-1.9000	2.6667**	2.5000**
C <sub>3</sub>	1.0333	-0.1000	0.3000	-0.5667	-0.6667	0.1667
C <sub>4</sub>	-1.5000	2.0333*	-0.5667	0.5667	-0.5333	-1.6333**
C <sub>5</sub>	-0.1000	0.7667	-1.1667	0.9667	-0.4667	-0.3667
C <sub>6</sub>	-1.1000	1.4333	0.5000	-0.3667	-0.4667	-1.3667**
C <sub>7</sub>	1.6333	-0.5000	-0.4333	0.3667	-1.0667	0.2333
C <sub>8</sub>	0.8333	-1.9667	-0.5667	-0.1000	1.8000	-1.3000**
C <sub>9</sub>	1.0333	-0.7667	-0.3667	0.1000	0	-0.5000
C <sub>10</sub>	-1.6333	0.2333	0.6333	1.7667	-1.0000	0.1667
<b>Gca effects of testers</b>	0.4333	0.9000**	-1.1667**	0.3667	-0.5333	
SE of lines	: 0.4558	SE of testers	: 0.3223	SE of hybrids	: 1.0192	
*Significant at 5% level				**Significant at 1% level		

Table 41. Expression of heterosis in cotton hybrids (percentage) - Uniformity ratio

Testers	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	df	dif	difi	df	dif	difi	df	dif	difi	df	dif	difi	df	dif	difi
C <sub>1</sub>	7.86**	7.09*	12.69**	2.46	1.39	8.96**	4.00	1.42	6.72*	0.35	-1.37	7.46*	0.35	-0.69	6.72*
C <sub>2</sub>	1.42	0	6.72*	3.14	2.78	10.45**	6.14**	2.80	9.70**	-1.73	-2.74	5.97	6.62**	6.25*	14.18**
C <sub>3</sub>	6.27**	3.60	7.46*	2.90	-1.39	5.97	3.01	2.24	2.24	-	-4.79	3.73	-1.45	-5.56	1.49
C <sub>4</sub>	-7.09**	-8.39**	-2.24	-0.35	-0.69	6.72*	-6.86**	-9.79**	-3.73	-5.19*	-6.16*	2.24	-8.71**	-9.03**	-2.24
C <sub>5</sub>	-0.36	-0.71	3.73	0.70	-0.69	6.72*	-4.38	-6.43*	-2.24	-0.70	-2.74	5.97	-4.93*	-6.25*	0.75
C <sub>6</sub>	-1.85	-4.32	-0.75	2.90	-1.39	5.97	-	-0.75	-0.75	-2.88	-7.53*	0.75	-4.35	-8.33**	-1.49
C <sub>7</sub>	5.04*	5.04	8.96**	-0.35	-2.08	5.22	-1.10	-2.88	0.75	-0.35	-2.74	5.97	-4.59*	-6.25*	0.75
C <sub>8</sub>	2.96	0	3.73	-4.00	-8.33**	-1.49	-1.89	-2.99	-2.99	-1.81	-6.85*	1.49	1.09	-3.47	3.73
C <sub>9</sub>	4.03	2.16	5.97	-0.72	-4.17	2.99	-0.75	-0.75	-0.75	-0.71	-4.79	3.73	-2.16	-5.56	1.49
C <sub>10</sub>	-5.88**	-9.33**	1.49	-2.72	-4.67	6.72*	-2.82	-8.00**	2.99	-1.35	-2.67	8.96**	-8.16**	-10.00**	0.75

\* Negligible      \* Significant at 5% level      \*\* Significant at 1% level

to 14.18 per cent in  $C_2 \times T_5$ . In all, fifteen hybrids recorded positive heterosis over their standard parental value (Table 41).

#### 4.9.14. Fibre fineness

The *gca* for fibre fineness was positive in  $C_{10}$  (0.3761) and negative in two lines,  $C_1$  and  $C_8$ . Among the testers,  $T_2$  showed positive *gca* effect of 0.1258 and negative *gca* effect of -0.1459 was discernible in  $T_3$  (Table 42).

The *sca* values were positive in three hybrids,  $C_7 \times T_1$ ,  $C_{10} \times T_2$  and  $C_2 \times T_5$ . The values were 0.3589, 0.2742 and 0.5245 respectively. On the other hand the estimates were negative in  $C_2 \times T_2$  and  $C_{10} \times T_5$  (Table 42). The variance due to GCA was equal to SCA (Table 15).

The estimate of hybrid vigour over their mid-parental values in the hybrids was found to range between -14.13 per cent in  $C_9 \times T_3$  and 25.00 per cent in  $C_2 \times T_5$ . Three hybrids ( $C_7 \times T_1$ ,  $C_{10} \times T_2$  and  $C_2 \times T_5$ ) recorded positive heterosis. The values were 12.71, 8.49 and 25.00 per cent respectively. Seven combinations had negative heterosis over their mid-parental value. Heterobeltiosis took a range from -21.92 per cent to 22.81 per cent, the crosses exhibiting low and high values being  $C_8 \times T_3$  and  $C_2 \times T_5$ . Two hybrids,  $C_7 \times T_1$  and  $C_2 \times T_5$  recorded heterosis in

Table 42. Gca and sca effects of parents and hybrids for fibre fineness

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	0.0229	0.0249	0.1399	-0.1075	-0.0801	-0.1179*
C <sub>2</sub>	-0.1258	-0.2405*	-0.0288	-0.1295	0.5245**	0.0741
C <sub>3</sub>	-0.0105	0.0149	-0.0635	-0.0008	0.0599	0.0088
C <sub>4</sub>	-0.1118	0.1302	-0.0648	0.1412	-0.0948	-0.0132
C <sub>5</sub>	-0.0398	-0.0978	-0.0428	0.1032	0.0772	-0.0185
C <sub>6</sub>	0.0035	0.0155	0.1272	-0.0701	-0.0761	-0.0719
C <sub>7</sub>	0.3589**	-0.1091	-0.0475	-0.0681	-0.1341	0.0595
C <sub>8</sub>	0.0089	-0.0891	0.0425	0.0485	-0.0108	-0.2705**
C <sub>9</sub>	-0.0785	0.0769	-0.0415	-0.0421	0.0852	-0.0265
C <sub>10</sub>	-0.0278	0.2742*	-0.0208	0.1252	-0.3508**	0.3761**
<b>Gca effects of testers</b>	-0.0055	0.1258**	-0.1459**	-0.0085	0.0341	

SE of lines : 0.0544    SE of testers : 0.0384    SE of hybrids : 0.1216

\*Significant at 5% level

\*\*Significant at 1% level

Table 43. Expression of heterosis in cotton hybrids (percentage) - Fibre fineness

Lines	T <sub>1</sub>				T <sub>2</sub>				T <sub>3</sub>				T <sub>4</sub>				T <sub>5</sub>					
	dI	dII	dIII	dI	dII	dIII	dI	dII	dIII	dI	dII	dIII	dI	dII	dIII	dI	dII	dIII	dI	dII	dIII	
C <sub>1</sub>	-1.95	-4.38	-13.36*	-1.97	-8.42	-9.19	-7.68	-14.09**	-14.09**	-5.11	-5.95	-17.54**	-3.45	-5.15	-15.34**							
C <sub>2</sub>	-0.41	-2.88	-12.00*	-4.45	-10.74	-11.48*	-6.90	-13.36*	-13.36*	1.02	0.12	-12.21*	25.00**	22.81**	9.60							
C <sub>3</sub>	3.50	-1.15	-10.44	4.02	-4.74	-5.53	-8.47	-16.49**	-16.49**	5.52	2.38	-10.23	8.33	4.21	-6.99							
C <sub>4</sub>	-5.31	-5.41	-14.30**	2.75	-1.79	-2.61	-13.05**	-17.22**	-17.22**	5.04	3.46	-6.47	-2.61	-3.23	-12.53*							
C <sub>5</sub>	-2.27	-3.11	-12.21*	-4.27	-9.16	-9.92	-11.87**	-16.70**	-16.70**	4.31	3.52	-7.83	3.98	3.86	-7.31							
C <sub>6</sub>	-2.16	-3.46	-12.53*	-1.84	-7.26	-8.04	-7.60	-13.05*	-13.05**	-3.26	-3.55	-14.93**	-2.82	-3.39	-13.78*							
C <sub>7</sub>	12.71**	12.07*	2.71	-3.39	-7.05	-7.83	-10.68*	-14.41**	-14.41**	-0.47	-2.62	-10.75*	-2.14	-3.42	-11.48*							
C <sub>8</sub>	-5.05	-10.14	-18.58**	-8.41	-16.84**	-17.54**	-13.68**	-21.92**	-21.91**	-2.04	-5.83	-17.43**	-3.56	-8.07	-17.95**							
C <sub>9</sub>	-6.24	-7.70	-13.67*	-1.08	-3.89	-4.70	-14.13**	-16.91**	-16.91**	-3.57	-6.58	-12.63*	1.43	-0.89	-7.31							
C <sub>10</sub>	-0.36	-9.58*	0.52	8.49*	2.63	14.09**	-8.75*	-13.33**	-3.65	5.83	-5.35	5.22	-8.54*	-17.56**	-8.35							

\* Significant at 5% level

\*\* Significant at 1% level

the positive direction. The heterosis in these hybrids were 12.07 and 22.81 per cent respectively. Thirteen hybrids showed negative estimate of heterosis over their better parent. Standard heterosis ranged from -21.92 per cent in  $C_8 \times T_3$  to 14.09 per cent in  $C_{10} \times T_2$ . Only one hybrid,  $C_{10} \times T_2$ , had positive heterosis of 14.09 per cent and 29 hybrids exhibited negative heterosis over standard parental value (Table 43).

#### 4.9.15. Maturity coefficient

Two lines,  $C_7$  and  $C_{10}$  and the tester,  $T_2$  had positive gca of 0.0253, 0.0780 and 0.0290 respectively for maturity coefficient. The two lines  $C_1$  and  $C_8$  had negative gca values of -0.0307 and -0.0767 respectively. Among the testers,  $T_2$  was a positive general combiner whereas the gca was negative in  $T_3$  (Table 44).

In hybrids, positive sca effect of 0.0640 was noticed in  $C_2 \times T_5$ . The combination  $C_1 \times T_4$  showed negative sca effect of -0.0537 (Table 44). The variance due to GCA was higher than that of SCA (Table 15).

Heterosis over the mid parental value ranged from -16.49 per cent in  $C_4 \times T_3$  to 16.67 per cent in  $C_2 \times T_5$ . Only one hybrid,  $C_2 \times T_5$  exhibited positive heterosis of 16.67 per cent and seven had negative heterosis over their

Table 44. Gca and sca effects of parents and hybrids for maturity coefficient

Testers	Sca effects of hybrids					Gca effects of lines
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	
<b>Lines</b>						
C <sub>1</sub>	0.0063	0.0077	0.0337	-0.0537*	0.0060	-0.0307**
C <sub>2</sub>	-0.0090	-0.0477	0.0083	-0.0157	0.0640*	0.0180
C <sub>3</sub>	-0.0010	0.0003	-0.0170	0.0090	0.0087	0
C <sub>4</sub>	-0.0263	0.0450	-0.0257	0.0370	-0.0300	-0.0113
C <sub>5</sub>	-0.0017	-0.0137	-0.0210	0.0250	0.0113	0.0007
C <sub>6</sub>	0.0090	-0.0030	0.0363	-0.0177	-0.0247	-0.0067
C <sub>7</sub>	0.0503	-0.0150	-0.0090	-0.0063	-0.0200	0.0253*
C <sub>8</sub>	-0.0077	-0.0130	-0.0037	0.0257	-0.0013	-0.0767**
C <sub>9</sub>	-0.0177	0.0237	-0.0270	0.0057	0.0153	0.0033
C <sub>10</sub>	-0.0023	0.0157	0.0250	-0.0090	-0.0293	0.0780**
<b>Gca effects of testers</b>	-0.0030	0.0290**	-0.0437**	0.0037	0.0140	

SE of lines : 0.0116 SE of testers : 0.0082 SE of hybrids : 0.0260

\*Significant at 5% level

\*\*Significant at 1% level

Table 45. Expression of heterosis in cotton hybrids (percentage) - Maturity coefficient

Testers	T <sub>1</sub>					T <sub>2</sub>					T <sub>3</sub>					T <sub>4</sub>					T <sub>5</sub>									
	di	dii	diii	diiii	d	dii	diii	diiii	d	dii	diii	diiii	d	dii	diii	diiii	d	dii	diii	diiii	d	dii	diii	diiii	d	dii	diii	diiii		
C <sub>1</sub>	-3.08	-6.99	-7.98	-7.98	-0.54	-7.11	-2.66	-5.85	-10.11	-10.11	-10.11	-10.11	-10.80*	-13.26*	-16.49**	0.56	-2.73	-5.32												
C <sub>2</sub>	0.83	-1.61	-2.66	-3.21	-3.21	-8.12	-3.72	-3.56	-6.38	-6.38	-6.38	-6.38	2.23	1.10	-2.66	16.67**	14.75*	11.70*												
C <sub>3</sub>	3.15	-3.23	-4.26	5.56	5.56	-3.55	1.06	-7.12	-13.30*	-13.30*	-13.30*	7.56	2.21	-1.60	8.67	2.73	-													
C <sub>4</sub>	-9.63*	-10.11	-10.11	3.90	3.90	1.52	6.38	-16.49**	-16.49**	-16.49**	2.98	1.06	1.06	1.06	-6.74	-7.98	-7.98													
C <sub>5</sub>	-2.70	-3.23	-4.26	-2.36	-1.32	-5.08	-0.53	-4.32	-5.85	-5.85	-5.85	4.11	3.26	1.06	3.00	2.72	0.53													
C <sub>6</sub>	-1.63	-2.69	-3.72	-1.32	-1.32	-5.08	-0.53	-4.32	-5.85	-5.85	-5.85	-3.58	-3.85	-6.91	-3.56	-3.83	-6.38													
C <sub>7</sub>	7.69	6.28	7.98	-0.52	-0.52	-2.03	2.66	-8.71*	-9.42	-7.98	1.08	-1.57	-	0	-2.09	-0.53														
C <sub>8</sub>	-8.82	-16.67**	-17.55**	-7.12	-17.26**	-13.30**	-15.79**	-23.40**	-23.40**	-23.40**	-0.30	-7.73	-11.17	-3.86	-11.48	-13.83*														
C <sub>9</sub>	-7.12	-8.81	-6.38	1.54	1.54	0.51	5.32	-15.49**	-16.58**	-14.36*	-1.07	-4.15	-1.60	1.60	-1.04	1.60														
C <sub>10</sub>	2.01	-4.25	7.98	6.60	6.60	2.83	15.96**	-0.50	-6.13	5.85	3.31	-4.25	7.98	1.27	-5.66	6.38														

\* Significant at 5% level  
 \*\* Significant at 1% level

mid-parental value. The estimate of heterobeltiosis over the better parental value was found to range from -23.40 per cent to 14.75 per cent. The minimum and maximum heterobeltiosis were encountered in  $C_8 \times T_3$  and  $C_2 \times T_5$ . Only one hybrid,  $C_2 \times T_5$  recorded positive heterosis of 14.75 per cent and eight hybrids based on better parental value were negatively heterotic. Standard heterosis took a range from -23.40 per cent in  $C_8 \times T_3$  to 15.96 per cent in  $C_{10} \times T_2$ . Nine hybrids recorded negative heterosis and two hybrids  $C_{10} \times T_2$  and  $C_2 \times T_5$  recorded positive heterosis of 15.96 and 11.70 per cent respectively over their standard parental value (Table 45).

#### 4.9.16. Bundle strength

Three coloured linted varieties among the lines,  $C_1$ ,  $C_2$  and  $C_8$  showed positive **gca** effects of 1.9253, 1.4053 and 1.5920 respectively. The lines possessing negative **gca** effects were  $C_6$ ,  $C_7$  and  $C_{10}$ . None of the testers, showed **gca** effects (Table 46).

Among the hybrids,  $C_6 \times T_2$  showed positive **sca** effect of 2.4480 and  $C_3 \times T_4$  had negative **sca** effect registering a value of -1.9787 (Table 46). The variance due to GCA was higher than that of SCA (Table 15).

The heterosis over mid-parental value was minimum in  $C_{10} \times T_1$  (-13.91 per cent) and maximum in  $C_1 \times T_1$  (12.73



Table 47. Expression of heterosis in cotton hybrids (percentage) - Bundle strength

Lines	T <sub>1</sub>			T <sub>2</sub>			T <sub>3</sub>			T <sub>4</sub>			T <sub>5</sub>		
	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii	di	dii	diii
C <sub>1</sub>	12.73**	4.64	6.98	-0.68	-5.86	-7.96	6.18	-0.42	-0.42	6.88	-2.12	3.07	-0.86	-10.01*	-3.35
C <sub>2</sub>	0.07	-2.73	-0.56	-4.82	-5.43	-7.54	0.64	-1.12	-1.12	-3.67	-7.69	-2.79	-2.47	-7.41	-0.56
C <sub>3</sub>	4.02	-6.28	-4.19	2.87	-5.43	-7.54	0.69	-8.38	-8.38	-10.96*	-20.82**	-16.62**	-0.74	-12.48*	-6.01
C <sub>4</sub>	0.45	-9.15	-7.12	7.12	-1.14	-3.35	-2.14	-10.61*	-10.61*	-4.31	-14.59**	-10.06	-0.96	-12.35*	-5.87
C <sub>5</sub>	4.12	-6.83	-4.75	5.79	-3.43	-5.59	1.08	-8.66	-8.66	-3.00	-14.32**	-9.78	-8.09	-19.51**	-13.55*
C <sub>6</sub>	-6.95	-16.80**	-14.94**	8.69	-0.86	-3.07	-13.69**	-22.07**	-22.07**	0.83	-11.01*	-6.28	-13.37**	-24.19**	-18.58**
C <sub>7</sub>	-5.27	-15.30**	-13.41*	-0.86	-9.57	-11.59*	-9.36*	-18.16**	-18.16**	-7.59	-18.44**	-14.11**	-1.34	-13.65**	-7.26
C <sub>8</sub>	10.64*	-0.55	1.68	4.52	-4.14	-6.28	1.38	-7.96	-7.96	8.07	-4.11	0.98	8.94*	-4.16	2.93
C <sub>9</sub>	3.21	-9.97	-7.96	5.22	-6.43	-8.52	4.52	-7.96	-7.96	4.54	-9.95	-5.17	3.35	-11.70*	-5.17
C <sub>10</sub>	-13.91**	-28.96**	-27.37**	-9.86*	-24.29**	-25.98**	-5.70	-21.51**	-21.51**	-8.13	-25.07**	-21.09**	-2.17	-20.81**	-14.94**

\* Significant at 5% level

\*\* Significant at 1% level

per cent). Three hybrids,  $C_1 \times T_1$ ,  $C_8 \times T_1$  and  $C_8 \times T_5$  recorded positive heterosis of 12.73, 10.64 and 8.94 respectively and six were negatively heterotic on the basis of mid-parental value. Heterosis of hybrids estimated over their better parental value ranged from -28.96 per cent in  $C_{10} \times T_1$  to 4.64 per cent in  $C_1 \times T_1$ . Twenty two hybrids recorded negative values over their better parental value. The standard heterosis ranged from -27.37 per cent in  $C_{10} \times T_1$  to 6.98 per cent in  $C_1 \times T_1$ . Fifteen hybrids showed negative heterosis over standard parental value for bundle strength (Table 47).

## Discussion

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## 5. DISCUSSION

Cotton occupies a unique position among the commercial crops of India. Among the different species of cultivated cotton including the tetraploid and diploid groups, the upland cotton *G. hirsutum* is the most important one in view of its high yield potential, spinning performance and adaptability to a wide range of environmental conditions. This species includes cottons of white coloured lint and naturally coloured fibres.

In India, yield improvement in cotton has made remarkable strides during the last few decades primarily due to the phenomenal achievement of developing high yielding varieties and commercial exploitation of heterosis through the release of intra and interspecific hybrids. This was responsible for transforming our country from a position of import to a place of export of high quality lint, earning substantial foreign exchange.

In this crop, various biometrical methods have been applied to evaluate the group of selected genotypes for further exploitation in heterosis breeding programmes or for varietal improvement. Such studies were found useful for pointing out, precisely, the most suitable genotypes and breeding methodology. One such method is the line x tester analysis developed by Kempthorne (1957) following the sire x

dam mating system adopted by the animal breeders. This is a simple model, in terms of lay out, analysis and interpretation to explain the additive-dominance mechanism.

In cotton, of late the naturally coloured lint is assuming importance in the textile industry, particularly in countries like USA, in view of the health hazards caused by bleaching and dyeing processes in the use of white coloured lint. The coloured linted varieties are poor spinners and also poor yielders. Exhaustive work has been accomplished in the line of determining gene action behind the development of coloured fibre and its dominance-recessive relationship vis a vis the white linted genotypes. Only a very few investigations deal about the suitability of their spinning performance and eventually, no previous work was carried out to study the combining ability of these genotypes with other white linted varieties so that, its fibre quality and yield potential can be improved either through recombination breeding or heterosis breeding. Such recombinants or hybrids will lend themselves fit for spinning cottons in 'natural colours'.

Therefore, it was thought to be worthwhile to take up investigations on genetic analysis involving a set of ten coloured linted varieties and five standard white linted genotypes of proven yield and spinning performance, to draw

information on the extent of variability in the parental genotypes, character association, and path relationship in the parents and in the hybrids, the genetic divergence in the parents, the general combining ability of the parents, specific combining ability of the hybrids, expression of heterosis in the hybrids and the genetic system that determines the different characters.

The ten coloured linted parental lines were used as seed parents and five standard varieties, MCU-5, MCU-7, MCU-9, KC-1 and LRA-5166 were chosen as pollinators (testers) in the present study. Among the coloured lines, C<sub>1</sub> and C<sub>2</sub> were green linted and C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>, C<sub>6</sub>, C<sub>7</sub>, C<sub>8</sub>, C<sub>9</sub> and C<sub>10</sub> were brown linted. The characters chosen for the study comprise seed cotton yield, six yield associated characters, three traits to evaluate the quality of produce viz., the ginning outturn, lint index and seed index and five fibre quality parameters, 2.5% span length, uniformity ratio, fibre fineness, maturity coefficient and bundle strength. A special character lint colour was included for the study and the colour was graded using the chart developed by Hutchinson and Ramaiah (1938).

The Tables 2 to 4 indicate the significant variability existing between the parents as well as in the hybrids for all the characters studied. The Table 1 also

reveals the geographic diversity of the different parental variants. Thus, the material chosen for the present investigation, has satisfied the important basic requirement of genetic and geographic variability in respect of yield, fibre and colour properties, and become fit for further evaluation.

The parental genotypes displayed high genotypic variance particularly for days to maturity, plant height and seed cotton yield. The genetic variability was however, low for lint index, fibre fineness and maturity coefficient (Table 5). For all the characters except fibre length, uniformity ratio, fibre fineness and bundle strength, the phenotypic variance was almost equal to the genetic variance indicating the negligible role of environment. This was also reflected in the high heritability values exceeding 90% for all these characters. Nevertheless, the genetic advance values should also be considered simultaneously as high heritability combined with high genetic advance is likely to result in maximum genetic progress during selection (Johnson et al., 1955). Such a situation is evident in the present study, in respect of seed cotton yield, plant height and days to maturity. High heritability and genetic advance for seed cotton yield was reported by Kalsy and Vithal (1980), Jehangir (1981), Seth and Singh (1984) and Nadarajan (1986),

for lint index by Nadarajan (1986) and for halo length by Kalsy and Vithal (1980) and Jehangir (1981). The indication that the seed cotton yield will respond to selection is a welcome feature in cotton breeding, because, the varietal improvement can be accomplished by simple selection programmes, particularly in the coloured linted genotypes. The breeding system featuring high autogamy prevailing in this crop will also offer scope to achieve substantial yield improvement through selection. The selection as the method of breeding has been recommended in this crop by Williams (1964).

The data pertaining to the hybrids also reflect more or less a similar trend of the parents. However, the variability at the genetic and phenotypic level in the hybrids is relatively less in the hybrids than the parental genotypes. Further, the heritability was also lower for number of sympodia per plant, lint index, seed index, lint colour, 2.5% span length, maturity coefficient and bundle strength, while for uniformity ratio and fibre fineness, it was slightly higher. A combination of high heritability and genetic advance observed in the case of seed cotton yield and plant height (Table 5) points to the fact that substantial yield progress can be achieved by resorting to simple selection programmes in the variable population developed from the hybrids.

The genotypic and phenotypic correlation coefficients estimated involving seed cotton yield as the dependent character and six yield components and three quality parameters viz., ginning outturn, lint index and seed index, as independent variables, in respect of parental genotypes revealed that days to maturity, plant height, number of sympodia per plant, number of bolls per plant, boll weight, ginning outturn and lint index had highly significant and positive correlation with seed cotton yield at the genotypic and phenotypic levels (Table 8). Yield is an interplay of several associated characters. Because, all the important characters such as number of sympodia per plant, number of bolls per plant and boll weight in the present study, have been found to be positively correlated with seed cotton yield, selection for these component characters is likely to bring about an overall improvement in the seed cotton yield. The positive association of plant height with seed cotton yield was reported by Alves (1970) and Paramasivam and Udayasoorian (1989). Reports on correlation between number of sympodia per plant with seed cotton yield (Paramasivam and Udayasoorian, 1989), number of bolls per plant with seed cotton yield (Kalsy et al., 1977; Giridharan, 1979; Singh et al., 1981; Jagtap and Kolhe, 1986; Vijaykumar and Choudhry, 1986; Singh et al., 1987; Paramasivam and Udayasoorian, 1989 and Vireshwar Singh et

al., 1990) and boll weight with seed cotton yield (Jagtap and Kolhe, 1986; Vijaykumar and Choudhry, 1986; Singh et al., 1987; Ananda Choudary and Hanumantha Rao, 1987; Paramasivam and Udayasoorian, 1989 and Vireshwar Singh et al., 1990) have been made in this crop.

Path coefficient analysis developed by Dewey and Lu (1959) provides a measure to split the total correlation between an yield component and the yield, into direct effect and indirect effects through other component characters so that the relative importance of a particular character can be precisely fixed. This procedure involves a multivariate analysis of correlation matrix.

In the present investigation, the genotypic correlation coefficients for the ten different characters recorded on parental genotypes were subjected to a path coefficient analysis to estimate the cause and effects. The direct and indirect effects of different characters on seed cotton yield in parents have been presented in Table 6.

Among the characters studied, boll weight, plant height, number of bolls per plant and days to maturity exhibited a high and positive direct effects, while number of sympodia per plant which had a high positive correlation with yield, exerted only a negative direct effect. Besides,

all the characters except days to first boll bursting influenced indirectly the seed cotton yield in the negative direction through the number of sympodia per plant. Thus the key characters for use as an index in the selection programme in the present study are boll weight, plant height and number of bolls per plant. The importance of plant height was emphasised by Ananda Choudary and Hanumantha Rao (1987), Tyagi et al. (1988) and Paramasivam and Udayasoorian (1989) and number of bolls per plant by Singh et al. (1979), Giridharan (1979), Singh et al. (1981), Gill and Singh (1981), Govila and Sharma (1981), Ananda Choudary and Hanumantha Rao (1987), Tyagi et al. (1988), Paramasivam and Udayasoorian (1989), Vireshwar Singh et al. (1990) and boll weight by Govila and Sharma (1981), Ananda Choudary and Hanumantha Rao (1987), Tyagi et al. (1988), Paramasivam and Udayasoorian (1989).

The correlation coefficients and path coefficients were also worked out for the data pertaining to the 50 hybrids. The data presented in Table 9 go to show that plant height, number of sympodia per plant, number of bolls per plant and boll weight were highly and positively correlated with the seed cotton yield. However, there was no correlation between seed cotton yield on the one hand and days to maturity, ginning outturn and lint index which had a high association with seed cotton yield in the parents. The

absence of parallelism in respect of character association, between parents and hybrids may be attributed to the recombination of genes during introgression or hybridisation. In the hybrids, the maximum positive direct effect of 0.8646 on seed cotton yield was exerted by number of bolls per plant. The other characters having direct influence on the yield are lint index and boll weight and days to maturity to a lesser extent (Table 7). Considering the direct and indirect effects, the number of bolls per plant and lint index were the most important characters that modify the expression of yield either directly or indirectly. Therefore, due weightage should be given for these characters during selection of suitable hybrids for pedigree breeding work. Reports on importance of number of bolls in the hybrids were made by Singh et al. (1979), Giridharan (1979), Kadambavanasundaram (1980), Gill and Singh (1981), Govila and Sharma (1981), Ananda Choudary and Hanumantha Rao (1987), Tyagi et al. (1988), Paramasivam and Udayasoorian (1989) and Vireshwar Singh et al. (1990), lint index by Govila and Sharma (1981) and Tyagi et al. (1988) and boll weight by Singh et al. (1979) and Govila and Sharma (1981).

Mahalanobis  $D^2$  statistics is a powerful biometrical tool designed to estimate the genetic divergence existing in a group of genotypes (Rao, 1952). As the knowledge on genetic diversity between the two parental genotypes is an essential pre-requisite for realising heterosis of a high order in the hybrids, the diversity in the parental genotypes was estimated.

In the present study, the 15 parental genotypes were grouped into five clusters based on the genetic divergence. This indicated that sufficient diversity existed within the parents. Among the clusters obtained, cluster I was the largest with six genotypes followed by cluster II including four varieties. All the varieties under cluster I and II were coloured linted. Thus the grouping was able to demarcate between the coloured linted types and white linted locally adapted cultivars. Further varieties under these two groups were used as seed parents to develop hybrids by combining genotypes from other three clusters. Hence the hybrids are expected to exhibit a reasonable degree of heterosis. There was no relationship between the geographical origin of the genotypes and the genetic divergence. Cluster I included genotypes from USA as well as Russia, the two ecologically divergent countries. Similarly the cluster II comprised two genotypes from USA, one from

Russia and one from India. The absence of relationship between the ecogeographic origin and genetic divergence has been reported earlier (Giridharan, 1979 and Amalraj, 1982).

In cluster III, two genotypes MCU-5 and MCU-9 released for winter irrigated situations of Tamil Nadu, were included while in cluster IV, there were two genotypes, developed for rainfed tract. MCU-7 which was particularly bred for rice fallow tracts of Tamil Nadu was the component of the cluster V (Table 11). Thus, the group constellations revealed the distinct morphological characters and adaptability status of the different varieties, especially in case of the tester parents.

The wide genetic distances between cluster I and cluster IV, cluster I and cluster III, cluster I and V cluster II and cluster III offer scope for realising high degree of heterosis in the combinations involving genotypes included in these clusters (Table 12).

Among the different characters studied, the three characters ginning outturn, seed index and days to maturity together accounted for more than 85 per cent of the total genetic divergence, revealing the importance of these three characters (Table 13). Higher genetic divergence indicates a broad genetic base and this in turn offers better scope for selection. In the present study, however, the most important

characters identified from path coefficient analysis failed to exhibit high degree of genetic divergence. Therefore, care should be exercised to correctly pinpoint the genotypes from the limited variability left out in the case of the important characteristics such as boll weight, plant height and number of bolls per plant.

#### 5.1. Line x tester analysis

The analysis of variance indicated that the parent Vs hybrid component was significant for all the characters except seed cotton yield, uniformity ratio, fibre fineness, maturity coefficient and bundle strength indicating the validity of comparison of parental and hybrid expressions in respect of these genotypes. The component of variance for lines and testers were significant for all the characters except bundle strength and the variance due to line x tester was significant for all the characters except 2.5% span length, uniformity ratio, maturity coefficient and bundle strength (Table 15). Hence, the combining ability analysis, should give a realistic estimation of combining ability effects of lines and testers and also the hybrids. The information on nature of gene action could also be drawn precisely. The results obtained from the line x tester analysis are discussed characterwise.

### 5.1.1. Days to first boll bursting

This character has been found to be predominantly under the control of additive genetic system as seen from the ratio between GCA and SCA variance (Table 15). This finding is in conformity with those reported by Duhoon et al. (1983) and Khajjidoni et al. (1986). Nevertheless, Baker and Verhalen (1973) noticed the influence of dominance genetic system.

The coloured cotton genotypes  $C_1$ ,  $C_3$ ,  $C_4$ ,  $C_5$ ,  $C_6$  and  $C_{10}$  and the white linted varieties  $T_2$ ,  $T_4$  and  $T_5$  were found to be negative general combiners for days to first boll bursting and expressed their usefulness in breeding for earliness (Table 16).

The hybrids exhibiting *sca* effects in the negative direction and involving the negative general combining parents will be more dependable combinations in view of the preponderance of additive genes. Accordingly  $C_1 \times T_2$ ,  $C_1 \times T_5$  and  $C_5 \times T_5$  were the most important combinations in the present study. All these crosses recorded low mean values and negative heterosis based on all the three criteria. High degree of negative heterosis was noticed by many authors in this crop (Patil and Chopde, 1985 and Sangwan and Yadava, 1986). Also negative heterosis was encountered in almost all the crosses irrespective of the *per se* performance *sca*

effects and negative **gca** effects of the parental genotypes in the present study. Such deviations could be interpreted to be due to the existence of epistatic interactions or inter cancellation of the effects of one set of alleles by another. Reports on absence of parallelism between mean performance and **sca** effects are common in cotton (Singh et al., 1976a).

Nevertheless, a combination of earliness and coloured lint can be achieved by resorting to pedigree breeding using the hybrids  $C_1 \times T_2$ ,  $C_1 \times T_5$  and  $C_5 \times T_5$  as base populations.

#### 5.1.2. Days to maturity

The higher magnitude of GCA than SCA for this character indicated the preponderance of additive genes. This finding is in accordance with the reports made by Duhoon et al. (1983).

Six out of ten lines,  $C_1$ ,  $C_3$ ,  $C_4$ ,  $C_5$ ,  $C_6$  and  $C_{10}$  showed negative **gca** effects while three testers,  $T_2$ ,  $T_4$  and  $T_5$  also exhibited negative values of **gca** (Table 18). The **sca** effect was negative in 15 hybrids. The data on mean performance revealed that in many hybrids there is a tendency to mature earlier than the parents. This is also supported by the expression of heterosis in the hybrids, which was found to be only in the negative direction (Table

19). A considerable degree of negative heterosis has been observed by Patil and Chopde (1985) and Sangwan and Yadava (1986). However, most of the hybrids possessing negative *sca* involved parents which did not have negative *gca* effects. On the other hand, positive general combining parents also produced early hybrids as exemplified by the combinations  $C_9 \times T_1$  and  $C_2 \times T_3$ . These factors support the role of epistatic gene action for days to maturity. The two hybrids  $C_1 \times T_5$  and  $C_5 \times T_5$  are of particular importance because they combined early maturity as seen from the *per se* performance, negative *sca* effect, negative heterosis and involved parents which were negative general combiners. The duration to first boll bursting was also shorter in these two hybrids (Table 2).

Thus, realisation of early maturing hybrids appears to be feasible from the present study. Since both the traits, days to first boll bursting and days to maturity were under the control of additive genes, selection of early maturing hybrids like  $C_1 \times T_5$  and  $C_5 \times T_5$  and subjecting to pedigree selection may result in recovering early genotypes combining coloured lint. The direct exploitation of these hybrids needs confirmation of their yield performance.

### 5.1.3. Plant height

Plant height is one of the important characteristic in cotton which exhibited a direct relationship with the seed cotton yield (Ananda Choudary and Hanumantha Rao, 1987; Tyagi *et al.*, 1988 and Paramasivam and Udayasoorian, 1989). In the present study, also it exhibited substantial direct effect on seed cotton yield in parents (Table 6). However its influence in hybrids is negative. The GCA variance was nearly double the variance of SCA, revealing the importance of additive genes (Table 15). The above results are in conformity with those reported by Chandramathi (1973a), Chinnadurai *et al.* (1973) and Duhoon *et al.* (1983). However, Singh and Phundan Singh (1985), reported that this character was under the control of non additive genes.

Among the lines,  $C_2$ ,  $C_4$ ,  $C_6$  and  $C_8$  and of the testers,  $T_4$  and  $T_5$  were positive general combiners. Sixteen out of the 50 hybrids had negative *sca* and the values of 13 hybrids is negative. The two hybrids  $C_1 \times T_1$  and  $C_1 \times T_2$  had negative *sca*, negative heterosis and involved negative general combiners as parents. These two hybrids can be used for further breeding work. Heterotic expression was on the negative side in most of the hybrids in the present study. A high degree of heterosis towards the negative direction has been reported by Nadre *et al.* (1984). Most of the high

specific combining hybrids did not have high general combiners as parents and negative general combining parents did not always result in hybrids with negative *sca*. These deviations may be due to the result of interallelic interactions of epistatic nature and/or high environmental influence.

#### 5.1.4. Number of sympodia per plant

Number of sympodia per plant was predominantly under the control of dominance genetic system, the ratio of GCA/SCA being 0.45 suggesting that number of sympodia can be improved by heterosis breeding. Earlier, reports on preponderance of dominance system were made by Salim *et al.*, 1984. However, the results obtained by Chandramathi (1973a), Duhoon *et al.* (1983), show that, additive genes control this character.

Three coloured cotton lines  $C_3$ ,  $C_4$  and  $C_8$  recording *gca* values of 0.7307, 0.5307 and 0.9307 were positive general combiners. Two white linted testers,  $T_1$  and  $T_5$  also recorded positive values of *gca* and proved to be useful for future breeding work (Table 22). None of the crosses involving the above lines and testers exhibited positive *sca* indicating the involvement of epistatic interaction.

The number of sympodia per plant however, is not an important character in the present study as it exerted negative direct effects on seed cotton yield and also all the other characters indirectly influenced the yield through this character in the negative direction (Table 7). Hence, selection for improving this character alone may lead to a loss in yield. Nevertheless, the hybrids  $C_2 \times T_3$  and  $C_5 \times T_4$  possessing high mean performance, significant sca effect and a considerable degree of heterosis may prove useful, provided they satisfy the requirement of high yield and fibre quality. Singh et al. (1977), Bhatt and Rao (1981), Duhoon et al. (1983) and Ansingkar et al. (1990) suggested heterosis breeding for this character.

#### 5.1.5. Number of bolls per plant

This is one of the important yield component in this crop which exerted substantial direct effect on yield in both the parents and hybrids in the present study (Table 6 and 7). Also the other characters indirectly influenced seed cotton yield through number of bolls in the positive direction.

A higher estimate of GCA variance as compared to SCA variance (GCA/SCA ratio : 2.46) for this character suggests the additive genetic control which finding is in conformity with those reported by Chandramathi (1973a),

Duhoon et al. (1983), Khajjidoni et al. (1986) and Amalraj (1989). Singh et al. (1971), Singh et al. (1976), Waldia et al. (1979), Singh and Phundan Singh (1985) and Jagtap (1986) however, inferred the predominance of additive genes in the genetic control of this character.

The genotypes  $C_3$ ,  $C_4$ ,  $C_8$ ,  $T_3$  and  $T_5$  were positive general combiners. Although, as many as nine hybrids had positive sca effects, the combination  $C_4 \times T_3$  is the best because, both of its parents are general combiners. The heterotic expression in this hybrid was also positive and substantial. The other eight hybrids viz.,  $C_7 \times T_1$ ,  $C_{10} \times T_2$ ,  $C_2 \times T_2$ ,  $C_1 \times T_3$ ,  $C_1 \times T_4$ ,  $C_5 \times T_4$ ,  $C_9 \times T_4$  and  $C_5 \times T_5$  are also important as they had significant sca effect and heterosis over the mid parent. Since the additive genes predominantly control this character, the above nine hybrids can be subjected to pedigree breeding for developing segregants which combine high number of bolls per plant and coloured lint. This may in turn, increase the yield level of the coloured linted genotypes.

#### 5.1.6. Boll weight

Boll weight is also one of the important yield contributing character in this crop as seen from its path relationship with the yield. Although the GCA and SCA variances are almost equal for this character, predominance

of additive system has been inferred from the larger proportion of GCA variance (Table 15).

Duhoon *et al.* (1983) and Kadapa and Prajapati (1990) encountered a preponderance of additive genes lending support to the present finding. However Waldia *et al.* (1979) and Singh and Phundan Singh (1985) reported the predominance of non-additive genes for this character.

Five lines  $C_2$ ,  $C_5$ ,  $C_6$ ,  $C_7$  and  $C_9$  were positive general combiners. Similarly the gca effect was positive in the two testers  $T_1$  and  $T_3$ . As many as eleven hybrids possessed positive sca effects among which two,  $C_5 \times T_4$  and  $C_7 \times T_3$  combined high *per se* performance also. The fact that most of the hybrids express negative heterosis for this character, does not support direct exploitation of the hybrids for cultivation. Nevertheless, selecting the two crosses  $C_5 \times T_4$  and  $C_7 \times T_3$ , particularly the latter, as it involved general combining parents, and resorting to pedigree breeding may throw good segregants with high boll weight and coloured lint.

#### 5.1.7. Seed cotton yield

All the cotton breeding programmes are oriented to increase the seed cotton yield which is a joint function of its important components. The most important yield

attributes are boll number and boll weight in the present study.

The seed cotton yield is under the additive genetic control as seen from the larger variance of GCA (27.41) than SCA (17.13). This is an encouraging situation as simple selection procedures can improve the yield (Table 15). Reports on additive gene control of seed cotton yield was made by Rajesh et al. (1979), Duhoon et al. (1983), Khajjidoni et al. (1986), Amalraj (1989) and Green and Culp (1990) while Singh et al. (1971), Chinnadurai (1973), Singh et al. (1976); Singh and Phundan Singh (1985) and Jagtap (1986) inferred the predominance of non additive genes.

Among the hybrids ten exhibited high yield level exceeding 40 g per plant. Six lines  $C_3$ ,  $C_4$ ,  $C_5$ ,  $C_6$ ,  $C_7$  and  $C_8$  and two testers  $T_3$  and  $T_5$  were general combiners in the positive direction (Table 28). Four hybrids  $C_4 \times T_3$ ,  $C_7 \times T_3$ ,  $C_5 \times T_5$  and  $C_6 \times T_5$  can be classified to be the most dependable as they combined high per se performance and positive sca. Among this only one hybrid  $C_5 \times T_5$  was the best with high mean, positive sca effect and positive heterotic expression over the mid parent. This will be useful as an intra *hirsutum* hybrid with coloured lint for cultivation. This combination also is superior in respect of the important yield component number of bolls per plant. The

absence of parallelism between high mean and negative heterosis in many hybrids in the present study, reveals the complicated nature of inheritance of this important character. Under such situations recurrent selection techniques will be reliable to tap the additive and non additive component of variance.

#### 5.1.8. Ginning outturn

The lint recovery is an important attribute which decides the suitability of a genotype for commercial exploitation.

Ginning outturn was under the control of additive genes as was evident from the larger magnitude of GCA than SCA (Table 15). Earlier reports also indicate the predominant role of additive genes (Singh et al., 1976; Rajesh et al., 1979; Vadne and Thombre, 1982; Jasmal Singh et al., 1982; Duhoon et al., 1983 and Amalraj 1989) as well as dominant genes (Khajjidoni et al., 1985; Singh and Phundan Singh, 1985 and Khajjidoni et al., 1986). The differences in the genetic system can be attributed to the genetic differences in the material involved, and variations in agro climatic conditions under which the experiments are conducted.

Seven hybrids surpassed the ginning percentage of 36.0 percentage and exhibited their superiority as high ginners.

Four lines, C<sub>2</sub>, C<sub>7</sub>, C<sub>8</sub> and C<sub>9</sub> and three testers T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub> had significant **gca** effects. As many as 15 hybrids had **sca** effects in the positive direction (Table 30). Out of which 12 involved either one or both parents as general combiners. The crosses C<sub>8</sub> x T<sub>4</sub> and C<sub>8</sub> x T<sub>5</sub> in particular were the best, based on all the criteria viz., high mean expression, significant positive **sca**, positive heterosis and **gca** of parents. Further exploitation of these combinations for direct release or for pedigree breeding will be useful for increasing the lint recovery. The absence of any type of relationship between seed cotton yield and ginning outturn will not stand in the way of realising high yielding pure genotypes with coloured lint and high ginning performance if the selection is based on high **per se** performance in respect of these two characters.

#### 5.1.9. Lint index

The lint index has a positive relationship with seed cotton yield. Six hybrids recorded high **per se** performance exceeding 3g/100 seeds. The inference of dominant genetic system predominating this character obtained from GCA:SCA ratio in the present investigation, is in conformity of earlier reports (Khajjidoni et al., 1985 and Khajjidoni et al., 1986) made in this crop.

The coloured linted lines  $C_6$ ,  $C_7$  and  $C_8$  and the white linted testers  $T_1$  and  $T_4$  are positive general combiners in the present study. Out of the ten hybrids with significant *sca* in the positive side, only one  $C_8 \times T_4$  is a combination of general combining parents. This hybrid can be exploited further for developing genotypes with good lint outturn and coloured lint. This will also in turn, improve the seed cotton yield as lint index is directly related to yield. The absence of relationship between *gca* of parents and *sca* of hybrids involving general combining parents, go to show the influence of epistatic gene action also. All the hybrids were negatively heterotic for this character indicating that developing hybrids with coloured lint and high lint recovery is not readily feasible. But the cross  $C_8 \times T_4$  can be forwarded to subsequent filial generations by selfing and selection for realising useful segregants. The effect of epistatic genes can be overcome by resorting to recurrent selection of different types.

#### 5.1.10. Seed index

A negative association between seed index and seed cotton yield was evident in the present study. Further the seed and lint indices were also positively related. Hence, the breeding programme should be carefully drawn up to get a high lint recovery and as far as possible a low seed index so that the seed cotton yield is not very much affected

during selection. For this character dominance genes had primary influence as observed from higher SCA than GCA. Earlier investigation also support the present finding (Kumar et al., 1984; Mehla et al., 1987 and Duhoon et al., 1983). In contrast, Bains et al. (1982), Duhoon et al. (1983), Singh and Phundan Singh (1985) and Nadarajan and Sree Rangasamy (1990) reported the predominance of the additive gene action.

Only two lines,  $C_6$  and  $C_{10}$  and two testers  $T_1$  and  $T_2$  possessed positive gca. Negative estimates of gca were evident in  $C_1$ ,  $C_5$  and  $C_9$  among the lines and  $T_3$  and  $T_5$  among the testers. Eight hybrids possessed negative sca values and nine had positive estimates. There was no relationship between gca of parents and the sca of hybrids suggesting the involvement of epistatic genes in the genetic control. The two hybrid combinations  $C_4 \times T_3$  and  $C_7 \times T_3$  possessing negative sca and heterosis are superior in respect of seed cotton yield. These hybrids can be utilized to make double crosses with crosses like  $C_8 \times T_4$  exhibiting positive sca and high mean performance in respect of lint index. From the descending progenies, it would be possible to identify high yielding segregants with good lint index. Procedures like reciprocal recurrent selection will be useful in tackling the epistatic component of gene interaction.

### 5.1.11. Colour of the lint

The lint colour has been subjected to a biometrical analysis for the first time in this crop.

Seven hybrids had high intensity of colour in the lint exceeding grade 4 in the 1 to 6 scale of Hutchinson and Ramaiah, 1938. The character is also under the joint control of additive and non additive genes though, the non additive genes predominate the expression. It is interesting to note that five lines and two testers were general combiners in the positive direction for this trait. In all, six hybrids,  $C_9 \times T_1$ ,  $C_5 \times T_2$ ,  $C_9 \times T_3$ ,  $C_{10} \times T_3$ ,  $C_4 \times T_4$  and  $C_6 \times T_4$  had **sca** in the positive direction. Particularly  $C_{10} \times T_3$  which is a combination of general combining line for lint colour will be desirable. All the six specific combining hybrids except  $C_9 \times T_3$  were also heterotic over the mid parental value for the colour. When the *per se* colour value is considered,  $C_5 \times T_2$  and  $C_6 \times T_4$  were the best and both of them were not superior in terms of yield. Hence, special techniques such as double cross technique and reciprocal recurrent selection are to be resorted to for achieving the combination of high yield and lint colour intensity.

In the present study among the two colour types, the green linted varieties were poor yielders and brown, especially  $C_8$  and  $C_4$  were fairly good in their potential.

The level in the hybrid involving brown linted cotton lines was also considerably higher than the combinations with green. Thus, the exploitation of brown types offer better scope to develop either varieties by pedigree breeding or hybrids by heterosis breeding.

#### 5.1.12. Fibre quality parameters

The variances due to lines and testers were significant only for fibre length, uniformity ratio, fibre fineness and maturity coefficient while for bundle strength none of the three components, lines, testers and line x testers were significant. The colour of the lint was also negatively correlated with bundle strength in the parents. In the hybrids, a negative correlation between colour and bundle strength and colour and 2.5% span length (Table 10) was noticed. Earlier reports showing a pronounced effect of lint colour on fibre fineness and fibre length (Hutchinson, 1946).

The reports on negative relationship between colour and fibre quality (Kottur, 1923; Silow, 1944 and Harland, 1935), incomplete dominance of colour genes (Hayes and Garber, 1927; Ware, 1932; Harland, 1939 and Christidis and Harrison, 1955) and modifier influence (Ramanathan and Balasubramanyan, 1933; Silow, 1941; Silow, 1944, 1944a and Harland, 1935) are not in support of developing high

yielding and quality cotton varieties with high lint colour intensity. However it would be possible to achieve the combination, provided special breeding procedures like intermating and reciprocal recurrent selection to break the linkage, are followed.

The line  $C_8$  and the tester  $T_1$  were positive general combiners for 2.5% span length which was predominantly under the additive genes. The results of Duhoon et al. (1983), Mohinder Singh et al. (1987), Green and Culp (1990) and Nadarajan and Sree Rangasamy (1990) support the above finding. Vadne and Thombre (1982) reported that 2.5% span length was under the control of non additive gene action.

Lines  $C_1$  and  $C_2$  and tester  $T_2$  were general combiners for uniformity ratio.  $C_{10}$  and  $T_2$  had gca effect in the positive direction for fibre fineness and  $C_7$ ,  $C_{10}$  and  $T_2$  were general combiners for maturity coefficient. While the uniformity ratio and maturity coefficient are under the control of additive genetic system, the importance of additive and dominance genes was evident for fibre fineness. All the above parents can be exploited for crossing with general combining parents for yield, ginning outturn and lint colour and selection in the progeny will improve the

Table 48. Comparative evaluation of parents for important yield components

Parents	No. of Bolls/plant		Boll weight		Lint index		Seed cotton yield	
	Mean	gca	Mean	gca	Mean	gca	Mean	gca
Lines								
C <sub>1</sub>	3.60	N	1.23	N	2.67	N	4.31	N
C <sub>2</sub>	9.53	N	2.01	P	2.90	-	18.57	N
C <sub>3</sub>	11.27	P	1.71	N	3.80	-	18.86	P
C <sub>4</sub>	11.47	P	1.77	N	4.17	-	19.83	P
C <sub>5</sub>	6.67	-	1.62	P	4.87	N	10.88	P
C <sub>6</sub>	10.67	N	1.70	P	4.40	P	17.71	P
C <sub>7</sub>	10.40	-	1.70	P	4.17	P	17.16	P
C <sub>8</sub>	14.53	P	2.21	-	4.20	P	32.01	P
C <sub>9</sub>	7.47	N	1.37	P	3.80	-	10.10	N
C <sub>10</sub>	8.00	N	1.63	N	5.37	-	13.07	N
Testers								
T <sub>1</sub>	16.67	N	4.26	P	5.63	P	70.41	-
T <sub>2</sub>	13.13	N	4.04	N	5.27	N	52.15	N
T <sub>3</sub>	19.40	P	4.50	P	5.43	N	86.73	P
T <sub>4</sub>	13.73	N	4.36	N	5.13	P	58.62	N
T <sub>5</sub>	21.80	P	3.00	N	5.33	-	65.11	P
GM+CD	10.74		1.79		4.16		19.11	
P - Positive value		N	Negative value					
								- - No significant expression

Table 49. Comparative evaluation of hybrids for important yield components

Hybrids	No. of bolls per plant			Boll weight			Lint index			Seed cotton yield		
	Mean	Sca	Heterosis	Mean	Sca	Heterosis	Mean	Sca	Heterosis	Mean	Sca	Heterosis
C <sub>1</sub> x T <sub>1</sub>	10.47	-	-	1.84	-	N	2.03	N	N	18.47	-	N
C <sub>1</sub> x T <sub>2</sub>	6.27	N	N	1.70	-	N	2.00	N	N	11.19	-	N
C <sub>1</sub> x T <sub>3</sub>	13.67	P	P	1.96	-	N	2.67	P	N	26.55	-	N
C <sub>1</sub> x T <sub>4</sub>	11.20	P	P	1.75	-	N	3.40	P	N	19.47	P	N
C <sub>1</sub> x T <sub>5</sub>	12.73	N	-	1.60	-	N	2.53	-	N	20.19	N	N
C <sub>2</sub> x T <sub>1</sub>	12.27	-	-	2.38	-	N	2.97	-	N	28.76	-	N
C <sub>2</sub> x T <sub>2</sub>	12.13	P	-	2.26	-	N	2.60	-	N	27.27	P	N
C <sub>2</sub> x T <sub>3</sub>	14.47	-	-	2.47	-	N	2.40	-	N	35.39	-	N
C <sub>2</sub> x T <sub>4</sub>	10.80	N	-	2.37	P	N	2.50	-	N	25.43	-	N
C <sub>2</sub> x T <sub>5</sub>	14.27	N	N	2.10	-	N	3.00	P	N	29.75	N	N
C <sub>3</sub> x T <sub>1</sub>	16.07	-	P	2.20	-	N	2.83	-	N	35.13	-	N
C <sub>3</sub> x T <sub>2</sub>	14.47	-	P	2.10	-	N	2.33	-	N	30.21	P	N
C <sub>3</sub> x T <sub>3</sub>	16.47	N	P	2.30	-	N	2.37	-	N	37.27	N	N
C <sub>3</sub> x T <sub>4</sub>	16.27	-	P	2.14	-	N	2.60	-	N	34.73	-	N
C <sub>3</sub> x T <sub>5</sub>	20.47	-	P	2.00	-	N	2.87	P	N	40.20	-	-
C <sub>4</sub> x T <sub>1</sub>	16.67	N	P	2.27	-	N	2.80	-	N	37.79	N	N
C <sub>4</sub> x T <sub>2</sub>	15.93	-	P	2.10	-	N	3.23	P	N	32.71	-	N

(Contd..)

Table 49. (Contd.)

Hybrids	No. of bolls per plant			Boll weight			Lint index			Seed cotton yield		
	Mean	Sca	Heterosis	Mean	Sca	Heterosis	Mean	Sca	Heterosis	Mean	Sca	Heterosis
C <sub>4</sub> x T <sub>3</sub>	20.60	P	P	2.40	-	N	2.10	N	N	49.11	P	N
C <sub>4</sub> x T <sub>4</sub>	15.53	N	P	2.25	P	N	2.80	-	N	34.78	N	N
C <sub>4</sub> x T <sub>5</sub>	22.07	-	P	2.10	-	N	2.50	-	N	45.24	-	P
C <sub>5</sub> x T <sub>1</sub>	12.60	N	-	2.33	N	N	2.83	P	N	29.05	N	N
C <sub>5</sub> x T <sub>2</sub>	9.47	N	-	2.24	N	N	2.40	-	N	20.99	N	N
C <sub>5</sub> x T <sub>3</sub>	13.80	N	-	2.40	N	N	2.47	-	N	32.57	N	N
C <sub>5</sub> x T <sub>4</sub>	17.07	P	P	2.82	P	-	2.43	-	N	46.67	P	P
C <sub>5</sub> x T <sub>5</sub>	21.60	P	P	2.20	-	-	2.10	N	N	46.27	P	P
C <sub>6</sub> x T <sub>1</sub>	13.93	-	-	2.68	-	N	2.87	-	N	36.30	-	N
C <sub>6</sub> x T <sub>2</sub>	10.07	-	N	2.56	P	N	2.60	-	N	25.59	N	N
C <sub>6</sub> x T <sub>3</sub>	15.73	-	-	2.80	-	-	2.60	-	N	46.70	-	N
C <sub>6</sub> x T <sub>4</sub>	12.27	-	-	2.42	N	N	2.87	-	N	29.47	N	N
C <sub>6</sub> x T <sub>5</sub>	17.60	-	P	2.40	-	-	3.10	P	N	40.79	P	-
C <sub>7</sub> x T <sub>1</sub>	15.80	P	P	2.30	-	N	3.00	-	N	36.07	P	N
C <sub>7</sub> x T <sub>2</sub>	11.87	-	-	2.19	-	N	3.03	P	N	25.69	-	N
C <sub>7</sub> x T <sub>3</sub>	16.33	-	P	2.76	P	N	2.10	N	N	44.64	P	N
C <sub>7</sub> x T <sub>4</sub>	13.73	-	P	2.13	N	N	3.00	-	N	29.17	N	N

(Contd..)

Table 49. (Contd.)

Hybrids	No. of bolls per plant			Boll weight			Lint index			Seed cotton yield		
	Mean	Sca	Heterosis	Mean	Sca	Heterosis	Mean	Sca	Heterosis	Mean	Sca	Heterosis
C <sub>7</sub> x T <sub>5</sub>	16.33	N	-	2.00	N	N	3.03	-	N	32.68	N	N
C <sub>8</sub> x T <sub>1</sub>	17.40	-	P	2.28	-	N	2.80	-	N	39.63	-	N
C <sub>8</sub> x T <sub>2</sub>	14.73	-	-	2.23	P	N	2.50	-	N	32.69	-	N
C <sub>8</sub> x T <sub>3</sub>	19.00	-	P	2.30	N	N	2.93	P	N	43.51	-	N
C <sub>8</sub> x T <sub>4</sub>	16.07	-	P	2.22	-	N	3.23	P	N	35.43	-	N
C <sub>8</sub> x T <sub>5</sub>	20.27	-	P	2.10	-	N	2.60	N	N	41.78	-	N
C <sub>9</sub> x T <sub>1</sub>	12.60	-	-	2.56	P	-	2.90	-	N	31.95	P	N
C <sub>9</sub> x T <sub>2</sub>	9.33	-	-	2.21	N	N	2.10	N	N	20.42	-	N
C <sub>9</sub> x T <sub>3</sub>	13.67	-	-	2.60	P	N	2.57	-	N	34.81	-	N
C <sub>9</sub> x T <sub>4</sub>	13.07	P	P	2.04	N	N	2.77	-	N	26.35	-	N
C <sub>9</sub> x T <sub>5</sub>	14.67	N	-	2.30	P	-	2.80	-	N	33.27	-	N
C <sub>10</sub> x T <sub>1</sub>	13.47	-	P	2.35	P	N	2.80	-	N	31.37	-	N
C <sub>10</sub> x T <sub>2</sub>	12.07	P	P	2.12	-	N	2.80	-	N	25.43	P	N
C <sub>10</sub> x T <sub>3</sub>	15.80	-	P	2.52	P	N	2.77	-	N	39.25	P	N
C <sub>10</sub> x T <sub>4</sub>	11.20	N	-	2.09	N	N	2.87	-	N	23.18	N	N
C <sub>10</sub> x T <sub>5</sub>	16.40	-	P	2.00	-	N	2.60	-	N	32.54	-	N
GM + CD <sub>11</sub>	16.15	-	-	2.32	-	-	3.03	-	-	35.26	-	-

P - Positive value      N - Negative value      - - No significant expression

yield level and fibre quality of coloured linted cotton genotypes.

A comparative evaluation of the parents and also the hybrids was made considering the superiority in terms of *per se* performance and *gca* in the case of parents and *per se* performance, *sca* and heterosis in the hybrids (Table 48 and 49)

The comparison revealed that two coloured linted genotypes  $C_4$  and  $C_8$  and the tester  $T_3$  exhibited superiority for any two of the characters considered in addition to the seed cotton yield. These genotypes can be exploited for further breeding work either through heterosis breeding or pedigree breeding.

Similarly, among the hybrids,  $C_5 \times T_4$  was the best exhibiting high mean performance and positive *sca* for two of the three yield components, and heterosis for one character besides satisfying all the three criteria for seed cotton yield.

## Summary

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## SUMMARY

Experiments were conducted in cotton (*G.hirsutum*) to assess the genetic make up of a group of genotypes including ten coloured linted varieties and five standard varieties possessing white lint. The gcv, pcv, heritability in broad sense and genetic advance were estimated in the parental and hybrid genotypes. Besides, the genetic divergence in the parents was also evaluated. Two separate analyses were made to get information on association and path relationship for the parental and the hybrid group of genotypes.

Fifty hybrids, involving coloured linted varieties as females and the standard varieties as males were synthesised in a line X tester design and subjected to combining ability analysis. Heterosis as per cent deviation from mid parent, better parent and standard parent was computed.

Sixteen characters, days to first boll bursting, days to maturity, plant height, number of sympodia per plant, number of bolls per plant, boll weight, seed cotton yield, ginning outturn, lint index, seed index, colour of the lint, 2.5 % span length, uniformity ratio, fibre

fineness, maturity coefficient and bundle strength were considered.

The variances for all the sixteen characters were significant for both parents and hybrids. The phenotypic coefficient of variability equalling the genotypic coefficient of variability for all the characters indicated the negligible role of environment.

The hybrids in general had a lower magnitude of heritability and genetic advance than the parental population. A combination of high heritability and high genetic advance was encountered in seed cotton yield and plant height in both parents and hybrids indicating greater reliance on these characters for selection.

Substantial yield progress can be achieved by resorting to simple selection programmes in the variable population developed from the hybrids as the hybrids exhibited high heritability together with genetic advance for seed cotton yield.

Boll weight, plant height, number of bolls per plant and days to maturity had maximum positive influences on seed cotton yield in parents. In hybrids, Number of bolls per plant and lint index were the most important

characters which influenced the yield directly or indirectly.

All the characters except days to first boll bursting and seed index had significant and positive correlation with seed cotton yield at the genotypic and phenotypic level in parents. In hybrids, plant height, number of sympodia per plant, number of bolls per plant and boll weight had positive association with seed cotton yield at both the levels.

In parents, colour of the lint had a positive correlation with fibre fineness and ginning outturn at the genotypic level while it was negatively correlated with bundle strength both at genotypic and phenotypic level. The colour of lint had negative relationship with 2.5 % span length and bundle strength in the hybrids, the genotypic and phenotypic correlation coefficients being negative.

The  $D^2$  analysis in parents indicated that ginning outturn contributed maximum to genetic divergence followed by seed index. The wide genetic diversity was brought out from the  $D^2$  analysis in which, the genotypes came under five clusters. The coloured linted cotton varieties occupied two separate clusters as against the adapted standard varieties falling in three different clusters according to the situations for which they were bred. There was no

relationship between the geographical origin of the genotypes and genetic divergence.

The GCA variances were greater than SCA variances for days to first boll bursting, days to maturity, plant height, number of bolls per plant, boll weight, seed cotton yield, ginning outturn, 2.5 % span length, uniformity ratio, fibre fineness, maturity coefficient and bundle strength indicating that these characters were governed predominantly by additive gene action.

The number of sympodia per plant, lint index, seed index and colour of the lint were predominantly under the control of non additive genes as seen from greater proportion of SCA variances than GCA variances.

The expression of heterosis was negative in most of the hybrids. Nevertheless, the hybrids exhibiting mid parental heterosis for seed cotton yield and the heterotic hybrids C5 X T4 and C5 X T5 for number of bolls are useful for further breeding work.

That there was no parallelism between the **gca** of parents and **sca** of hybrids, the heterotic expression and **per se** performances and heterosis and **sca** effect in the hybrids indicative of epistatic gene action, suggests the adoption

of recurrent selection procedures for developing coloured linted, high yielding cultivars.

Among the two lint colour types, the green linted varieties were poor yielders and brown types particularly, C8 and C4 were fairly good in their yield potential.

The yield level in the hybrids involving brown linted cotton lines was also considerably higher than the combinations with green linted genotypes. Thus, the exploitation of brown types offers better scope to develop varieties combining yield and lint colour.

The two coloured linted genotypes C4 and C8 and the tester T3 exhibited superiority in respect of *gca* and *per se* performance and these are worthy of further exploitation in the breeding work.

Among the hybrids C5 X T4 was the best exhibiting high mean performance and positive *sca* for two of the three important yield components, and heterosis for one character besides satisfying all the three criteria for seed cotton yield.

Thus, the study has brought out the possibility of developing brown linted cultivars coupled with high yield potential and moderate fibre qualities by resorting to recurrent selection procedures using boll number as the selection index.

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