CHARACTERIZATION OF COTTON (*Gossypium* spp) GENOTYPES AND EVALUATION OF THEIR HETEROTIC POTENTIAL

Thesis submitted in part fulfilment of the requirements for the award of degree of

Master of Science (Agriculture) in Plant Breeding and Genetics

to the Tamil Nadu Agricultural University,

Coimbatore

By

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CERTIFICATE

This is to certify that the thesis entitled **"CHARACTERIZATION OF COTTON (*Gossypium* spp) GENOTYPES AND EVALUATION OF THEIR HETEROTIC POTENTIAL"** 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 is a record of bonafide research work carried out by **Mr.R.MANIMARAN** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree / diploma / fellowship / other similar titles / prizes and that the work has not been published in part / full in any scientific / popular journal / magazine.

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R. Manimaran

(R.MANIMARAN)

Abstract

ABSTRACT

CHARACTERIZATION OF COTTON (*Gossypium* spp) GENOTYPES AND EVALUATION OF THEIR HETEROTIC POTENTIAL

BY

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Genetic diversity analysis was carried out using 29 cotton genotypes comprising 19 *Gossypium hirsutum* and 10 *Gossypium barbadense*. Simultaneously, 49 intra-*hirsutum* and 21 inter-specific hybrids involving the above parents were evaluated for their mean performance and heterotic expression. Seventeen characters including seven yield and yield determinants, four economic characters and five quality characters were used as parameters for the evaluation. Besides, study of biochemical characters like total soluble protein, seed oil content and isozyme pattern was also carried out for the parents.

A combination of high heritability with high genetic advance was noticed for seed cotton yield. Existence of sufficient genetic diversity among the parental genotypes was noticed as seen from the six divergent clusters accommodating these genotypes. Among the different yield and quality characters studied, boll weight, seed oil content, 2.5 per cent span length, fibre fineness and bundle strength accounted for nearly 99 per cent of the total divergence. The interspecific hybrids were superior to intra-*hirsutum* hybrids for fibre while the latter were superior in yield and yield components, quality characters. The hybrids involving highly diverse parents were superior for quality characters whereas maximum heterosis for both yield and quality characters occurred at optimal or intermediate level of genetic diversity. Eventhough the genotypes could be grouped into six different clusters based on morphological characters, polymorphism could not be detected for the isozymes peroxidase and superoxide dismutase. The hybrids MCU 9 x TCH 1223, MCU.11 x TCH 1218, LRA 5166 x TCH 1223, LRA 5166 x TCH 1233, LRA 5166 x TCH 1452, MCU.5 x EC 97631, TCH 976 x Suvin and TCH 976 x Bhaksh 5230 were the best for yield as well as quality traits and proved worthy of future exploitation.

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ABBREVIATIONS

CPBG	-	Centre for Plant Breeding and Genetics
CIRCOT	-	Central Institute for Research on Cotton Technology
CICR	-	Central Institute for Cotton Research
TNAU	-	Tamil Nadu Agricultural University

Introduction

CHAPTER - I

INTRODUCTION

Cotton, often called as "White Gold" has been in cultivation in India for more than five thousand years. There has been no decline in the importance of cotton over years. Even though the synthetic fibres had a great impact in recent years, cotton still occupies a prime position in the textile industry. Besides it also earns a foreign exchange of worth $10 billion to India (Kairon, 1997).

Cotton production in India has made great strides during the last two decades and it reached the high of 160 lakh bales during 1996-97 (Kairon, 1997). The total lint output has increased six times as compared to 1947-48 which not only has helped our country to become quantitatively self sufficient for internal consumption but also to leave a comfortable surplus for export (Basu, 1994). This is primarily due to the evaluation of high yielding varieties and hybrids as well as standardisation of proper insect and disease management strategies (Sekhsaria, 1996).

With the growing demand of cotton for international consumption and export, the production for 2000 AD has been projected at 20 million bales. Hence, there is an immense need to formulate the breeding approaches for the improvement of quantity and quality of cotton as well as their pest and disease resistance capacity.

Plant breeding is a continuous process and the breeders are constantly engaged in the selection of genotypes, synthesising crosses and studying them for heterotic expression. This necessitates continuous generation and evaluation of newer genotypes for their genetic potential. Although substantial work has been done in the study of genetic diversity of cotton based on morphological characters and to a limited extent on biochemical traits, the information obtained from each study is restricted to that particular set of genetic material and to that environment in which such evaluation was made. Keeping this in mind, the present investigation was taken up with the following objectives :

* To assess the variability present in the group of genotypes selected from the cultivated species *Gossypium hirsutum* and *Gossypium barbadense.*
* To group the genotypes / strains based on certain important morphological characters, isozyme patterns and protein content.
* To assess the characters that contribute largely to genetic diversity.
* To evaluate the heterosis in hybrids originated from parents belonging to different diversity levels for commercial exploitation.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

The literature on various aspects of cotton breeding is reviewed in this chapter as it is indispensable to have a comprehensive knowledge on genetic diversity (based on morphological and biochemical characters), heterosis, correlation and path co-efficient studies.

2.1 Genetic diversity

The variability among different genotypes of a species is known as genetic diversity. Genetic diversity arises either due to geographical separation or due to genetic barriers to crossability. Genetic diversity plays an important role in plant breeding because hybrids between lines of diverse origin are generally expected to display a greater degree of heterosis than those between closely related strains.

Duvick (1984) carried out a survey, which indicated that the genetic base of the elite germplasm gene pool is wider and provides more useful diversity than is supposed. The national germplasm repositories are also regarded as indispensable sources of needed diversity.

Ekbote and Khorgade (1984) studied 33 genotypes and the data on boll weight and sympodia, bolls and seed cotton yield per plant revealed highly

significant differences among genotypes for all the characters, indicating considerable genetic variability. Geographical origin had little effect on the clustering pattern, indicating its limited influence on their genetic diversity in this study.

Singh and Gill (1984) studied yield and seven related characters in 62 genotypes of *Gossypium hirsutum* grown in four environments, differing in fertilizer conditions and plant density and reported that genetic diversity was not related to geographical diversity of the genotypes.

A large number of germplasm collections of *G. hirsutum* L. were analysed for their genetic diversity in which 11 distinct groups were identified and each of them included members showing wide variability for a constellation of characters. The study also indicated that correspondence between geographic origin and genetic diversity was not universal though in a large number of cases this was found true. The information gathered from the study and classification of chosen genetic stocks into distinctly divergent groups can be of practical use in choice of suitable parents for hybridization programmes (Singh and Singh, 1984).

Pattern of genetic divergence was assessed by Dani (1985) in 22 cultivars of *G. hirsutum*, on the basis of 20 characters related to seed oil and lint yield. Cultivars of similar geographical origin were found distributed in different clusters. The proportional contribution of earliness percentage and days to first

flower appearance was more to the divergence than seed size and seed oil percentage.

Amalraj and Gawande (1986) studied the manifestation of heterosis in relation to the magnitude of the genetic diversity of parental pairs in 70 interspecific hybrids involving crosses between *Gossypium hirsutum* L. and *Gossypium barbadense*. High heterosis over mid-parent value was noticed for seed cotton yield and bolls per plant. Halo length showed maximum range of diversity. Parental pairs of high overall genetic diversity did not show high heterotic effects.

Genetic divergence of cotton cultivars in relation to N concentration and seed cotton yield was studied by Mali *et al.* (1987). A positive correlation between fertilizer treatment and cultivar interaction was observed.

The genetic divergence in 11 *Gossypium hirsutum* parents belonging to different geographical origin was assessed by Cheng and Liu (1988). The 11 parents were grouped into six clusters, including two, with only a single variety each. The maximum inter cluster distance was observed between cluster two and five, with a minimum distance between cluster two and three. Genetic divergence was clearly exhibited in terms of cluster means for lint yield and its components, and fibre quality.

Cluster analysis and principal component analysis performed using 15 quantitative characters and 53 genotypes indicated that, there was no direct correlation between geographical distribution and intergenotypic distance. Pedigree analysis suggested that the genetic divergence of genotypes was accurately revealed by intergenotypic distance (Peng and Guo, 1988).

In determining the genetic distance and mid-parental heterosis for yield in 56 F_1s of *Gossypium hirsutum* parents, Wang and Pan (1990) found a significant parabolic regression relationship between D^2 values and heterosis. Within a restricted range, increased genetic distance was associated with increased heterosis. The parents were grouped into five clusters and a larger degree of heterosis was obtained in crosses between clusters compared with intra cluster crosses.

Data from 10 yield and fibre quality characters of 40 *Gossypium hirsutum* varieties obtained over three successive years were used to ascertain the usefulness of correspondence analysis. Results showed the relationship among characters and among varieties, and between characters and varieties. The geographical origin of the material did not have a direct effect on the relationships between factors. Hence, Cheng and Zhao (1992) suggested that inter and intra-cluster divergence and the performance of the parents should be considered while selecting parent materials.

A set of 538 accessions representing the full spectrum of morphological and geographical diversity of the species *G. hirsutum* was analysed for allozyme variation at 50 loci to assess levels and patterns of genetic variation in the species and to elucidate the origin of upland cotton. The levels of variation are generally moderate but low in upland cotton. In contrast to expectations, two centres of diversity were evident, one in Southern Mexico - Guatemala and the other in Caribbean. The germplasm of present cultivars traces to Mexican highland stocks, which, inturn was derived from the material originally received from Southern Mexico and Guatemala (Wendel *et al.*,1992).

Dejoode and Wendel (1992) studied the genetic diversity and origin of the *Gossypium tomentosum* which revealed two species pairs, *G. barbadense* - *G.darwinii* as sisters and *G. hirsutum* - *G.tomentosum* as sisters.

Genetic diversity in a population of 40 genotypes of cotton (*Gossypium hirsutum* L.) assessed by Rajarathinam and Nadarajan (1993) indicated considerable diversity in the material studied. The genotypes were grouped into eight different clusters. The proportional contribution of seed cotton yield, 2.5 per cent span length and boll weight was more towards genetic divergence.

While assessing the genetic divergence among 51 genotypes of upland cotton (*Gossypium hirsutum* L.) in 10 characters, all the genotypes were grouped into 12 clusters. This was reported by Sumathi and Nadarajan (1994) representing wide genetic and geographic diversities. The analysis further

revealed the absence of parallelism between genetic divergence and geographic diversity of the genotypes. The existence of ample genetic diversity among the genotypes was adequate for improvement by hybridization and selection for several combinations of characters.

Rajarathinam *et al* (1994) evaluated 40 genotypes for five yield related traits. The variance analysis revealed significant differences for all the five characters studied. In the six clusters grouped, highest intercluster divergence was observed between genotypes in cluster III and IV (23.3) and the lowest between those clusters in V and VI to 13.6 in cluster IV. Boll weight (41.3 per cent), number of bolls per plant (34.6 per cent) and 2.5 per cent span length (12.3 per cent) contributed more to the total divergence. Hybridization between genotypes from clusters III and V is recommended for maximum hybrid vigour.

Allozyme analysis was used by Wendel *et al.*(1994) to assess levels and patterns of genetic diversity in *G.mustelinum.* They observed genetic variation and panmictic heterozygosity relative to other tetraploid cotton species. Inter-populational genetic identities were uniformly high. Despite several centuries of sympatric cultivation of *G. barbadense* and *G. hirsutum,* there was little evidence of interspecific introgression of alleles from cultivated cottons into *G.mustelinum.*

Stanton *et al. (*1994) evaluated 400 accessions of *Gossypium arboreum* and *G.herbaceum* for 53 morphological characters using multivariate techniques to evaluate the morphological parameters contributing to the variation in each

species. Means for 41 of the 53 characters were significantly different between species, although infraspecific variability resulted in range overlap for all characters.

Five yield components of 43 genotypes (exotic and indigenous) of *Gossypium hiusutum* were recorded and analysed for genetic diversity. Six clusters were obtained indicating prevalence of genetic diversity. Geographical origin did not appear to be the sole character causing wide genetic diversity. The maximum contribution to the total genetic divergence was by mean fibre length followed by seed cotton per plant (Sambamurthy *et al.*, 1995a).

The diversity among 126 upland cotton *(Gossypium hirsutum)* cultivars released between 1980 and 1990 was assessed by May *et al.* (1995) based on mean coefficient of percentage. The mean coefficient of percentage among the 126 cultivars was 0.07, implying selection of genetically diverse group. Cluster analysis revealed 12 distinct gene pools with larger mean within-cluster coefficient percentage of 0.25 as compared to mean between-cluster coefficient percentage of 0.04.

The apparent association between genetic divergence and geographic origin was evident in the study of divergence of seven cotton cultivars by Carvalho *et al.* (1995). Selection for disease resistance against ramulose (causal agent *Colletotrichum gossypii* var. *cephalosporioides)* was an important factor in

the divergence and the most divergent traits were plant height, fibre percentage and earliness.

Pattern of genetic divergence was assessed in 50 cultivated *G. hirsutum* cultivars. The study disclosed considerable genetic diversity for the eight traits studied. Cultivars of similar geographical origin were distributed among different clusters. Number of bolls per plant followed by ginning percentage contributed most of the total divergence indicating their importance in any cotton improvement programme. The clustering pattern clearly indicated that the geographical distribution in cotton was not related to genetic diversity (Sambamurthy *et al.*, 1995b).

Fifteen cotton *(G. hirsutum)* genotypes along with their 105 F_1 hybrids were evaluated for seven yield related traits. The existence of ample genetic diversity among the genotypes, as revealed by the inter cluster distances, obtained through D^2 analysis was revealed by the study and this diversity is adequate for improvement by hybridization and selection for different combinations of characters (Kalsy *et al.*, 1995).

Genetic diversity of 16 near - homozygous elite cotton genotypes derived from interspecific hybridization was investigated at the DNA level using the RAPD procedure and at the phenotypic level using stable and highly heritable morphological characters. Both procedures produced two clusters with one resembling *G. hirsutum* and the other *G. barbadense*. Classification of all

genotypes based on the two methods gave similar results with a correlation of 0.63 between the genetic distance and taxanomic distance and the level of polymorphism exhibited by these genotypes could be exploited in genetic mapping populations to tag economically important traits, such as fibre quality (Tatineni *et al.*, 1996)

In the study of average coefficient of percentage for 260 upland cotton (*G. hirsutum*) cultivars released between 1970 and 1990 and of various ancestral lines to the genetic diversity, coefficients of percentage among 260 cultivars showed an average value of 0.07 which suggests substantial genetic diversity. The genetic contribution of 54 ancestral lines, including nine introductions, accounted for less than 25 per cent of the total genetic variation among the 260 cultivars. This low value is thought to result from the loss of genetic information through the process of reselection and the genetic base in modern cotton cultivars is not particularly narrow (Bowman *et al.*, 1996).

Variability and genetic analysis of ten coloured linted cotton genotypes by Amudha *et al.*, (1997) showed wide differences between coloured lint genotypes and white lint varieties. High heritability together with genetic advance for seed cotton yield suggested pedigree breeding for effectively enhancing yield potential of coloured lint varieties.

Genetic diversity in seven yield and quality characteristics in *G.arboreum* was evaluated by Sandhu and Boparai (1997) . The genotypes were grouped

into 12 clusters, suggesting a wide range of genetic diversity. No definite relationship between geographic and genetic diversity was observed. In general, genetic diversity among parents was reflected in their progenies.

Coefficient of parentage (γ_p) and field uniformity (γ_f ; γ_p) were worked out for cultivars while studying the trends in genetic diversity of upland cotton in USA. Regional γ_p values were relatively stable at 0.12 to 0.15 from 1970 to 1990 and then sharply increased to 0.20 in 1995. Field uniformity (γ_f) remained at about (0.30) for all the regions during the past 25 years because increases in γ_p were matched by an increase in the number of cultivars. The frequent use of several parents for the creation of new cultivars and the planting of only a small portion of the available cultivars have led to a high level of genetic uniformity (Esbroeck *et al.*, 1998)

2.2 Study of heterosis

2.2.1 Heterosis in intra - *hirsutum* hybrids

Heterosis refers to the superiority of F_1 hybrid for one or more characters over its parents. The term hybrid vigour is used as synonym for heterosis. Mell (1894) first observed increase of F_1 in fibre length and agronomic characters over both the parents in a cross between *G. hirsutum* and *G. barbadense* and Cook (1909) first suggested the possibility of commercial exploitation of heterosis in cotton.

Hawkins *et al.* (1965) studied the intra-*hirsutum* hybrids and reported on an average over three years, 19 per cent increase in lint yield over better parent. He also confirmed that genetic diversity to be important for expression of high heterosis.

Singh and Murthy (1971) reported more pronounced heterosis for number of sympodia, number of bolls and per plant yield in the hybrids developed between two locally adapted varieties and 15 genetically diverse strains.

Chinnadurai (1972 and 1973) noticed heterosis over mid parent as well as better parent for seed cotton yield, boll weight, ginning outturn and seed index in intra-*hirsutum* hybrids but none of the hybrids showed heterosis for halo length.

Gururaj Rao *et al.* (1977) studied intra-*hirsutum* hybrids involving parents of diverse origin and reported highest heterosis for fibre weight followed by seed index, lint index, ginning outturn, fibre length and fibre strength.

Kadambavanasundaram (1980) studied 64 intra-*hirsutum* hybrids and reported high heterosis for yield, boll number and other characters. He observed highest heterosis only in a particular cross combination of parents which had greater potency in the cross than expected from their *per se* performance.

The magnitude of heterosis in 45 F_1's was studied by Phundan Singh (1982) and reported that boll weight, lint index and seed index contributed

maximum to increased yield. Ginning outturn and halo length also contributed to yield but to a lesser extent.

Duhoon *et al.* (1983) studied nine genetically diverse strains of *G. hirsutum* and reported high heterosis for monopodial and sympodial branches, boll number and yield per plant and low heterosis for halo length.

The magnitude of heterobeltiosis for seed cotton was much higher as reported by Nadre *et al.* (1984) while that of boll number was lower. They also observed very low magnitude and negative heterosis for boll size, halo length and plant height.

Lather (1985) observed heterosis ranging from 3.25 to 29.97 per cent for boll weight, - 46.57 to 19.43 per cent for boll number, -22.48 to 22.34 per cent for plant height.

Patil and Chopde (1985) noticed significant and positive heterosis over mid-parent and better parent for seed cotton yield and number of bolls. Hybrid vigour for earliness indicated by negative heterosis for boll bursting was also encountered.

Heterosis for plant height, seed cotton yield, bolls per plant, boll weight, ginning outturn and staple length in intra specific hybrids of upland cotton was observed by Khan *et al.* (1986).

Heterosis for various fibre properties in *G. hirsutum* revealed heterosis for lint yield from -49.6 to 142.4 per cent, for 2.5 per cent span length from -9.0 to 119.2 per cent, for fibre fineness from -12.2 to 143.9 per cent and for maturity co-efficient from -9.4 to 105.7 per cent (Nadarajan, 1986).

Tiwari *et al.* (1987) reported heterobeltiosis for yield resulted from increased boll number per plant and the highest heterosis for yield over better parent was recorded as 219.5 per cent.

The percentage of F_1 heterosis for seed cotton yield, halo length, lint index and seed index ranged from -22.63 to 50.99, -8.40 to 3.19, -16.87 to 14.41 and -10.29 to 11.19 respectively in the studies of Gupta and Singh, (1987 a).

In a different study, the same authors reported heterosis (Gupta and Singh, 1987 b) for seed cotton yield, halo length, lint index and seed index. They reported heterosis for seed cotton yield to be more pronounced than that for the other three characters studied.

Heterosis for three major fibre properties namely fibre length, micronaire value and maturity co-efficient was studied by Patil *et al.* (1988). The study revealed that for achieving desirable heterosis, not only the genetic divergence between parents is a prerequisite, but also the performance and/or the cluster mean of the parents need to be considered.

Nagarajan (1989) studied heterosis for seed characters in *G. hirsutum* and noticed very low heterosis for all seed characters while the seed cotton yield showed a heterosis of -15.7 to 80.8 per cent.

Kalsy and Garg (1989) observed hybrid vigour for seed cotton yield which ranged from 6.0 to 92.9 per cent over better parents. The highest heterotic effects of 92.8 per cent over the better parent was recorded by the hybrid A 218 x Grace Wichla. They also reported that heterotic effects were not marked in characters like halo length and ginning outturn as in other characters like yield per plant and bolls per plant.

Positive heterosis was recorded for number of fruiting points, number of bolls per plant and seed index over both mid-parental and better parental values. Heterosis over the mid-parental value of 113.6 per cent for number of fruiting points, 146.5 per cent for number of bolls per plant and 111.0 per cent for seed cotton yield over the better parent values of 69.3, 99.6 and 104.3 per cent respectively (Rathinavelu and Premsekar, 1990).

In a study on the expression of F_1 was intermediate between the parental values in hybrids resulting from crossing American cultivars with wild forms. Heterosis was observed in some crosses only (Munasov *et al.*, 1989) .

The study on fibre properties of four *Gossypium hirsutum* parents and 12 F_1's revealed high environmental influence for fibre strength and standard

fineness. Variability was absent when environmental influence was minimal. Variability in the hybrids appeared to be a function of the variability of the parents, especially for fibre fineness (Dever *et al.*, 1990).

Yield and fibre quality potentials evaluated in F_1 showed significantly short fibres than parents and no differences in adaptive ability between parents and F_1's were detected (Meredith, 1990).

Duhoon (1990) observed high heterobeltiosis for seed cotton yield and boll number per plant while it was low for halo length and ginning percentage. High heterotic combinations for seed cotton yield were also heterotic for boll number and boll weight. Heterobeltiosis exceeded 100 per cent over the commercial check CV H.777, in two hybrids namely HS.45 x SH 481 and H.777 x 8S.383.

Koodalingam *et al.* (1991) estimated heterosis for seven yield components in the F_1 of crosses between 10 *G. hirsutum* genotypes and three cultivars from Tamil Nadu. Heterosis for seed cotton yield and its components was observed in CU 112 X MCU 6 and CU 112 X P 216 F.

Patil *et al.* (1991), studying a half diallel cross of nine genetically diverse parents of *G. hirsutum* observed heterosis of 102.3 per cent for boll number, 51.6 per cent for boll weight and 139.3 and 169.4 per cent for seed cotton and lint

yield respectively. They noticed boll number to be the major component of yield heterosis.

Wang and Pan (1991) used the North Carolina II mating design to calculate the yield and quality components in 56 populations of *G. hirsutum* and observed heterosis for lint yield, boll weight and fibre length. Lint yield, lint percentage and 2.5 per cent span length showed high heritability.

Two intra-*hirsutum* hybrids were found to be high yielding combined with high heterosis for seed cotton yield in the study of Krishnadoss (1991). Lint index, number of bolls per plant and boll weight contributed to seed cotton yield significantly in the above studies.

All the 18 intra-*hirsutum* hybrids tested by Katageri *et al.* (1992) showed significantly positive heterosis over the mid-parent for seed cotton yield and 14 showed it for boll number. None of the hybrids showed significant heterosis over the mid-parent for boll weight (Katageri *et al.*, 1992).

High lint yield with high fibre quality was recorded in the two F_1's involving *G. hirsutum* mid long staple lines 116 and 117; their respective lint yields were three and six per cent higher than that of cv. Zhong Mian 112 (Zhai *et al.*, 1992) .

Gururajan and Basu (1992) evaluated eight synthetic cultures of medium staple cotton in a diallel cross and reported only moderate heterosis for seed

cotton yield per plant, ginning per cent and 2.5 per cent span length. Only one hybrid BD X LRA exhibited considerable heterosis for commercial exploitation.

Sohu *et al.* (1993) determined heterosis over better parent for traits related to yield and earliness in hybrids from a complete set of crosses involving 10 parents. Of the ninety hybrids studied, six showed significant heterosis in a favourable or unfavourable direction for, respectively, number of days to the start of flowering, seed cotton yield and per day production.

Siddiqui (1993) in a study on twenty-one hybrids in intra-*hirsutum* cotton noticed the hybrid combination J 207 X G.Cot 10. showing significant heterotic effects for seed cotton yield, number of bolls per plant and mean halo length.

Heterotic effects under three irrigation regimes were studied by Jagmail Singh and Munshi Singh (1993) and reported that the hybrids showed high degree of heterosis for seed cotton yield in all regimes. Two hybrids showed 58.9 per cent and 72.4 per cent heterosis over the superior parents under rainfed conditions.

Patel *et al.* (1993) evaluated eight parents of *G. hirsutum* and their twenty-eight crosses and recorded that the relative ranking on the basis of *per se* performance and heterosis differed widely indicating the poor yielding ability of the parents.

Siddiqui and Patil (1994) in their study involving intra-*hirsutum* hybrids, reported -11.17 to 76.78 per cent heterosis for seed cotton yield per plant. Negative heterosis was observed for days to 50 per cent flowering which is considered as desirable character. None of the hybrids showed significant heterotic effects over the respective better parent.

Saeed Ahmed *et al.* (1994) evaluated twelve intra-*hirsutum* crosses. They observed heterotic response in the range of 1.1 to 26.1 per cent, 2.0 to 32.1 per cent, 0.9 to 3.6 per cent, 9.1 to 14.1 per cent and 0.6 to 2.3 per cent for seed index, lint index, ginning outturn, staple length, fibre fineness and fibre strength respectively.

In a thirteen diallel cross analysis involving diverse and elite genotypes of cotton Bhatade and Rajeswar (1994) observed low to high heterobeltiosis and useful heterosis for seed cotton yield while low to moderate heterobeltiosis and useful heterosis for number of bolls per plant, boll weight, seed index and plant height. None of the crosses exhibited heterosis over check variety, PH 93 for ginning outturn.

Eleven *Gossypium hirsutum* lines were crossed to produce 33 F_1 hybrids and observations were made by Das and Shunmugavalli, (1995) on five quantitative traits in each genotype. The magnitude and direction of heterosis depended on the cross and on the trait. Tashkent 3 X P 216 F was the best cross in terms of heterosis for seed cotton yield and other yield components.

Sixty F_1 hybrids involving six lines and ten testers were studied by Kowsalya and Raveendran, (1996) to investigate the expression of heterosis over mid parent, better parent and best parent (standard check) for 11 characters. Number of bolls per plant, ginning outturn, 2.5 per cent span length, fibre fineness and bundle strength showed significant values of heterosis. Meade 18 - 7.1 - 5 was one of the best testers which registered highest mid parental heterosis in various combinations.

Rajput *et al.* (1997) established top crosses between 17 different homozygous *desi* (*G. arboreum*) cotton cultivars and the stable GMS line GAK.423 A. Heterosis over mid parent, better parent and control AKA - 8401 was estimated for six yield components. A significant degree of heterosis was observed for bolls per plant and plant height, while days to first flowering, days to 50 per cent flowering and boll weight exhibited medium to low levels of heterosis. Boll number contributed much to seed cotton yield in this study.

In a study on heterosis carried out by Jain and Tiwari (1998), the highest heterosis for yield was found for cross 79 BH 5 -3 x WH 216 (73.1 and 37.12 per cent) followed by Reba B.50 x G.Cot 10 (66.49 and 14.84 per cent) and 79 BH - 5 -3 x Reba B 50 (53.37 and 37.23 per cent) over better parent and standard respectively.

2.2.2 Heterosis in interspecific hybrids

Interspecific crosses involving *G. hirsutum* x *G. barbadense* were found to produce very large, F_1 plants and recorded high heterosis for plant height in the study conducted by Stroman (1961).

Marani (1963) found that the heterosis for lint yield was (82 per cent) in interspecific hybrids of *G. hirsutum* x *G. barbadense.* He also observed heterosis for seed yield which was mainly due to significant increase in number of bolls produced. Heterosis for seed index was much larger than for lint index and they had very low lint percentage. He opined that high yielding hybrid cotton can be evolved using interspecific crosses.

Vaman Bhat (1965) studied the expression of hybrid vigour in *G. hirsutum* x *G. barbadense* hybrids and reported hybrid vigour for plant height, earliness in flower production, boll production, seed cotton yield, size of seeds and fibre length. Marani (1967) observed very high magnitude of heterosis for seed cotton yield and lint yield in interspecific hybrids of *G. hirsutum x G. barbadense.*

Javad Hussain (1972) reported 42.1 per cent heterosis for number of bolls, 40 per cent heterosis for boll weight and 42.1 per cent heterosis for seed

cotton yield in interspecific hybrids of *G. hirsutum x G. barbadense*. In *G. hirsutum x G. barbadense* hybrids, Krishnaswami and Kothandaraman (1977) reported high and positive heterosis for plant height, boll number and yield. Gomea and Redy (1978) noticed pronounced heterosis for yield in interspecific hybrids.

David and Appa Rao (1980) observed contrasting features in *G. hirsutum* and *G. barbadense* parents with regard to boll size, number of bolls and yield but recorded high heterosis for yield on interspecific hybrids.

Guibordeau and Hequet (1985) studied reciprocal hybrids between *G. barbadense* and *G. hirsutum* varieties and reported significant reciprocal effect only for ginning percentage. The F_1 hybrids had finer fibre, higher strength and high yarn resistance but lower fibre maturity compared to the parents. Khan and Rao (1985) found that in interspecific hybrids high yield and quality fibres could be combined.

Simongulyan and Chzhai Syutszyuan (1989) studied the prospects for developing short hybrids through interspecific hybridisation. Marked heterosis for seed cotton yield was obtained in the early ripening short hybrids involving short varieties of tetraploid cotton species and also between tall varieties of *G. barbadense* and dwarfs of *G. hirsutum*.

Egmderdiev (1991) developed short and early ripening cotton varieties involving *G. barbadense x G. hirsutum* crosses and found that most of the hybrids showed heterosis for yield.

Krishnadoss (1991) found that four interspecific hybrids BT.1 x HL.34, HL.34 x BT.2, BT.4 x HT.1 AND HL.11 x BT.3 possessed three to five times higher seed cotton yield combined with good characteristics over intra-*hirsutum* and intra-*barbadense* hybrids.

Katageri *et al.* (1992) studied heterosis for seed cotton yield and its component characters in thirty interspecific hybrid cottons. They reported 20.12 to 54.45 per cent heterosis for seed cotton yield in nine hybrids. Significant positive heterosis was reported for number of bolls, boll weight and number of sympodia in some hybrids.

Singh and Randhawa (1993) studied various economic traits and yield components in 78 interspecific hybrids and found that the hybrids showed good fibre quality traits.

Sundaramurthy and Gururajan (1993) in their study on interspecific hybrids, selected two hybrids DHB1 and CDHB2 which exhibited 27 per cent higher seed cotton yield over the standard hybrids HB.224, TCHB.213 and

DCH.32. High heterosis for seed cotton yield and quality traits in interspecific hybrids were observed by Valarmathi (1996).

Hybrids had longer fibres if *G. barbadense* was used as the female parent Tanfik and Stoilova (1998). Lint yield was higher if *G. hirsutum* was used as the female parent. Crosses with Egyptian *G. barbadense* cultivar Giza 75 had the longest fibre yields and longest fibres (Tanfik and Stoilova, 1998).

2.3 Correlation and path co-efficient studies

A knowledge on genetic correlation between different characters is very essential for a plant breeder to design appropriate selection indices for crop improvement. Inter relationship between different characters can be estimated through correlation and path coeffecient studies. Therefore, the literature pertaining to the association studies and on cause and effect relationship in intra-*hirsutum* hybrids have been reviewed hereunder.

Venkataraman and Santhanam (1962) noticed a positive correlation between number of bolls per plant and seed cotton yield. Lint index was positively correlated with ginning outturn while seed index was negatively correlated. Butany *et al.* (1966) observed positive correlation between boll number and seed index and negative correlation between boll number and ginning percentage. Path coefficient analysis by Butany *et al.* (1968) further revealed that number of sympodia and boll weight were the most important

components of yield, contributing both directly and indirectly through each other. A positive correlation between yield and plant height was encountered by Alves (1970).

School and Miller (1976) reported positive association between ginning percentage and yield. High positive association between boll number and yield of seed cotton and negative association between yield and halo length were highlighted by Kalsy *et al.* (1977). Narayanan (1978) observed a positive association between yield with seed index and fibre length.

Fifty varieties of *G. hirsutum* L. were subjected to path analysis by Singh *et al.* (1979) and they reported that boll number and boll weight had strong direct influence on the seed cotton yield. Lint index and fibre length were positively correlated in the studies of Kadambavanasundaram (1980).

Path analysis showed that bolls per plant contributed more towards the yield than ginning outturn (Dhanda, 1984). These results were also noticed by Al-Rawi *et al.* (1986).

Association studies by Gunaseelan and Krishnaswami (1987) disclosed positive correlation of plant height with boll number and yield. The yield components contributing directly to seed cotton yield were boll number, seed

index, lint index, height and boll weight as indicated in the studies of Tyagi *et al.* (1988).

Vireshwar Singh *et al.* (1990) observed significant positive correlation with number of bolls per plant and boll weight. Green and Culp (1990) reported that there were significant correlations of uniformity ratio and high volume instrumentation length with yarn strength. Correlations of 50 per cent span length and upper-half mean length with yarn strength were moderately high, yet not significant.

Path analysis in *G. hirsutum* cotton revealed that, the direct effect on ginning percentage was negative in diallel single cross mating while it was positive and maximum 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. (Jehangir and Krishnaswami, 1990).

Alam and Islam (1991) noticed that seed cotton yield had significant positive correlation with number of bolls per plant and boll weight.

Seed cotton yield was significantly correlated positively with bolls per plant (Kenchanagouder *et al.*, 1991). It did not show any sort of association with traits related to earliness. Correlations across the environments between seed cotton yield and seed index were noticed by Tomer and Singh (1992). Number of

bolls, ginning percentage and lint index were the indirect contributors for the seed cotton yield.

Strong and positive correlation between plant height, number of sympodia per plant and number of bolls per plant were encountered by Shanti and Selvaraj (1993). Singh (1993) noticed seed cotton yields showing non-significant correlation with growth and maturity characters in the parent population. According to Shanti and Selvaraj (1994) lint index was the main fibre quality character influencing seed cotton yield. In the improvement of seed cotton yield, emphasis should be given to high ginning outturn. (Sambamoorthy *et al.* (1994).

Sumathi and Nadarajan (1995) concluded that number of bolls per plant and plant height had positive correlation with seed cotton both at phenotypic and genotypic levels. Path co-efficient analysis indicated that plant height, bolls per plant, ginning outturn, lint index and seed index contributed directly to yield.

The studies on intra-*hirsutum* hybrids by Valarmathi (1996) showed that number of sympodia per plant, number of bolls per plant, boll weight and lint index had significant positive correlation with seed cotton yield. Negative correlation was observed between seed cotton yield and 2.5 per cent span length and bundle strength and between bundle strength and maturity co-efficient. Number of bolls per plant, number of sympodia per plant, boll weight and lint index exerted positive direct effect on seed cotton yield.

Information on yield correlations was derived from data on 13 yield related traits in 45 F_1 hybrids of cotton and their 10 parents by Murthy (1997) under protected and unprotected conditions with respect to bollworms. The results revealed that, number of bolls, sympodia and plant height showed significant and positive correlation with seed cotton yield in both the environments.

Hussain *et al.* (1998) evaluated twelve upland cotton (*Gossypium hirsutum*) genotypes for average boll weight, staple length, seed index, lint index and yield of seed cotton per plant and the results indicated that, ginning percentage and lint index were positively correlated with each other and staple length with seed cotton yield. Path coefficient analysis revealed that lint index had the largest positive direct effect on seed cotton yield followed by staple length. Lint index also contributed to the seed cotton yield via ginning percentage, staple length and seed index.

2.4 Biochemical studies

2.4.1 Isozymes

Activities of peroxidase isoenzymes of true leaves (at the flower bud stage) and anthers of interspecific advanced lines (ALs) from *Gossypium hirsutum* X *G.arboreum* which have been steadily progressed for 20 generations were studied by Wang Zhilong *et al.* (1995). The peroxidase isoenzymes were similar in different varieties of plants from the same species, but some differences were presented among species originated from the same genome

group, and large differences were observed among species originated from different genome groups.

Variation in superoxide dismutase (SOD) isoenzyme band patterns were studied in 47 accessions from 33 *Gossypium* species/races. There were no significant differences among the isoenzyme electrophoretic banding patterns from cultivars from the same species. Species with the same genome type had more bands in common than those with different genome. The greatest number of similar bands was found in the D genome and the fewest in the C genome. There were similarities in migration rates among the A,B and E genomes. The B genome was considered to be the most primitive group. In the C genome, *G.australe, G.nelsonii* and the unspecified accession A 111 were closely related, but *G.bickii* (G genomes) had a distinctive pattern. The unspecified accession A 120 had a characteristic *Gossypium* banding pattern (Zhou - Bao Liang *et al.*, 1995).

Wendel *et al.* (1989) studied 103 accessions of *Gossypium arboreum* and 31 of *G.herbaceum* for allelic variation at 40 isoenzyme loci. All measures of genetic variability demonstrated that *G.arboreum* contains greater diversity than *G.herbaceum*, although both species have relatively low levels of isoenzyme variation.

2.4.2 Seed oil

Ali (1996) observed a range of 12.5 to 26.0 per cent of seed oil in cotton. However, the progenies of crosses between high and low oil content showed that the parental differences were mostly of environmental denoting little scope for intravarietal selection for this trait.

On the other hand, genetic studies of seed oil in cotton by Kohel (1980) using parent progeny regression revealed that the heritability estimate for seed oil percentage was 35 per cent and showed the possibility of genetic improvement. Seed oil percentage was not highly correlated with seed physical properties such as seed index.

Genetic research on cotton seed oil is primarily directed towards the simultaneous improvement of cotton-seed oil composition, while retaining or improving the established superior fibre qualities and productivity (Dani, 1984).

Seed quality traits, such as oil and protein were highly influenced by the environment as seen from the wide variation (Kohel and Cherry, 1983). There was a negative correlation between oil content and protein content of seed. Nevertheless, positive correlation was observed between seed index and percentage of oil in seeds and kernels.

Six cultivars of *Gossypium hirsutum* and two of *G.arboreum* were evaluated by Malik and Baluch (1986) for eight seed quality traits, seed content

of four minerals and four oil quality characters. All traits except crude fibre content varied significantly between cultivars and oil content was positively correlated with kernel percentage but was independent of seed index.

Singh (1986) reported that seed oil improvement could be possible without reduction in the important characters, seed cotton yield, ginning outturn, halo length and seed index. Seed oil content showed significant positive association with seed cotton yield and negative correlation with lint index in Asiatic cotton.

Dani (1986) reported that oil percentage was positively associated with lint yield, only in the bolls set during fourth week. He also suggested that selection among single cross derivatives would be more effective than from the progenies of double cross and back cross derivatives for improving the seed oil content.

Dani and Kohel (1987) found significant differences in oil content per seed due to time of boll set in both high and low oil lines. Oil content showed a marginal increase in early set bolls, followed by a more increase and finally a sharp decline in the boll set during the last two or three weeks in *Gossypium hirsutum* L.

Narayanan *et al.* (1988) found that in upland cotton, disruptive selections for earliness resulted in simultaneous improvement in seed oil content and seed

oil index besides seed cotton yield, boll number, halo length and ginning percentage.

Dani (1989a) tested the oil content and fibre quality of 14 very early and 21 early *Gossypium hirsutum* selections and suggested that plant-to-row selection may be more effective than bulk selection for the improvement of oil content and lint yield.

In a three year study of the cotton seed oil content of *Gossypium hirsutum* and *G. barbadense*, variation was greater in *G. hirsutum* (33-42 per cent oil vs 39-45 per cent in the other species), but the varieties with the highest oil content belonged to *G. barbadense*. *G. hirsutum* varieties had high concentrations of palmitic acid, while oil content of *G. barbadense* varieties were correlated positively with linoleic acid but negatively with palmitic, stearic and oleic acids (Gubanova, 1989).

Bhale *et al.* (1989) observed significant variation in cultivars L 147, B 1007 and SRT 1, for in fibre length, seeds per boll, lint per seed, seed index. Levels of variability in lint per seed, seed index and seed oil index were relatively higher in the oil cultivars L 147 and B 1007.

Patterns of inter and intra seasonal variations were noticed in 10 elite cultivars. The study showed a decrease in oil content at the third harvest in each year. Effects of years, cultivars, harvests and their two factor interactions were

highly significant for oil content. A small increase in oil content over parents was recorded in the F_1 (Dani, 1989 b).

Inheritance of oil content, its fatty acid composition and fibre outturn cotton and variation in fatty acid composition of the reserve lipids in seeds of cotton were studied by Topvoldiev *et al.* (1990)

Singh and Narayanan (1991) suggested pedigree breeding for improving seed oil content and seed oil index in upland cotton without affecting the other economic characters.

Higher magnitude of variability was encountered in *G.arboreum* L. (12.5 - 22.8 per cent) than in *G.herbaceum* L. (13.5 - 20.4 per cent) suggesting possible genetic improvement of seed oil content in diploid cotton through hybridization and selection (Singh and Singh, 1993).

Liu *et al.* (1994) analysed 300 accessions in *Gossypium barbadense* and found the mean oil content to be 40.99 per cent. Twenty two accessions were identified as being of high quality oil content (45 per cent). Oil content was relatively high in cultivars with large seeds, okra type leaves and long fruiting branches.

2.4.3 Seed protein

Turner *et al.*, (1976) studied seed and fibre samples of four upland cotton (*G. hirsutum* L.) cultivars and observed the lack of significant correlation for protein content and yield. The strongest correlation for protein was a negative relationship with fibre maturity. No environmental influence was noticed.

Negative correlation between oil content and protein content was encountered by Hamid and Youssef (1979). According to Hossain (1983) oil content can be increased without a reduction in seed protein as there was no negative correlation between these two traits.

Kohel and Cherry (1983) found that in *Gossypium hirsutum* L. protein percentage increased with stratified harvests. The correlations between seed oil and protein indices have changed from a significant to a non-significant positive correlation (r=0.35) and to a non-significant negative correlation (r=0.44).

In a study aimed at finding out the effect of environment on cotton seed constituents *viz.*, protein and oil, Meenakshisundaram *et al.* (1986) observed significant environmental influence. Eight varieties recorded more than 22 per cent protein under Arabhavi conditions among the 232 entries tested.

Dani and Pundarikakshudu (1986) investigated the changes in cotton seed protein and oil with repeated harvests. The studies revealed that the varietal differences for seed protein percentage and protein content per seed

were highly significant at second harvest. Inspite of highly significant differences due to stages of harvest, the cultivar X stage interactions were not significant for percentage protein in both *G. hirsutum* L. and *G. arboreum* L.

Dani (1989b) observed different levels of protein over the year and harvests. Effects of years, cultivars, harvests and their two factor interactions were non significant for protein content.

Seed weight and contents of oil and protein increased rapidly during 0-45 days and more slowly until 55-60 days. Oil content was positively correlated with seed index and protein (Taneja *et al.*, 1993).

A mean protein content of 32.7 per cent was noticed among the 300 accessions analysed by Liu *et al.* (1994) in *Gossypium barbadense*. Twenty two accessions have been identified to have higher protein content of 37 per cent. Protein content was relatively high in accessions with small seeds, normal leaves and short fruiting branches. Series with highest protein content (33-52 per cent) were established among accessions of nine series introduced from different eco systems.

The preceding review reveals that much work has been carried out in the areas of genetic diversity, heterosis and correlation and path coefficients in cotton. However, the results are not consistent and vary with the materials used and environment. As the present investigation leads to identification of potential hybrids and good segregants from different filial generation, a separate study of various characters was attempted.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiments were conducted at the Cotton Breeding Station, Tamil Nadu Agricultural University, Coimbatore - 641 003, during the Summer 1998 and Winter 1998-99 Seasons.

3.1 Materials

3.1.1 Experiment I : Parental evaluation and synthesize of hybrids

A set of 19 genotypes belonging to the species *Gossypium hirsutum* L. (2n = 4 x = 52) and 10 genotypes belonging to *Gossypium barbadense* L. (2n = 4 x = 52) were used for evaluation of variability, genetic diversity and character association. The genotypes were also used for synthesizing intra-*hirsutum* and interspecific crosses (Table 1). The selfed seeds of the parental genotypes for the above experiment were obtained from the Professor and Head, Department of Cotton, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore. Selfing was also done in these genotypes to get the pure seeds for raising during the next season.

3.1.2 Experiment II : Evaluation of heterosis

A set of 49 intra-*hirsutum* hybrids and 21 interspecific (*hirsutum* x *barbadense*) crosses synthesized from experiment I along with the respective

Table 1. List of cotton genotypes used in the study

A. *Gossypium hirsutum* L.

S. No	Parents	Duration (days)	Category	Parentage	Source
1.	MCU 5	165	Released variety	Multiple cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
2.	MCU 7	135	Released variety	X-ray irradiation of L1143 EE	Department of Cotton, CPBG, T.N.A.U, Coimbatore
3.	MCU 9	165	Released variety	MCU 8 x MCU 5 hybrid derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
4.	MCU 11	155	Released variety	MCU 5 x Egyptian ***hirsutum*** cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
5.	TCH 976	155	Culture in Multi location testing	MCU 9 x LRA 5166 cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
6.	MCU 12	150	Released variety	Cross derivative from the cross MCU 11 x LRA 5166	Department of Cotton, CPBG, T.N.A.U, Coimbatore
7.	TCH 1028	150	Culture from the main strain trial	Cross derivative from the cross LRA 5166 x TCH 655	Department of Cotton, CPBG, T.N.A.U, Coimbatore
8.	TCH 1218	155	Culture from Advanced Varietal Trial	MCU 9 x TCH 92-7 Cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
9.	TCH 1223	155	Culture from Advanced Varietal trial	Double cross derivative from the cross (TCH 665 x TCH 9-7) x (TCH 665) x (TCH 21)	Department of Cotton, CPBG, T.N.A.U, Coimbatore

Contd...

10.	TCH 1233	155	Culture under Advanced Varietal Trial	Double cross derivative from the cross (TCH 92-7 x TCH 102) x (TCH 665 x TCH 21)	Department of Cotton, CPBG, T.N.A.U, Coimbatore
11.	TCH 1452	155	Culture under MLT (Multi Location Trial)	(TCH 665 x LS 149) (TCH 665 x TCH 21) x (TCH 21 x EECH) (TCH 92-7 x EECH)	Department of Cotton, CPBG, T.N.A.U, Coimbatore
12.	TCH 1458	155	Culture under MLT	(TCH 665 x LS 149) (TCH 665 x TCH 21) x (TCH 21 x EECH) (TCH 92-7 x EECH)	Department of Cotton, CPBG, T.N.A.U, Coimbatore
13.	TCH 1569	150	Culture under MLT	TCH 1002 x MCU 5/3 Cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
14.	TCH 1609	150	Culture under Multi Location Trial	LRA 5166 x SRT.1 Cross derivative	Department of Cotton, CPPG, T.N.A.U, Coimbatore
15.	LRA 5166	160	Released variety	Triple cross derivative from the cross Laxmi x (Reba B.50 x AC 122)	Department of Cotton, CPBG, T.N.A.U, Coimbatore
16.	LRK 516 (Anjali)	145	Released variety	Back cross derivative (Reba B50 x Khandwa - 2)	Department of Cotton, CPBG, T.N.A.U, Coimbatore
17.	Sahana	150	Released variety	Multiple cross derivative	University of Agricultural Sciences, Dharwad.
18.	Surabhi	160	Released variety	MCU 5 VT x (MCU 5 x ***G.mexicanum*** spp ***nervosum***)	CICR, Regional Station, Coimbatore.
19.	SVPR 2	160	Released variety	Cross derivative from the cross TSDT.22 x JR 36	Department of Cotton, CPBG, T.N.A.U, Coimbatore

Contd...

B. *Gossypium barbadense* L.

S. No.	Parents	Durations (Days)	Category	Parentage	Source
1.	TCB 7	165	Culture	Kitts x 76/3-6 cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
2.	TCB 15	165	Culture	Kitts x 76/2 Cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
3.	TCB 209	170	Culture	CBS 202 x Sudan G.45 Cross derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
4.	Bhaksh 5230	170	Genetic accession	Russia	Department of Cotton, CPBG, T.N.A.U, Coimbatore.
5.	EC 9256	150	Genetic accession	Russia	Department of Cotton, CPBG, T.N.A.U, Coimbatore.
6.	EC 97631	160	Genetic accession	Russia	Department of Cotton, CPBG, T.N.A.U, Coimbatore.
7.	EC 111248	165	Genetic accession	Hybrid derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore.
8.	BCS 9-76	170	Genetic accession	Hybrid derivative	Department of Cotton, CPBG, T.N.A.U, Coimbatore
9.	Sudan G.45	170	Genetic accession	Sudan	Department of Cotton, CPBG, T.N.A.U, Coimbatore
10.	Suvin	180	Released variety	Hybrid derivative from the cross Sujatha x St.Vincent	Department of Cotton, CPBG, T.N.A.U, Coimbatore

parents and standard checks were raised in this experiment for estimation of heterosis.

3.2 Methods

3.2.1 Experimental lay-out

3.2.1.1 Experiment I

During summer 1998, the parents were raised in an experiment laid in RBD with four replications. Three replications were used for evaluation of variability and character association. The plants in the fourth replication were used for synthesizing hybrids. The row length was maintained as six metres. A spacing of 75 cm between rows and 45 cm between plants in a row, was adopted so as to have 13 plants in each row. Recommended agronomic practices and plant protection measures as per the Crop Production Manual were followed. Crosses were done in a diallel mating design. However, due to excess heat, seeds of F_1 could not be secured in all combinations. The seeds from available F_{1s} were however secured. Selfing was also done to get pure seeds of parents.

3.2.1.2 Experiment 2

During winter 1998-99, the parents and their hybrids along with the standard check were raised in an experiment laid out in RBD with three replications. A spacing of 75 cm between rows and 60 cm between plants in a row, was adopted so as to have 10 plants in each row. Agronomic practices and plant protection measures were followed similar to that followed for Experiment 1

Table 2. Hybrids used for the evaluation

Intra-*hirsutum* hybrids			
1.	MCU 5 x Surabhi	26.	MCU 11 x TCH 1233
2.	MCU 5 x SVPR 2	27.	MCU 11 x TCH 1452
3.	MCU 5 x LRK 516	28.	MCU 11 x TCH 1609
4.	MCU 5 x TCH 1569	29.	TCH 976 x TCH 1218
5.	MCU 5 x TCH 1609	30.	TCH 976 x TCH 1233
6.	MCU 7 x Surabhi	31.	TCH 976 x TCH 1452
7.	MCU 7 x SVPR 2	32.	TCH 976 x TCH 1458
8.	MCU 7 x LRK 516	33.	TCH 976 x TCH 1569
9.	MCU 7 x Sahana	34.	TCH 976 x TCH 1609
10.	MCU 7 x TCH 1218	35.	TCH 976 x Sahana
11.	MCU 7 x TCH 1223	36.	TCH 1025 x Surabhi
12.	MCU 7 x TCH 1233	37.	TCH 1025 x SVPR 2
13.	MCU 7 x TCH 1452	38.	TCH 1025 x LRK 516
14.	MCU 7 x TCH 1458	39.	TCH 1025 x TCH 1458
15.	MCU 7 x TCH 1569	40.	TCHL 1028 x LRK 516
16.	MCU 7 x TCH 1609	41.	TCH 1028 x Sahana
17.	MCU 9 x TCH 1223	42.	TCH 1028 x TCH 1218
18.	MCU 9 x TCH 1233	43.	TCH 1028 x TCH 1233
19.	MCU 9 x TCH 1452	44.	TCH 1028 x TCH 1458
20.	MCU 9 x TCH 1458	45.	TCH 1028 x TCH 1569
21.	MCU 9 x TCH 1569	46.	LRA 5166 x TCH 1223
22.	MCU 9 x TCH 1609	47.	LRA 5166 x TCH 1233
23.	MCU 11 x LRK 516	48.	LRA 5166 x TCH 1452
24.	MCU 11 x TCH 1218	49.	LRA 5166 x TCH 1609
25.	MCU 11 x TCH 1223	50.	Savitha (Standard check)

Contd...

Interspecific hybrids	
1.	MCU 5 x TCB 7
2.	MCU 5 x TCB 209
3.	MCU 5 x EC 97631
4.	MCU 7 x TCB 7
5.	MCU 7 x TCB 209
6.	MCU 7 x Bhaksh 5230
7.	MCU 7 x EC 9256
8.	MCU 7 BCS 9-76
9.	MCU 7 x Sudan G.45
10.	MCU 7 x Suvin
11.	MCU 9 x EC 111248
12.	MCU 11 x TCB 15
13.	MCU 11 x BCS 9-76
14.	TCH 976 x Suvin
15.	TCH 976 x Bhaksh 5230
16.	TCH 1025 x Sudan G.45
17.	TCH 1025 x Bhaksh 5230
18.	TCH 1025 x EC 9256
19.	TCH 1028 x BCS 9-76
20.	TCH 1028 x Sudan G.45
21.	TCH 1028 x EC 111248
22.	TCHB 213 (Standard check)

3.2.2 Observations

In parents and F_1, five competitive plants were chosen from each replication at random and tag labelled for recording observations. The average values of the observations from these five plants represented the mean of that replication. For isozyme analysis, tender leaves were collected from the parent materials. For the estimation of biochemical parameters, seeds of the parent materials were used.

3.2.2.1 Yield parameters

3.2.2.1.1 Days to first flowering

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

3.2.2.1.2 Plant height

The height of the plant from the cotyledonary node to the tip of the plant at maturity, was recorded in cm.

3.2.2.1.3 Number of monopodia per plant

The number of monopodial branches i.e., vegetative branches, present at maturity was counted.

3.2.2.1.4 Number of sympodia per plant

The number of sympodial branches i.e., number of fruiting branches present in the plants at maturity was counted.

3.2.2.1.5 Number of bolls per plant

Number of matured bolls were counted at maturity in five samples of both F_1 and parents and the mean worked out.

3.2.2.1.6 Seed cotton yield per plant

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

3.2.2.1.7 Boll weight

Five well burst bolls in each of the five plants were collected and the kapas from the bolls was weighed. The weight of seed cotton per boll was worked out and expressed as boll weight in grams.

3.2.2.1.8 Number of seeds per locule

The number of seeds in all the locules of a boll was counted and the mean number of seeds per locule was worked out.

3.2.2.1.9 Ginning percentage

One hundred seeds with fibres (kapas pooled) were taken and weighed. Then, this sample was ginned by means of a power operated gin to separate the lint from the seeds. The quantity of lint obtained was weighed and the lint outturn from the kapas sample taken was calculated and expressed as ginning outturn in percentage.

$$\text{Ginning outturn (Per cent)} = \frac{\text{Weight of the lint}}{\text{Weight of seed cotton}} \times 100$$

3.2.2.1.10 Lint index

The quantity of lint obtained from the 100 seeds (kapas pooled) ginned was weighed separately and the lint index was computed using the formula given below.

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

The lint index is expressed in grams per 100 seeds.

3.2.2.1.11 Seed index

The weight of 100 seeds without fibres (vide item 9) was weighed to find out the seed index using the formula given below.

$$\text{Seed index} = \frac{\text{Weight of seeds}}{\text{Number of seeds taken}} \times 100$$

The seed index is expressed in grams per 100 seeds.

3.2.2.2 Quality parameters

The kapas samples were pooled from the five sample plants, ginned and the lint obtained was sent to the CIRCOT, Coimbatore for assessing the following fibre characters

3.2.2.2.1 2.5 per cent span length

2.5 per cent span length is the length of fibre estimated by digital fibrograph. This is the fibre length representing majority of the fibres and expressed in millimetre.

3.2.2.2.2 Uniformity ratio

This is the ratio between two span lengths viz., 50 per cent span length and 2.5 per cent span length and it is expressed as percentage Uniformity ratio was determined as follows.

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

Uniformity ratio denotes the percentage of longer fibres.

3.2.2.2.3 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 resistance to airflow through a plug of fibres. It was estimated by placing a lint 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.

3.2.2.2.4 Maturity coefficient

This indicates the unitary expression of fibre maturity usually represented by the percentage of mature, half mature and immature fibres.

About 100 fibres were placed on a slide from an alligned 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 cover slip and irrigated with 18 per cent caustic soda solution. The mounted slide was placed on the microscope stage so as to get the central portion of the fibres beneath the objective lens. The fibres were examined one by one by moving the stage of the microscope in the transverse direction. Maturity co-efficient was then calculated by using the formula given below.

$$\text{Maturity co-efficient} = \frac{M + 0.6\,H + 0.4\,I}{100}$$

Where,

M, H and I indicates the percentage of mature, half mature and immature fibres respectively.

3.2.2.2.5 Bundle strength

This denotes the strength of the fibres. This is also referred as tensile strength i.e., the maximum specific stress that is developed in a tensile test to rupture the fibres. The fibre strength was evaluated by using 1/8 gauge length of the fibres. The instrument used for estimating the tensile strength is the stelometer and this parameter is expressed as tenacity in g./tex.

3.2.2.3 Biochemical studies

3.2.2.3.1 Isozyme analysis

Isozyme analysis was carried out for enzymes peroxidase and superoxide dismutase in nineteen *Gossypium hirsutum* and ten *G. barbadense* parental genotypes.

The electrophoretic separation of isozymes was done using PAGE (Poly Acrylamide Gel Electrophoresis) as described by Laemmli (1970)

Composition of solutions used for PAGE

The following set of solutions were prepared with compositions mentioned against each.

Phosphate buffer (0.2 M, pH 7.0)

Thirty nine parts of KH_2Po_4 solution mixed with 61 parts of K_2HPo_4 solution.

KH_2Po_4 : A quantity of 1.36 g. of Potassium dihydrogen phosphate was dissolved in 100 ml. of distilled water

K_2HPo_4 : A quantity of 1.7418 g. of Di Potassium hydrogen phosphate was dissolved in 100 ml. of distilled water.

Stock acrylamide solution

A quantity of 30 g acrylamide (30 per cent w/v)+ 0.8 g. (0.8 per cent w/v) bisacrylamide was dissolved in 100 ml. distilled water

Separating gel buffer (pH 8.8)

A quantity of 22.7 g. Tris - HCl was dissolved in 80 ml. distilled water, pH was adjusted to 8.8 with dilute HCl and volume was made up to 100 ml. with distilled water.

Stacking gel buffer (pH 6.8)

A quantity of 7.26 g. Tris - HCl was dissolved in 80 ml. distilled water, pH was adjusted to 6.8 with dilute HCl and final volume was made up to 100 ml. with distilled water.

Electrode buffer (pH 8.2 - 8.4)

A quantity of 14.4 g. of glycine and 6 g. of Tris in 1 litre of distilled water.

Polymerising agents

i. 10 per cent Ammonium per sulphate (APS)
A quantity of 100 mg of APS in 1 ml. of distilled water,prepared freshly and used

ii. TEMED (N, N, N', N' - Tetra Methylene Ethylene Diamine)

Sample buffer

Bromophenol blue (0.5 per cent) 1 ml. + Tris - HCl (pH 6.8) buffer 5 ml. + Sucrose 5 g. + 10 ml. distilled water.

Enzyme extraction

Tender leaf samples of 500 mg were taken and stored at 4°C. Each sample was ground to paste with 1 ml. of phosphate buffer (0.2 M, pH 7.0) using a prechilled pestle and mortor. The homogenate was centrifuged at 10000 rpm for 30 minutes at 4°C in a refrigerated centrifuge and the supernatant was transferred into fresh eppendorf tube. This sample extract was maintained at O°C for further analysis.

Setting up the gel unit

The cleaned glass plates (18 x 16cm.), wiped with ethanol were separated using spacers and the side screws were tightened. The set up was made to stand on the boat and 1.0 per cent agar solution was poured into the boat, to seal the bottom portion of the glass plates.

Table 3. Preparation of gradient gel solutions

Solutions	Separating gel (ml.)	Stacking gel (ml.)
Stock Acrylamide	20.00	2.00
Tris (pH 8.8)	12.00	-
Tris (pH 6.8)	-	1.50
Distilled water	7.40	6.00
APS (10 per cent)	0.40	0.40
TEMED	0.06	0.30

Procedure

Gel casting

1. About 40 ml. of running gel (seperating gel) solution was prepared (Table 3) with out adding the APS and TEMED
2. The solution was degased for 10 minutes using a vaccum pump.
3. TEMED and APS were added and the solution was poured down into the sandwitch to a level of leaving about 4 cm from the top and a thin layer of distilled water or water saturated butanol was over layed on the gel. Set up was left for polymerisation of the gel.
4. After polymerisation, the casting stand was tilted to pour off the overlying solution.
5. Stacking gel solution measuring about 10 ml. without APS and TEMED was prepared and degased for 10 minutes as in step 2.

6. APS and TEMED were added and the stacking gel was poured into the sandwitch above the running gel
7. The comb was inserted into the sandwitch carefully, without any air bubble formation under the teeth.
8. The gel was allowed to polymerise for 30 minutes and after polymerisation the comb was removed from the gel gently without damaging the wells.
9. The set up was removed from the gel casting boat and kept ready for running in lower buffer chamber.

Running the gel

10. The lower buffer chamber was filled with electrode buffer and the gel unit was installed into the unit.
11. The electrode buffer in the upper chamber was adjusted till the gel sandwitch was fully immersed in the buffer
12. The gel was pre run for 30 minutes before loading of samples.
13. 60 µl of samples and 30 µl of tracking dye were mixed and loaded carefully into the wells using 1 ml. syringe, and the power supply was set to a constant current of 25 mA .
14. After the dye front had reached the bottom of the gel, the gel was run for another 4 hours and the power supply was turned off.

Staining

Staining was done using the method described by Sadasivam and Manickam (1992) with slight modifications as per the need.

Peroxidase (10 per cent gel)

Peroxidase enzyme was detected by incubating the gel for 30 minutes in dark in a mixture of ammonium chloride (6 per cent) and Benzidine (100 mg dissolved in 1 ml. of acetic acid) After 30 minutes, 1 ml. of hydrogen peroxide (30 per cent) was added. After the appearance of blue colour bands, the reaction was stopped by transfering the gel to 7 per cent acetic acid. The gel was photographed before the bands changed to brown colour.

Superoxide dismutase (15 per cent gel)

SOD enzyme was detected by incubating the gel for 30 minutes in dark in the staining solution prepared as given below.

Potassium phosphate buffer (250 mM stock)	-	20 ml.
EDTA (10 mM stock)	-	1.0 ml.
TEMED	-	200 µl
Riboflavin (300 mM stock)	-	1.0 ml.
Nitro blue tetrazolium (10 mM stock)	-	2.5 ml.

After incubation, the gel was kept under electric light with slight shaking till the bands appeared and the gel was photagraphed.

3.2.2.3.2 Seed oil content

Representative samples of seed from each of the parents in three replications were analysed for oil content by employing Nuclear Magnetic Resonance (NMR) analyser available at Ankur Seeds Private Ltd, Kalmeshwar. The oil content was expressed as percentage.

3.2.2.3.3 Seed protein content

Seed protein content was estimated by the method described by Bradford (1976) using the concept of "proteins" capacity to bind a dye-quantitatively. Cotton seed was decoated and the endosperm was used for protein estimation after defatting. The absorbance value was read at 595 nm in colorimeter and a standard curve was plotted using the standard protein concentration ranging from 10 – 100 μg of bovine serum albumin Vs absorbance. Then, the amount of protein in the experimental samples were calculated using the standard curve.

3.2.3 Statistical analysis

Statistical analysis was carried out using the Indostat statistical package.

3.2.3.1 Analysis of variance

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

ANOVA

Source	df	S.S	M.S	Expectation
Replications	r - 1	SS_r	M_r	$\sigma^2_e + g\sigma^2_r$
Genotypes	t - 1	SS_t	M_t	$\sigma^2_e + r\sigma^2_g$
Error	(r - 1) (t - 1)	SS_e	M_e	σ^2_e
Total	r_t - 1			

Test of significance was carried out by referring to the 'F' table given by Snedecor and Cochran (1967). The analysis was done separately for parents and for hybrids.

3.2.3.2 Genotypic and phenotypic variance and coefficient of variability

Genotypic and phenotypic variances, genotypic and phenotypic coefficient of variability, heritability and genetic advance were worked out for the different characters following the method suggested by Singh and Choudhary (1979).

3.2.3.2.1 Genotypic variance (σ^2_g)

$$\sigma^2_g = \frac{M_t - M_e}{r}$$

where,

M_t = Mean squares for varieties

M_e = Error mean square and

r = Number of replications

3.2.3.2.2 Phenotypic variance (σ^2_p)

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

where,

σ^2_g = Genotypic variance and

σ^2_e = Error mean square

3.2.3.2.3 Genotypic co-efficient of variability (GCV)

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

where,

σ_g = Genotypic standard deviation and

x = Grand mean

3.2.3.2.4 Phenotypic co-efficient of variability (PCV)

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

where,

σ_p = Phenotypic standard deviation and

x = Grand mean

3.2.3.2.5 Heritability (h^2)

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

where,

σ^2_g = Genotypic variance and

σ^2_p = Phenotypic variance

3.2.3.2.6 Genetic advance (GA)

$$GA = K\sigma_p h^2$$

where,

K = Selection differential at 5 per cent selection intensity which is 2.06

σ_p = Phenotypic standard deviation and

h^2 = Heritability

3.2.3.3 Correlation coefficient

Genotypic correlation coefficients were worked out as per the method suggested by Goulden (1959) to find out the relationship between yield and its

components in the parents. The variance and covariance values were utilised to calculate the correlation coefficients by applying the following formula.

$$r_{xy} = \left(\frac{\text{Cov. } (X,Y)}{V(X)\, V(Y)} \right)^{1/2}$$

where,

r_{xy} = Correlation co-efficient between character X and Y

V(X) = Variance of character X and

V(Y) = Variance of character Y

The significance of correlation co-efficients was tested with reference to the 't' table given by Snedecor and Cochran (1967).

3.2.3.4 Path coefficient analysis

Path coefficient analysis was done for yield and yield components in parents to find out the direct and indirect effects of different characters on seed cotton yield. By using the genotypic correlation co-efficients, path co-efficients were worked out following the procedure suggested by Wright (1921) and Dewey and Lu (1959).

All the above analysis were done only for the parents.

3.2.3.5 D^2 analysis

The data on yield and yield components obtained for the parents were utilised for estimating the genetic divergence using Mahalanobis (1928) D^2

analysis. Variance in respect of characters and the covariance between character pairs were calculated as outlined by (Rao, 1952). The generalised distance between any two population is given by the following formula.

$$\Delta^2 = \Sigma \Sigma_{ij} \delta_i \delta_i$$

where,

Δ^2 = matrix reciprocal to the common dispersion matrix and

δ_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,

$$D^2 = \Sigma \Sigma S_{ij} \delta_i \delta_i$$

where,

S_{ij} = Sample estimate of $_{ij}$ and i j

To workout D^2 statistics, the correlated variables were transformed into uncorrelated variables using pivotal condensation method (Rao, 1952).

The D^2 value obtained for a pair of population was taken as the calculated χ^2 value and was tested against the table value of χ^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 by 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 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 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 intra-cluster distances were worked out taking into consideration of all the component D^2 values. The square root of the D^2 values gave the distance (D) between the different clusters.

Contribution of individual characters to divergence

In all the combinations, each character was ranked on the basis of $di = Y_i^j - Y_i^k$ values. Rank one was given to the highest mean differences 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 came under different clusters.

With the help of the D distances between and within the clusters, the cluster diagram was drawn to show the relationship between different populations or groups. Clusters separated by largest or highest D distance was considered to have maximum divergence. A dendrogram was also constructed to depict the diversity of genotypes within and outside the clusters.

3.2.3.6 Estimation of heterosis

The overall mean value for each parent or hybrid in all the three replications for each character was taken for the estimation of heterosis.

3.2.3.5.2 Relative heterosis (d_i)

Heterosis over mid - parental value (d_i) was estimated using the following formula.

$$\text{Relative heterosis (per cent)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

where,

$\overline{F_1}$ = Mean of F_1 hybrid and

$\overline{MP}$ = Mean of mid-parental value

3.2.3.5.2 Heterobeltiosis (d_{ii})

Heterosis over better parent (d_{ii}) was calculated using the followig formula.

$$\text{Heterobeltiosis (per cent)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{F_1}$ = Mean of F_1 hybrid and

$\overline{BP}$ = Mean of better parental value

3.2.3.5.3 Standard heterosis (d_{iii})

Heterosis over the standard parent was worked out using the following formula.

$$\text{Standard heterosis (per cent)} = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

where,

$\overline{F_1}$ = Mean of F_1 hybrid and

$\overline{SV}$ = Mean of standard parental value

Test of significance

Test of significance for heterosis was carried out by comparing the difference between original values with the CD values.

Results

CHAPTER IV

EXPERIMENTAL RESULTS

4.1 Genetic diversity and association studies

4.1.1 Mean expression

The mean expression of the seventeen characters recorded on 29 parental genotypes including 19 *G.hirsutum* and 10 *G.barbadense* parents are presented in Table 4.

Significant variation was observed in respect of all the metrical traits, the range for different characters is furnished Table 4a.

4.1.2 Analysis of variance

The analysis of variance for the different characters studied in parental trial is presented in Table 5.

The variation between parental genotypes was significant for all the traits.

4.1.3 Genotypic and phenotypic variances, heritability and genetic advance

The estimates of genotypic and phenotypic variances, heritability in broad sense, genetic advance and genetic advance as percentage of mean are furnished in Table 6.

Table 4. Mean expression of different characters in the parents

Characters / Parents	Days to first flowering	Plant height (cm)	No. of sympodia/ plant	No. of monopodia / plant	No. of bolls / plant	Boll weight (g)	Seed cotton yield / plant (g)
G.hirsutum							
MCU 5	69.67	59.76	16.07	1.87	**20.60**	3.60	72.67
MCU 7	68.67	50.79	12.07	1.33	11.40	3.35	36.80
MCU 9	70.33	66.37	16.73	2.27	15.23	4.05	59.88
MCU 11	63.33	74.79	17.97	1.33	17.07	4.12	69.02
TCH 976	67.67	72.64	15.00	2.00	19.53	3.16	59.74
TCH 1025	71.00	68.92	15.43	1.67	18.10	3.28	58.60
TCH 1028	71.67	68.93	17.97	2.40	18.39	3.75	66.63
TCH 1218	71.00	80.22	**18.87**	1.00	18.46	4.52	81.16
TCH 1223	65.33	81.71	18.70	2.67	19.29	**4.64**	**86.74**
TCH 1233	65.33	68.03	18.80	2.13	19.54	3.81	72.68
TCH 1452	71.33	70.41	16.07	2.47	17.39	3.04	52.64
TCH 1458	71.00	72.01	17.83	2.00	18.96	4.19	78.20
TCH 1569	70.33	76.71	18.33	2.67	20.43	4.13	81.47
TCH 1609	68.33	69.77	15.27	2.3	17.57	3.17	52.66
LRA 5166	62.67	69.25	16.33	1.47	19.37	3.15	59.08
LRK 516	**61.00**	51.00	11.60	2.20	15.13	3.03	44.01
Sahana	67.00	65.19	16.33	1.13	14.29	3.08	42.41
Surabhi	**72.33**	72.89	16.00	1.67	15.85	3.05	46.22
SVPR 2	71.33	**83.23**	16.80	**3.47**	19.37	3.85	71.51
G.barbadense							
TCB 7	69.67	42.41	8.47	0.47	4.64	2.46	10.94
TCB 15	69.33	42.52	10.33	**0.13**	5.63	2.60	13.51
TCB 209	68.33	50.91	10.40	1.80	9.53	2.72	23.71
Bhaksh 5230	69.33	52.64	9.40	0.27	6.26	2.18	12.63
EC 9256	70.33	57.70	**6.77**	0.77	6.34	2.22	12.78
EC 97631	71.67	49.33	8.47	0.20	6.12	3.08	17.39
EC 111248	69.33	42.47	9.17	0.17	**3.98**	2.42	**8.98**
BCS 9-76	68.33	42.66	11.70	0.73	6.33	**2.17**	12.89
Sudan G.45	68.33	50.72	8.69	0.20	6.33	2.34	14.08
Suvin	68.00	**41.96**	10.20	0.93	6.33	2.68	15.88
SE	1.17	3.47	0.74	0.38	0.5	0.06	1.39
CD 5 %	3.31	9.83	2.10	1.08	1.59	0.16	3.93

Contd...

Characters Parents	No. of seeds/ locule	Ginning outturn (%)	Lint index (g)	Seed index (g)	Seed oil content (%)
G.hirsutum					
MCU 5	6.93	36.80	2.91	8.56	23.80
MCU 7	7.27	33.54	1.87	**7.33**	22.42
MCU 9	7.20	34.76	2.86	9.60	24.16
MCU 11	6.50	38.45	3.29	8.49	24.18
TCH 976	6.63	37.59	3.32	9.04	24.70
TCH 1025	6.63	33.81	2.27	8.62	24.15
TCH 1028	6.57	37.95	**3.89**	10.40	23.71
TCH 1218	6.60	38.31	3.35	8.69	24.48
TCH 1223	7.37	38.26	3.56	9.26	24.10
TCH 1233	6.27	38.52	3.31	8.37	25.24
TCH 1452	6.93	35.85	2.88	9.21	23.54
TCH 1458	7.13	35.88	2.85	9.09	25.12
TCH 1569	6.93	36.18	3.02	9.37	24.24
TCH 1609	6.43	32.67	2.38	9.80	**25.51**
LRA 5166	6.10	33.69	2.29	8.92	23.72
LRK 516	5.63	34.35	2.34	8.54	22.27
Sahana	6.27	**39.98**	3.44	7.74	24.54
Surabhi	7.00	33.86	2.24	8.50	23.65
SVPR 2	**8.30**	37.76	2.73	7.41	22.60
G.barbadense					
TCB 7	4.98	32.64	2.82	**12.02**	**20.47**
TCB 15	5.51	34.11	2.36	8.79	24.32
TCB 209	5.79	32.65	2.19	9.32	22.15
Bhaksh 5230	6.05	35.13	2.47	8.41	21.92
EC 9256	5.39	33.74	2.30	8.80	21.41
EC 97631	6.17	**30.87**	**1.84**	9.20	23.71
EC 111248	5.45	35.62	2.51	8.21	22.31
BCS 9-76	4.71	32.29	2.14	9.39	22.10
Sudan G.45	5.12	34.03	2.37	8.89	22.12
Suvin	**4.59**	31.94	2.20	10.00	24.47
SE	0.40	0.74	0.20	0.26	0.10
CD 5 %	1.15	2.08	0.56	0.74	0.29

Contd...

Characters Parents	2.5 % Span length (mm)	Uniformity ratio (%)	Fibre fineness (micronaire)	Maturity coefficient (%)	Bundle strength (1/8 gauge g/tex)
G.hirsutum					
MCU 5	31.10	41.67	3.51	0.69	23.60
MCU 7	28.03	43.67	3.47	0.69	19.63
MCU 9	31.61	44.67	3.62	0.69	20.77
MCU 11	29.23	44.67	3.94	0.71	20.10
TCH 976	30.27	**40.00**	3.62	0.71	19.80
TCH 1025	29.47	43.00	3.66	0.70	21.10
TCH 1028	30.17	42.67	3.82	0.71	18.87
TCH 1218	30.03	43.67	4.09	0.71	19.43
TCH 1223	30.27	43.33	**4.21**	**0.72**	**17.33**
TCH 1233	28.80	44.00	3.84	0.71	17.57
TCH 1452	29.17	45.00	4.02	0.71	17.77
TCH 1458	28.73	44.00	3.66	0.69	18.63
TCH 1569	28.70	44.00	3.43	0.69	21.07
TCH 1609	28.77	43.67	3.70	0.69	20.93
LRA 5166	27.93	42.33	3.54	0.70	19.87
LRK 516	26.63	48.33	3.66	0.70	18.03
Sahana	26.10	46.33	4.01	0.70	22.07
Surabhi	31.60	43.33	3.56	0.70	17.87
SVPR 2	**24.93**	**48.33**	3.94	0.71	17.63
G.barbadense					
TCB 7	30.37	45.33	**3.05**	**0.63**	23.47
TCB 15	30.53	44.33	3.25	0.64	**24.10**
TCB 209	**33.10**	41.00	3.45	0.69	20.20
Bhaksh 5230	29.87	43.00	3.09	0.66	22.50
EC 9256	30.50	43.33	3.62	0.70	22.80
EC 97631	30.47	43.00	3.29	0.69	20.60
EC 111248	29.43	40.33	3.52	0.70	18.50
BCS 9-76	28.53	45.67	3.92	0.70	22.30
Sudan G.45	31.40	46.33	3.21	**0.63**	22.80
Suvin	32.67	40.33	3.41	0.64	21.60
SE	0.10	0.40	0.04	0.01	0.08
CD 5 %	0.28	1.13	0.09	0.02	0.23

Table 4a. The range for different characters in parental genotypes

S. No.	Character	Min. value	Max. value	Parents recording	
				Lowest value	Highest value
1.	Days to first flowering	61.00	72.33	LRK 516	Surabhi
2.	Plant height (cm)	41.96	82.23	Suvin	SVPR 2
3.	No. of sympodia per plant	6.77	18.87	EC 9256	TCH 1218
4.	No. of monopodia per plant	0.13	3.47	TCH 15	SVPR 2
5.	Number of bolls per plant	3.98	20.60	EC 111248	MCU 5
6.	Boll weight (g)	2.17	4.64	BCS 9-76	TCH 1223
7.	Seed cotton yield (g/plant)	8.98	86.74	EC 111248	TCH 1223
8.	No. of seeds per locule	4.59	8.30	Suvin	SVPR 2
9.	Ginning outturn (%)	30.87	39.98	EC 97631	Sahana
10.	Lint index	1.84	3.89	EC 97631	TCH 1028
11.	Seed index	7.33	12.02	MCU 7	TCH 7
12.	Seed oil content (%)	20.47	25.51	TCB 7	TCH 1609
13.	2.5% span length	24.93	33.10	SVPR 2	TCB 209
14.	Uniformity ratio	40.00	48.33	TCH 975	SVPR 2
15.	Fibre fineness	3.05	4.21	TCH 7	TCH 1223
16.	Maturity coefficient	0.63	0.72	TCH 7	TCH 1223
17.	Bundle strength	17.33	24.10	TCH 1223	TCB 15

The variation was however, limited in respect of maturity coefficient

Table 5. Mean squares for different sources for metrical traits in parents

Sl.No	Characters	Genotypic mean squares (df = 28)	Error mean squares (df = 56)
1.	Days to first flowering	23.98**	4.10
2.	Plant height	526.80**	36.09
3.	No. of sympodia/plant	44.90**	1.64
4.	No. of monopodia/plant	2.44**	0.43
5.	No of bolls/plant	106.26**	0.94
6.	Boll weight	1.54**	0.01
7.	Seed cotton yield/plant	2071.18**	5.79
8.	No. of seeds / locule	2.28**	0.50
9.	Ginning outturn	17.11**	1.62
10.	Lint index	0.86**	0.12
11.	Seed index	2.48**	0.204
12.	Seed oil content	4.71**	0.031
13.	2.5% span length	9.87**	0.03
14.	Uniformity ratio	12.86**	0.48
15.	Fibre fineness	0.27**	0.003
16.	Maturity coefficient	0.002**	0.0001
17.	Bundle strength	12.20**	0.02

** Significant at 1% level

* Significant at 5% level

The phenotypic variances of all the characters were higher than the respective genotypic variances, but for the boll weight, fibre fineness and maturity coefficient, the values were similar.

The GCV and PCV values were generally low to moderate for all the characters studied. The highest GCV was encountered in seed cotton yield per plant and number of monopodia per plant recording the values of 57.00 and 54.32 per cent respectively. However, monopodia per plant had the highest value of 59.82 per cent followed by the seed cotton yield per plant and number of bolls per plant for PCV, the respective values being 57.08 and 43.42 per cent. Low estimates of GCV and PCV were noticed for maturity coefficient, days to first flowering, uniformity ratio, seed oil content, 2.5 per cent span length and ginning outturn (Table.6)

The heritability was high for all the characters. It ranged from 78.34 to 99.84 per cent for different characters. Low and high heritability were recorded by number of seeds per locule and bundle strength respectively. The genetic advance had a range from 0.05 to 53.98 for the characters maturity coefficient and seed cotton yield per plant. The genetic advance as percentage of mean had a range from 6.86 to 117.26 per cent. Seed cotton yield per plant and number of bolls per plant combined high heritability and genetic advance as percentage of mean, while bundle strength, seed oil content, 2.5 per cent span length and fibre fineness registered high heritability and low genetic advance as

Table 6. Mean, genotypic and phenotypic variances, heritability (broad sense) and genetic advance in parents

S. No	Character	Mean	Genotypic variance	Phenotypic variance	GCV (%)	PCV (%)	Heritability (%)	Genetic advance	Genetic advance as percentage of mean
1.	Days of first flowering	68.69	6.63	7.99	3.75	4.12	82.90	4.83	7.03
2.	Plant height	61.93	163.57	175.60	20.65	21.40	93.15	25.43	41.06
3.	No. of sympodia/plant	13.99	14.42	14.97	27.14	27.65	96.34	7.68	54.87
4.	No. of monopodia/plant	1.51	0.67	0.81	54.32	59.82	82.45	1.53	101.6
5.	No of bolls/plant	13.71	35.10	35.42	43.23	43.42	99.11	12.15	88.66
6.	Boll weight	3.24	0.51	0.51	22.08	22.15	99.37	1.47	45.33
7.	Seed cotton yield/plant	46.03	688.47	690.40	57.00	57.08	99.72	53.98	117.26
8.	No. of seeds / locule	6.29	0.60	0.76	12.28	13.87	78.34	1.41	22.38
9.	Ginning outturn	35.22	5.16	5.70	6.45	6.78	90.52	4.45	12.64
10.	Lint index	2.69	0.25	0.29	18.46	19.88	86.29	0.95	35.33
11.	Seed index	8.97	0.76	0.83	9.71	10.14	91.78	1.72	19.17
12.	Seed oil content	23.49	1.56	1.57	5.31	5.33	99.34	2.56	10.91
13.	2.5% span length	29.60	3.28	3.29	6.12	6.13	99.70	3.73	12.59
14.	Uniformily ratio	43.77	4.13	4.29	4.64	4.73	96.29	4.11	9.38
15.	Fibre fineness	3.63	0.09	0.09	8.15	8.20	98.86	0.61	16.69
16.	Maturity coefficient	0.69	0.0006	0.0006	3.42	3.51	95.00	0.05	6.86
17.	Bundle strength	20.38	4.06	4.07	9.89	9.90	99.84	4.15	20.36

percentage of mean. Boll weight had high heritability with moderate genetic advance as percentage of mean. (Table.6).

4.1.4 Genotypic and phenotypic correlations

The seed cotton yield was positively correlated with all the characters except for the days to first flowering, seed index, 2.5 per cent span length and bundle strength which expressed negative correlations both at genotypic and phenotypic levels.

The inter correlations between days to first flowering and all the other characters were negative and low at the genotypic as well as phenotypic levels. Significant positive inter correlations existed between the characters plant height, number of sympodia per plant, number of monopodia per plant, number of bolls per plant, boll weight, number of seeds per locule, ginning outturn, seed oil content and fibre fineness (Table 7 and 8).

Uniformity ratio showed positive correlation with all the other characters except seed index, seed oil content, maturity coefficient and bundle strength. These character combinations showed negative inter correlations both at genotypic and, phenotypic levels. Significant negative inter correlations existed between 2.5 per cent span length and most of the seed and quality characters. Seed index had negative inter correlations with all characters except lint index, 2.5 per cent span length and bundle strength. Negative significant inter correlations existed between bundle strength and other characters except with

Table 7. Genotypic correlation coefficients between different characters in the parents

Character	Plant height	No. of sympo-dia/ plant	No. of mono-podia/ plant	No. of bolls/ plant	Boll weight	No. of seeds/ loule	Ginn-ing outturn	Lint index	Seed index	Seed oil content	2.5% span length	Unifor mity ratio	Fibre fine-ness	Matu-rity coeffi-cient	Bundle strength	Seed cotton yield/ plant
Days to first flowering	0.0562	-0.0770	-0.0696	-0.1274	-0.0401	0.3061	-0.1663	-0.0958	0.1373	-0.0388	0.3055	-0.1578	-0.1829	-0.0866	0.1409	-0.0888
Plant height		0.8908**	0.8076**	0.9120**	0.8217**	0.9571**	0.7043**	0.6700**	-0.2155	0.5620**	-03146	0.1258	0.6845**	0.7037**	-0.5619**	0.9232**
No. of sympodia/ plant			0.8038**	0.9415**	0.8801**	0.8750**	0.7352**	0.7320**	-0.1642	0.7076**	-0.3119	0.0962**	0.7042**	0.6365**	-0.5325	0.9635**
No. of monopodia/ plant				0.9173**	0.7285**	0.9603**	0.4840**	0.5109**	-0.0584	0.4209*	-0.3539	0.2175	0.6244**	0.6390**	-0.6697**	0.8684**
No. of bolls/ plant					0.8092**	0.8689**	0.6417**	0.6118**	-0.1999	0.6300**	-0.3357	0.0670*	0.6043**	0.6713**	-0.5239	0.9615**
Boll weight						0.8411**	0.6393**	0.6657**	-0.1162	0.6117**	-0.1888	0.0841	0.5851**	0.5410**	-0.5200	0.9290**
No. of seeds/ loule							0.6075**	0.4456*	-0.4716**	0.4498*	-0.3873*	0.1633	0.4925**	0.6476**	-0.6061**	0.8806**
Ginning outturn								0.8797**	-0.3833*	0.4013*	-0.3946*	0.1479	0.6614**	0.5283**	-0.3803**	0.7018**
Lint index									0.0932	0.4187*	-0.1448	0.0367	0.5916**	0.4119*	-0.2927	0.6985**
Seed index										-0.1203	0.4872*	-0.1710	-0.2918	-0.3973*	0.2778	-0.1605
Seed oil content											-0.0385	-0.2214	0.4124**	0.3276	-0.2577	0.6319**
2.5% span length												0.6302**	-0.4085*	-0.3831*	0.3047	0.2877
Uniformity ratio													0.2322	-0.0507	-0.0551	0.0789
Fibre fineness														0.8088**	-0.5778**	0.6316**
Maturity coefficient															-0.6992**	0.6388**
Bundle strength																-0.5303

Table 8. Phenotypic correlation coefficients between different characters in the parents

Character	Plant height	No. of sympo-dia/ plant	No. of mono-podia/ plant	No. of bolls/ plant	Boll weight	No. of seeds/ loule	Ginn-ing outturn	Lint index	Seed index	Seed oil content	2.5% span length	Unifor mity ratio	Fibre fine-ness	Matu-rity coeffi-cient	Bundle strength	Seed cotton yield/ plant
Days to first flowering	0.0476	-0.0675	-0.0441	-0.1224	-0.0324	0.2349	-0.1412	-0.0738	0.1333	-0.0431	0.2796	-0.1482	-0.1594	-0.0778	0.1269	-0.0829
Plant height		0.8626**	0.7335**	0.8936**	0.8796**	0.7906**	0.6491**	0.5978**	-0.2107	0.5422**	-0.3009	0.1202	0.6525**	0.6572**	-0.5426**	0.8915**
No. of sympodia/ plant			0.7291**	0.9196**	0.8624**	0.7132**	0.6943**	0.6804**	-0.1497	0.6957**	-0.3034	0.0934	0.6889**	0.6201**	-0.5221	0.9448**
No. of monopodia/ plant				0.8284**	0.6573**	0.7281**	0.4188*	0.4239*	-0.0678	0.3799*	-0.3286	0.1903	0.5549**	0.5667**	-0.6037**	0.7859**
No. of bolls/ plant					0.7992**	0.7540**	0.6065**	0.5677**	-0.1850	0.6261**	-0.3345	0.0672	0.5976**	0.6510**	-0.5212	0.9600**
Boll weight						0.7490**	0.6068**	0.6140**	-0.1148	0.6068**	-0.1878	0.0789	0.5785**	0.5237**	-0.5185**	0.9245**
No. of seeds/ locule							0.5087**	0.3602	-0.3972*	0.3960*	-0.3360	0.1323	0.4408*	0.5683**	-0.5380**	0.7728**
Ginning outturn								0.8772**	-0.3535	0.3822*	-0.3716*	0.1406	0.6256**	0.4837**	-0.3609	0.6651**
Lint index									0.1270	0.3903*	-0.1301	0.0341	0.5494**	0.3679*	-0.2705	0.6472**
Seed index										-0.1156	0.4673*	-0.1623	-0.2736	-0.3714*	0.2659	-0.1521
Seed oil content											-0.0377	-0.2150	0.4082*	0.3236	-0.2561	0.6289**
2.5% span length												-0.6164**	-0.4035*	-0.3718*	0.3038	-0.2871
Uniformity ratio													0.2261	-0.0422	-0.0551	0.0772
Fibre fineness														0.7884**	-0.5743**	0.6264**
Maturity coefficient															-0.6806**	0.6205**
Bundle strength																-0.5295

seed index (0.2778) and 2.5 per cent span length (0.3047) where the association is positive.

4.1.5 Path analysis

Among the seven yield components subjected to path analysis, number of bolls per plant and boll weight exerted high and positive direct effect (Table 9) values being 0.6011 and 0.3769 respectively. The direct effects of number of seeds per locule and number of sympodia per plant were also positive but low in magnitude. Plant height, days to first flowering and number of monopodia per plant influenced the seed cotton yield in the negative direction as seen from the negative values of direct effect - 0.0042, - 0.0236 and - 0.1026 respectively (Fig.1)

The indirect effects of days to first flowering on seed cotton yield was negligible. Plant height influenced the seed cotton yield negatively through all the characters.

Number of sympodia per plant influenced the seed cotton yield positively through plant height (0.0728), number of bolls per plant (0.0769), boll weight (0.0719), number of seeds per locule (0.0666) and number of monopodia per plant (0.0657). However, its indirect effects were low. The indirect effects of monopodia per plant on seed cotton yield were low and positive through days to first flowering, the value being 0.0071. Its indirect effect through all the other characters were negative and low.

Table 9. Direct and indirect effects of different characters in parents (based on genotypic correlations)

Character	Days to first flowering	Plant height (cm)	No. of sympodia/ plant	No. of monopodia / plant	No. of bolls/plant	Boll weight (g)	No. of seeds/ locule	Seed cotton yield/ plant (g)
Days to first flowering	**-0.0236**	-0.0013	0.0018	0.0016	0.0030	0.0009	-0.0072	-0.0888
Plant height	-0.0002	**-0.0042**	-0.0038	-0.0034	-0.0038	-0.0035	-0.0040	0.9232
No. of sympodia/ plant	-0.0063	0.0728	**0.0817**	0.0657	0.0769	0.0719	0.0666	0.9638
No. of monopodia/ plant	0.0071	-0.0828	-0.0825	**-0.1026**	-0.0941	-0.0747	-0.0985	0.8684
No. of bolls/ plant	-0.0766	0.5482	0.5659	0.5514	**0.6011**	0.4864	0.5223	0.9615
Boll weight	-0.0151	0.3097	0.3317	0.2746	0.3050	**0.3769**	0.3170	0.9290
No. of seeds/ locule	0.0259	0.0809	0.0689	0.0812	0.0735	0.0711	**0.0845**	0.8806

Residual effect = 0.0979

Diagonal values indicate direct effects

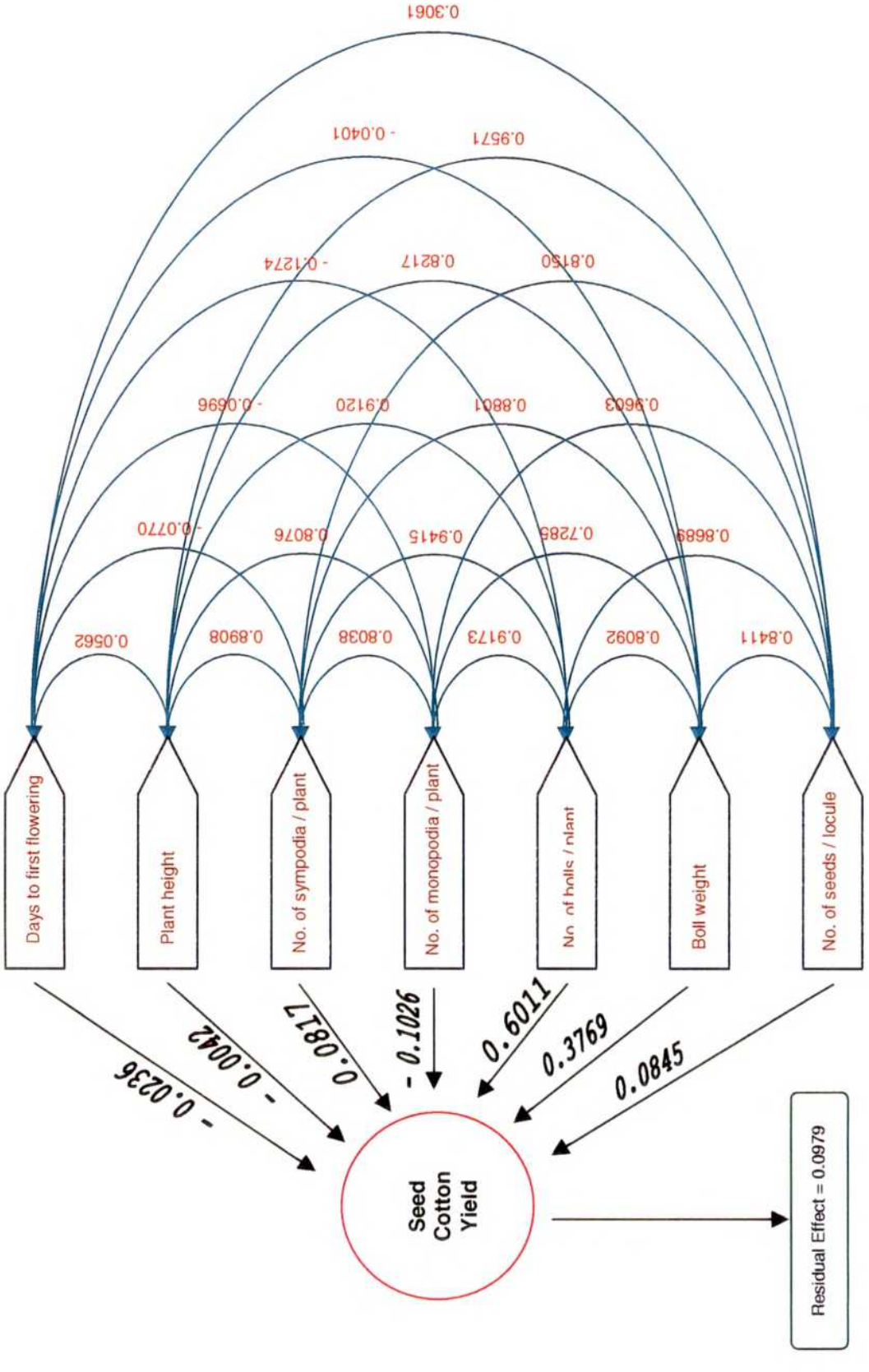

Fig.1 Path diagram of yield and yield component characters

Number of bolls per plant influenced seed cotton yield directly through boll weight, number of seeds per locule, plant height, number of monopodia per plant and number of sympodia per plant, which registered the values 0.4864, 0.5223, 0.5482, 0.5514 and 0.5659 respectively for the characters in the order mentioned. Indirect effect of days to first flowering was negative. Boll weight exerted moderate and positive effects on yield through all the characters while the indirect effect of days to first flowering was negative. Seed cotton yield was influenced positively by number of seeds per locule through all the characters and the effect was low.

In summary it was noticed that the two most important characters in the present study that contribute to seed cotton yield were number of bolls per plant and boll weight.

A very low residual effect of 0.0979 was noticed in the present study.

4.1.6 D^2 analysis

Mahalonobis D^2 statistics was applied to find out the genetic divergence among the 29 parental genotypes used for the study and to classify them based on the relative degree to their diversity.

The genotype constitution of different clusters, inter and intra cluster distances, proportional contribution of different characters to the total genetic

diversity and the mean values for different clusters are presented in tables 10, 11, 12 and 13 respectively and depicted in figures 2 and 3.

The 29 genotypes grouped themselves into six different clusters. Cluster I was the largest comprising 17 genotypes followed by cluster II which included eight genotypes. The clusters III, IV, V and VI had only one genotype each.

Among the 17 genotypes of cluster I, 16 belonged to *G.hirsutum* and one was from *G.barbadense*. In cluster II all the eight genotypes were from *G.barbadense*. Cluster IV had only one genotype from *G.barbadense* and the clusters III, V, and VI included one genotype from *G.hirsutum*.

The intra and inter cluster D and D^2 values are presented in Table 11. The data showed that the cluster I was the least divergent followed by cluster II with D values of 29.55 and 30.12 respectively. The clusters II and V were the most divergent constallations with an inter cluster distance of 72.13 followed by the clusters III and V separated by a D value of 67.03 and cluster III and IV with the inter cluster distance of 60.70.

Regarding the relative contribution of different characters to the total genetic divergence, bundle strength, 2.5 per cent span length, boll weight, fibre fineness and seed oil content, accounted for 99 per cent of the total genetic divergence among the 17 characters studied (Table 12). Their relative contributions were 37.44, 26.11, 16.01, 13.54 and 5.91 per cent respectively for the characters mentioned in the above order. The share of uniformity ratio,

Table 10. Distribution of genotypes in clusters

Cluster number	No. of genotypes	Constituent genotypes	Geographical origin
I	17	MCU 11	Tamil Nadu
		TCH 1218	Tamil Nadu
		TCH 1458	Tamil Nadu
		TCH 1569	Tamil Nadu
		TCH 1025	Tamil Nadu
		TCH 1609	Tamil Nadu
		LRA 5166	Tamil Nadu
		TCH 1028	Tamil Nadu
		TCH 976	Tamil Nadu
		TCH 1233	Tamil Nadu
		TCH 1452	Tamil Nadu
		MCU 9	Tamil Nadu
		MCU 7	Tamil Nadu
		TCH 1223	Tamil Nadu
		LRK 516	Tamil Nadu
		EC 97631	Russia
		Surabhi	Tamil Nadu
II	8	Bhaksh 5230	Russia
		EC 9256	Russia
		Sudan G.45	Sudan
		TCB 7	Tamil Nadu
		TCB 15	Tamil Nadu
		BCS 9-76	India
		Suvin	Tamil Nadu
		TCB 209	Tamil Nadu
III	1	MCU 5	Tamil Nadu
IV	1	EC 111248	Russia
V	1	SVPR 2	Tamil Nadu
VI	1	Sahana	Karnataka

Table 11. Inter and intra cluster distances (D) (and D^2 values in brackets) between different groups of cotton genotypes

Cluster number	I	II	III	IV	V	VI
I	29.55 (873.20)	48.39 (2341.59)	42.90 (1840.41)	41.64 (1733.89)	44.52 (1982.03)	44.84 (1996.28)
II		30.12 (907.21)	41.66 (1735.56)	41.17 (1694.97)	72.13 (5202.74)	57.26 (3278.71)
III			0	60.70 (3684.49)	67.03 (4493.02)	50.06 (2506.00)
IV				0	58.26 (3394.23)	58.64 (3438.65)
V					0	36.75 (1350.56)
VI						0

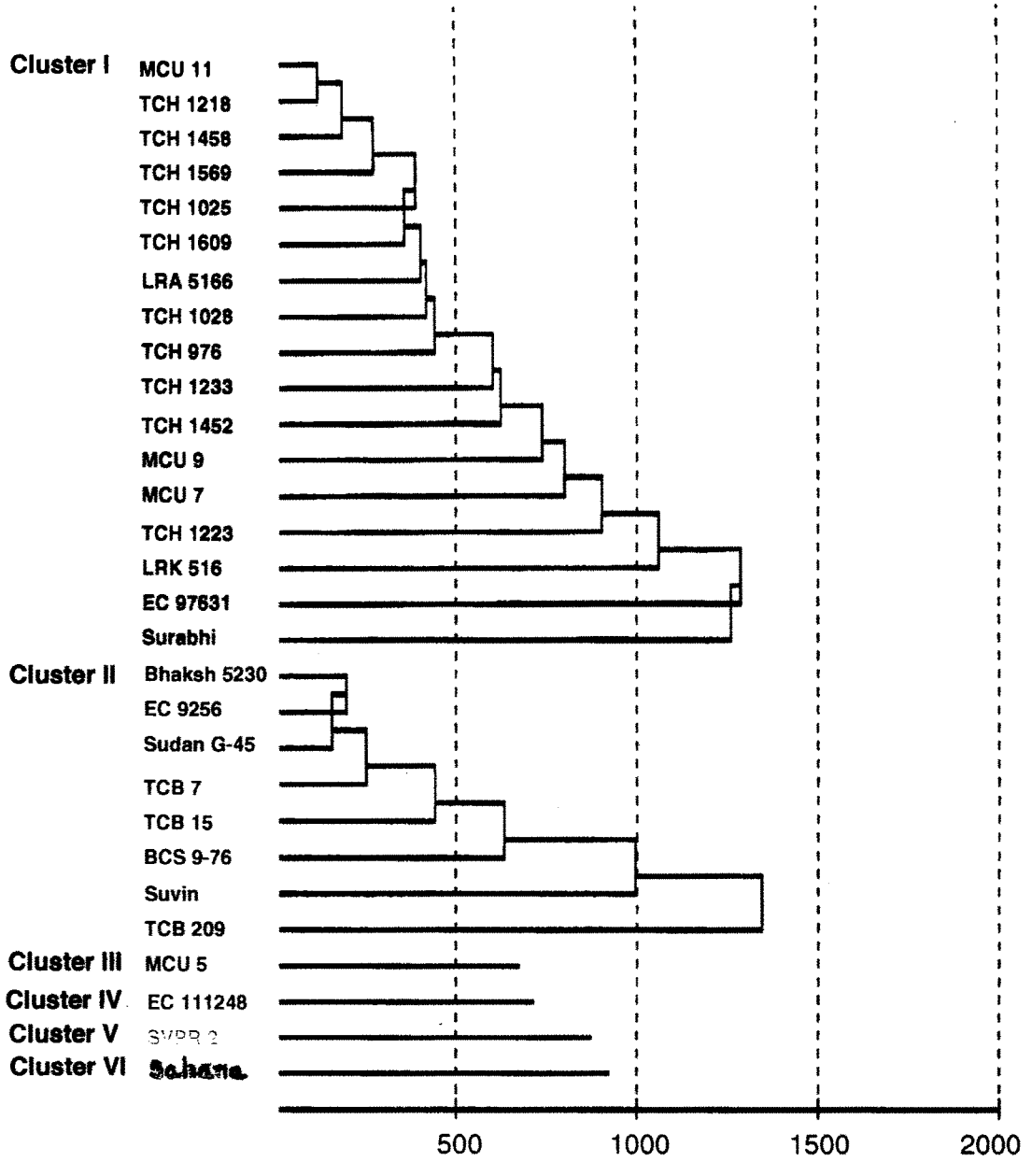

Fig.2 Dendrogram showing the grouping of parental genotypes as per D^2 analysis

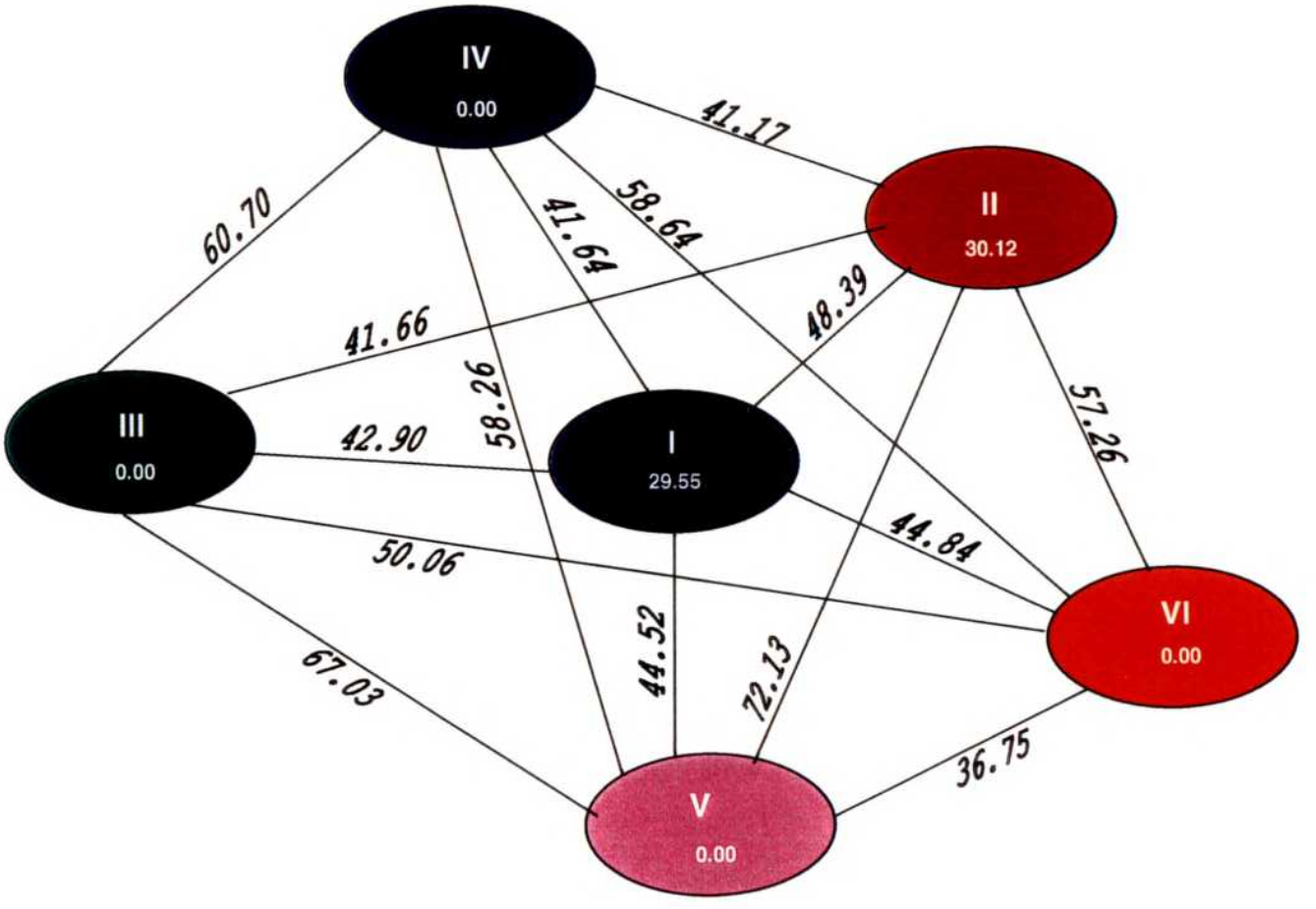

Fig.3 Cluster diagram showing the inter- cluster and intra - cluster distances

Table 12. Contribution of characters to genetic divergence in parental genotypes

Characters	Number of first ranks	Percentage contribution to genetic divergence
Bundle strength	152	37.44
2.5 per cent span length	106	26.11
Boll weight	65	16.01
Fibre fineness	55	13.54
Seed oil content	24	5.91
Uniformity ratio	2	0.49
Number of bolls per plant	1	0.25
Seed index	1	0.25
Total		**100.00**

The contribution of other characters towards genetic diversity was nil.

number of bolls per plant and seed index was very meagre while the contribution of other characters was totally nil.

In general, the mean values of different clusters for the characters studied (Table. 13) indicated that the means of different clusters differed significantly for bundle strength and for the other characters, the cluster means were within the limit of critical difference.

4.2 Study of intra-*hirsutum* hybrid

4.2.1 Mean expression of different traits in the F_1 hybrids

The mean expression of 15 characters recorded on 49 hybrids are presented in Table 14.

4.2.1.1 Days to first flowering

The range for days to first flowering was from 64.47 to 70.33. The lowest value was recorded by MCU 11 x LRK 516 and the highest value was seen in the hybrids MCU 9 x TCH 1233, TCH 1025 x TCH 1458, TCH 1028 x TCH 1218, TCH 1028 x TCH 1233, LRA 5166 x TCH 1233 and LRA 5166 x TCH 1452. The mean value was 68.37 and six hybrids were lower than the mean value.

4.2.1.2 Plant height

The lowest and highest values for plant height of 43.72 and 80.95 were recorded in MCU 11 x LRK 516 and TCH 976 x TCH 1458 respectively. The mean was 61.72 cm and seven hybrids surpassed the mean expression.

Table 13. Mean values of different traits for group constellations of cotton

Group	No. of geno types	Days to first flowering	Plant height	No. of sympodia / plant	No. of monopodia /plant	No. of bolls /plant	Boll weight	Seed cotton yied /plant	No. of seeds/ locule	Ginning outturn
I	17	68.41	68.46	15.97	1.87	16.93	3.62	60.17	6.67	35.56
II	7	68.96	47.69	9.50	0.66	6.42	2.42	14.55	5.27	33.32
III	1	69.67	59.76	16.07	1.87	20.60	3.60	72.67	6.93	36.80
IV	2	69.33	42.47	9.17	0.17	3.98	2.42	8.98	5.45	35.62
V	1	71.33	83.23	16.80	3.47	19.37	3.85	71.51	3.30	37.76
VI	1	67.00	65.19	16.33	1.13	14.29	3.08	42.41	6.27	39.98
	CD	3.31	9.83	2.10	1.08	1.59	0.16	3.93	1.15	2.08

Group	No. of genotypes	Lint index	Seed index	Seed oil content	2.5% span length	Uniformity ratio	Fibre fineness	Maturity coefficient	Bundle strength
I	17	2.80	8.97	24.05	29.41	43.73	3.71	0.70	19.38
II	7	2.36	9.45	22.37	30.87	43.67	3.37	0.66	22.47
III	1	2.91	8.56	23.80	31.10	41.67	3.51	0.69	23.60
IV	2	2.51	8.21	22.31	29.43	40.33	3.52	0.70	18.50
V	1	2.73	7.41	22.60	24.93	48.33	3.94	0.71	17.63
VI	1	3.44	7.74	24.54	26.10	46.33	4.01	0.70	22.07
	CD	0.56	0.74	0.29	0.28	1.13	0.09	0.02	0.23

Table 14. Mean expression of different characters in the intraspecific hybrids

Characters / Hybrids	Days to first flowering	Plant height (cm)	No. of sympodia per plant	No. of monopodia per plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)	No. of seeds per locule	Ginning out-turn (%)	Lint index (g)	Seed index (g)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micronaire)	Bundle strength (1/8 gauge g/tex)
MCU 5 x Surabhi	68.67	55.71	11.47	0.60	20.81	3.98	80.67	6.63	35.54	2.68	8.79	29.10	45.00	3.60	19.60
MCU 5 x SVPR 2	69.33	69.68	16.13	1.22	21.45	4.29	89.78	6.75	**41.81**	3.68	8.58	30.50	42.00	3.63	21.00
MCU 5 x LRK 516	69.00	50.89	14.33	1.40	16.09	**3.33**	**51.89**	**5.95**	37.12	3.01	8.64	30.10	44.00	3.33	20.50
MCU 5 x TCH 1569	69.33	54.91	11.87	0.73	25.57	3.96	99.71	6.88	36.45	3.03	9.20	30.00	**40.00**	3.53	20.50
MCU 5 x TCH 1609	70.00	66.55	16.27	1.27	19.93	4.23	82.21	6.66	35.87	3.21	10.26	**31.20**	43.00	3.73	19.50
MCU 7 x Surabhi	69.33	60.25	12.67	1.60	18.08	3.42	59.76	6.78	36.01	2.73	8.60	26.90	43.00	3.43	21.50
MCU 7 x SVPR 2	69.67	60.57	14.31	0.60	19.52	4.00	77.08	7.61	33.63	2.14	8.32	**25.70**	44.00	3.83	**16.50**
MCU 7 x LRK 516	67.33	45.20	10.13	0.38	18.28	3.60	63.66	6.78	35.20	2..55	8.62	26.50	42.00	3.93	18.60
MCU 7 x Sahana	65.33	64.99	15.20	1.07	17.06	3.74	61.45	7.37	37.50	3.09	8.60	27.80	44.00	4.03	16.57
MCU 7 x TCH 1218	69.00	55.51	15.13	0.30	22.34	3.74	79.89	6.52	38.02	3.01	8.02	27.80	43.00	**4.53**	17.90
MCU 7 x TCH 1223	67.00	63.55	14.27	0.93	19.68	4.40	83.34	7.31	36.44	2.82	8.59	28.80	45.00	3.48	20.70
MCU 7 x TCH 1233	66.67	65.89	12.93	1.13	20.32	3.96	78.65	6.82	37.02	3.27	9.44	27.60	45.00	3.63	20.20
MCU 7 x TCH 1452	68.33	65.28	15.93	0.93	15.56	4.64	70.18	7.30	35.96	2.83	8.98	27.00	45.00	3.73	21.70
MCU 7 x TCH 1458	65.33	67.65	15.53	1.13	19.89	4.01	77.62	7.25	36.07	2.65	8.21	26.30	44.00	4.03	18.70
MCU 7 x TCH 1569	67.33	46.45	11.80	**0.29**	16.68	3.66	59.16	6.28	33.64	2.19	8.51	28.40	41.00	3.43	18.70
MCU 7 x TCH 1609	66.00	51.53	13.67	1.20	16.65	3.99	64.28	6.58	37.39	3.10	8.67	28.10	44.00	4.03	19.00
MCU 9 x TCH 1223	69.33	54.32	13.10	0.3	25.91	3.93	100.04	6.68	37.39	3.28	9.08	29.40	41.00	4.23	20.20
MCU 9 x TCH 1233	**70.33**	57.37	15.50	0.87	17.84	4.94	84.98	7.07	37.49	4.79	10.32	30.30	43.00	3.63	20.70

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Characters / Hybrids	Days to first flowering	Plant height (cm)	No. of sympodia per plant	No. of monopodia per plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)	No. of seeds per locule	Ginning outturn (%)	Lint index (g)	Seed index (g)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micronaire)	Bundle strength (1/8 gauge g/tex)
MCU 9 x TCH 1452	69.67	66.10	14.07	1.40	16.31	4.79	75.45	6.92	37.69	4.29	10.27	29.70	41.00	3.23	20.50
MCU 9 x TCH 1458	69.00	55.98	12.40	0.88	15.08	4.71	69.00	7.38	39.24	3.88	9.85	30.10	42.00	3.60	20.50
MCU 9 x TCH 1569	68.67	59.33	14.78	0.78	19.18	3.87	72.32	7.17	38.57	3.43	10.10	30.60	45.00	3.68	**24.10**
MCU 9 x TCH 1609	69.33	47.96	**9.44**	0.33	23.15	3.52	79.40	6.81	36.82	3.65	8.52	30.70	42.00	3.40	20.80
MCU 11 x LRK 516	**64.67**	**43.72**	10.84	0.67	19.93	3.90	75.68	6.59	39.55	3.39	8.60	27.60	44.00	3.23	22.70
MCU 11 x TCH 1218	69.67	70.47	15.40	0.93	20.73	4.97	100.81	**8.06**	37.98	3.40	9.02	26.40	44.00	3.35	20.40
MCU 11 x TCH 1223	69.00	58.07	13.87	0.73	23.87	4.20	97.38	7.04	38.81	3.78	9.40	26.50	46.00	3.78	20.90
MCU 11 x TCH 1233	67.33	66.59	1658	0.64	17.84	4.75	82.64	7.58	38.72	3.80	9.51	27.10	42.00	3.13	18.30
MCU 11 x TCH 1452	67.67	65.01	15.33	1.27	22.02	3.88	83.09	6.87	39.03	3.55	8.66	27.10	44.00	3.78	18.90
MCU 11 x TCH 1609	65.67	52.47	11.67	1.07	24.04	4.02	94.19	7.04	36.88	3.27	9.54	26.30	45.00	3.83	19.80
TCH 976 x TCH 1218	69.67	79.26	**17.36**	1.24	16.05	4.57	71.03	7.10	36.07	3.12	9.82	26.60	45.00	3.05	19.80
TCH 976 x TCH 1233	65.67	76.97	16.40	1.38	16.07	4.25	66.34	7.08	38.58	3.89	9.66	28.20	40.00	3.38	18.40
TCH 976 x TCH 1452	69.00	74.99	16.13	1.33	18.67	4.49	82.05	7.04	37.18	3.68	10.45	28.80	43.00	2.99	18.40
TCH 976 x TCH 1458	68.67	**80.95**	16.37	1.07	19.18	4.73	88.46	6.69	36.46	3.68	**11.16**	28.70	43.00	3.34	19.30
TCH 976 x TCH 1569	69.00	59.81	11.20	1.00	**27.87**	3.44	93.04	7.18	**33.11**	**2.04**	8.32	26.40	43.00	3.31	16.50
TCH 976 x TCH 1609	66.00	64.80	15.17	1.89	20.72	4.05	81.06	6.77	36.78	3.91	9.26	29.20	43..00	3.77	18.30
TCH 976 x Sahana	67.00	69.65	16.53	1.40	19.33	4.18	70.80	7.12	38.35	3.32	8.59	26.30	**47.00**	3.33	19.30
TCH 1025 x Surabhi	69.00	56.72	13.22	0.87	20.59	3.68	74.02	6.77	36.16	2.79	8.69	26.80	45.00	3.10	19.80
TCH 1025 x SVPR 2	68.67	71.91	16.93	1.60	22.93	4.84	109.01	7.90	37.08	3.56	10.35	26.50	46.00	3.87	19.60

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Characters / Hybrids	Days to first flowering	Plant height (cm)	No. of sympodia per plant	No. of monopodia per plant	No. of bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)	No. of seeds per locule	Ginning out-turn (%)	Lint index (g)	Seed index (g)	2.5% span length (mm)	Uniformity ratio (%)	Fibre fineness (micronaire)	Bundle strength (1/8 gauge g/tex)
TCH 1025 x LRK 516	70.00	57.24	11.47	0.40	**13.18**	4.11	51.90	6.40	38.10	3.51	9.25	26.90	45.00	3.25	18.30
TCH 1025 x TCH 1458	70.33	65.08	14.07	0.93	20.41	4.39	87.60	6.86	40.56	**4.44**	9.51	28.50	43.00	3.55	18.80
TCHL 1028 x LRK 516	65.00	53.07	13.60	0.38	20.96	3.66	74.85	6.38	37.82	3.37	9.10	27.80	41.00	3.52	19.20
TCH 1028 x Sahana	67.67	51.16	11.80	1.68	19.36	3.87	76.03	6 .96	40.19	4.01	10.15	29.00	42.00	3.82	19.20
TCH 1028 x TCH 1218	70.33	79.74	16.68	1.85	21.51	**5.02**	105.57	7.43	38.52	4.09	9.43	20.20	42.00	3.50	19.00
TCH 1028 x TCH 1233	70.33	50.14	14.85	0.47	15.80	4.15	63.33	6.65	39.71	3.27	9,48	29.90	40.00	3.38	20.00
TCH 1028 x TCH 1458	69.67	65.48	15.00	0.67	24.74	4.10	88.02	6.30	36.99	2.78	11.03	30.50	40.00	3.62	29.90
TCH 1028 x TCH 1569	69.33	80.16	17.33	1.87	22.04	4.63	99,69	6.18	33.42	2.86	**7.75**	27.10	45.00	3.45	21.00
LRA 5166 x TCH 1223	66.67	39.05	11.20	0.74	20.81	4.57	92.44	7.01	38.01	3.32	10.45	29.70	42.00	3.93	21.70
LRA 5166 x TCH 1233	70.33	65.66	14.04	1.11	23.29	4.81	**110.00**	7.01	35.49	4.02	9.91	29.00	43.00	3.72	21.20
LRA 5166 x TCH 1452	70.33	76.24	14.13	**2.09**	23.13	4.61	104.81	7.01	38.92	3.38	10.10	28.10	41.00	**2.84**	21.10
LRA 5166 x TCH 1609	69.67	54.35	14.17	0.67	20.15	3.52	69.42	6.31	36.68	3.31	9.27	28.23	43.20	3.17	19.90
Savitha (Check)	69.67	56.66	12.30	1.33	21.71	3.72	80.27	6.93	35.78	3.18	8.50	30.10	45.00	3.20	20.90
Mean	68.37	61.72	14.13	1.01	20.02	4.17	80.85	6.92	37.29	0.20	0.33	0.13	0.53	3.57	19.75
SE	0.89	3.75	1.12	0.44	1.06	0.21	3.45	0.32	0.97	0.20	0.33	0.13	0.53	0.02	0.07
CD (5%)	2.49	10.49	3.13	1.23	2.96	0.59	9.65	0.90	2.71	0.56	0.92	0.36	1.48	0.06	0.20

4.2.1.3 Number of sympodia per plant

Number of sympodia per plant was minimum in MCU 9 x TCH 1609 and the maximum in TCH 976 x TCH 1218, the values being 9.44 and 17.36 respectively. Two hybrids were superior to the mean expression of 14.13.

4.2.1.4 Number of monopodia per plant

The range for number of monopodia per plant was from 0.29 to 2.09 recorded by MCU 7 x TCH 1569 and LRA 5166 x TCH 1452 respectively. None of the hybrids had lower values than the genotypic mean.

4.2.1.5 Number of bolls per plant

The range for number of bolls per plant was from 13.18 to 27.87. The lowest and highest number of bolls were registered by TCH 1025 x LRK 516 and TCH 976 x TCH 1569 respectively. Nine hybrids surpassed the mean value of 20.02.

4.2.1.6 Boll weight

The smallest bolls weighing 3.33 g. were produced by the cross MCU 5 x LRK 516 while biggest bolls weighing 5.02g were discernible in TCH 1028 x TCH 1218. The mean value was 4.17 g. and six hybrids exceeded the mean expression.

4.2.1.7 Seed cotton yield per plant

The lowest value of 51.89 g. for single plant yield was recorded in MCU 5 x LRK 516 and the highest yield of 110.00g was found in LRA.5166 x TCH 1233. Twelve hybrids were higher yielding when compared to the mean value of 80.85 g.

4.2.1.8 Number of seeds per locule

MCU 5 x LRK 516 and MCU 11 X TCH 1218 recorded the lowest and highest values of 5.95 and 8.06 respectively for number of seeds per locule and two hybrids were superior to the hybrid mean.

4.2.1.9 Ginning outturn

Ginning outturn recorded the mean expression of 37.29 per cent, and the range was from 33.11 per cent in TCH 976 x TCH 1569 and 41.81 per cent in MCU 5 x SVPR.2 respectively. Three hybrids had higher ginning outturn as compared to the general mean.

4.2.1.10 Lint index

The range for lent index was from 2.04 to 4.44 grams registered by TCH 976 x TCH 1569 and TCH 1025 x TCH 1458 respectively. The lint index was superior in seven hybrids when the mean lint index of 3.31 was considered as the standard.

4.2.1.11 Seed index

The hybrids LRA 5166 x TCH 1223 and TCH 976 x TCH 1458 recorded the minimum and maximum values of 7.75 g. and 11.16g respectively for seed index. Eight hybrids exceeded the mean expression of 9.27 g.

4.2.1.12 2.5 per cent span length

The 2.5 per cent span length displayed a range of 25.70 mm in MCU 7 x SVPR.2 and 31.20 mm in MCU 5 x TCH 1609 respectively. The mean was 28.23 mm and a total of 21 hybrids surpassed this value.

4.2.1.13 Uniformity ratio

The range for uniformity ratio was from 40.00 to 47.00 per cent. The lowest value was recorded by the hybrids MCU 5 x TCH 1569, TCH 976 x TCH 1233, TCH 1028 x TCH 1458 and TCH 1028 x TCH 1569 and the highest value by TCH 976 x JK 876 - 8 - 2. The mean value was exceeded by 14 hybrids.

4.2.1.14 Fibre fineness

Fibre fineness recorded the mean expression of 3.57 micronaire, and the range was from 2.84 to 4.53 micronaire in LRA.5166 x TCH 1452 and MCU 7 x TCH 1218 respectively. Seventeen hybrids exhibited micronaire values exceeding the general mean of hybrids and three were equal to the mean expression.

4.2.1.15 Bundle strength

Bundle strength was found to be minimum in MCU 7 x SVPR.2 and TCH 976 x TCH 1569, the values registered being 16.5 g./tex while MCU 9 x TCH 1569 registered maximum bundle strength of 24.10 g./tex. Twenty one hybrids had higher bundle strength than the average strength of hybrids.

4.2.2 Expression of heterosis

4.2.2.1 Days to first flowering

The manifestation of heterosis over the mid parental value, better parental value and best check has been presented in Table 15.

Twelve cross combinations were heterotic over the respective mid parental values in the positive direction and the expression varied from 3.69 to 9.90 per cent. Seven hybrids displayed negative heterosis which ranged from -3.12 to 6.44 per cent. Significant negative expression for heterobeltiosis between -3.74 to -9.30 per cent was exhibited by 12 hybrids.The hybrids MCU 11 x TCH 1223 and LRA 5166 x TCH 1233 registered significant positive heterosis, the values being 5.61 and 7.65 per cent respectively. The estimates of standard heterosis was found to be negatively significant in 12 hybrids and the values ranged from -3.83 to -7.18 per cent.

4.2.2.2 Plant height

The heterotic expression for plant height is presented in Table 16.

Table 15. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for days to first flowering

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-3.29*	-5.07**	-1.44
MCU 5 x SVPR 2	-1.65	-2.80	-0.48
MCU 5 x LRK 516	5.61**	-0.96	-0.96
MCU 5 x TCH 1569	-0.95	-1.42	-0.48
MCU 5 x TCH 1609	1.45	0.48	0.48
MCU 7 x Surabhi	-1.65	-4.15*	-0.48
MCU 7 x SVPR 2	-0.48	-2.34	0.00
MCU 7 x LRK 516	3.86*	-1.94	-3.35
MCU 7 x Sahana	-3.69*	-4.85**	-6.22**
MCU 7 x TCH 1218	-1.19	-2.82	-0.96
MCU 7 x TCH 1223	0.00	-2.43	-3.83*
MCU 7 x TCH 1233	-0.50	-2.91	-4.31*
MCU 7 x TCH 1452	-2.38	-4.21*	-1.91
MCU 7 x TCH 1458	-6.44**	-7.98**	-6.22**
MCU 7 x TCH 1569	-3.12*	-4.27*	-3.35
MCU 7 x TCH 1609	-3.65*	-3.88*	-5.26**
MCU 9 x TCH 1223	2.21	-1.42	-0.48
MCU 9 x TCH 1233	3.69*	0.00	0.96
MCU 9 x TCH 1452	-1.65	-2.34	0.00
MCU 9 x TCH 1458	-2.36	-2.82	-0.96
MCU 9 x TCH 1569	-2.37	-2.37	-1.44
MCU 9 x TCH 1609	0.00	-1.42	-0.48
MCU 11 x LRK 516	4.02*	2.11	-7.18**
MCU 11 x TCH 1218	3.72*	-1.88	0.00
MCU 11 x TCH 1223	7.25**	5.61**	-0.96
MCU 11 x TCH 1233	4.66**	3.06	-3.35
MCU 11 x TCH 1452	0.50	-5.14**	-2.87
MCU 11 x TCH 1609	-0.25	-3.90	-5.74**
TCH 976 x TCH 1218	0.48	-1.88	0.00
TCH 976 x TCH 1233	-1.25	-2.96	-5.74**
TCH 976 x TCH 1452	-0.72	-3.27	-0.96
TCH 976 x TCH 1458	-0.96	-3.29	-1.44
TCH 976 x TCH 1569	0.00	-1.90	-0.96
TCH 976 x TCH 1609	-2.94	-3.41	-5.26**
TCH 976 x Sahana	-0.50	-0.99	-3.83*
TCH 1025 x Surabhi	-3.72*	-4.61**	-0.96
TCH 1025 x SVPR 2	-3.51*	-3.74*	-1.44
TCH 1025 x LRK 516	6.06**	-1.41	0.48
TCH 1025 x TCH 1458	-0.94	-0.94	0.96
TCHL 1028 x LRK 516	-2.01	-9.30**	-6.70**
TCH 1028 x Sahana	-2.40	-5.58**	-2.87
TCH 1028 x TCH 1218	-1.40	-1.86	0.96
TCH 1028 x TCH 1233	2.68	-1.86	0.96
TCH 1028 x TCH 1458	-2.34	-2.79	0.00
TCH 1028 x TCH 1569	-2.35	-3.26	-0.48
LRA 5166 x TCH 1223	4.17*	2.04	-4.31**
LRA 5166 x TCH 1233	9.90**	7.65**	0.96
LRA 5166 x TCH 1452	4.98**	-1.40	0.96
LRA 5166 x TCH 1609	6.36**	1.95	0.00
SE	0.77	0.89	0.89

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Significant negative heterosis over mid-parental value was noticed in 17 hybrids. The expression had a range from - 14.62 to - 35.02 per cent. Twenty six hybrids exhibited significant negative expression for heterobeltiosis. The values varied from -13.60 to -41.54 per cent. Standard heterosis was found to be positively significant in 12 hybrids. In these combinations heterosis ranged from 19.41 to 42.88 per cent, MCU 7 x TCH 1458 and TCH 976 x TCH 1458 recording the lowest and highest values. It was also negatively significant in the hybrids MCU 7 x LRK 516 and MCU 11 x LRK 516 and these hybrids registered the values -20.23 and -22.83 respectively.

4.2.2.3 Number of sympodia per plant

Expression of heterosis based on all the three criteria is furnished in Table 17. None of the hybrids were heterotic when compared to their mid parental or better parental values. However, standard heterosis was found to be significant in the positive direction in 14 hybrids. The range was from 26.02 to 41.11 per cent in hybrids MCU 9 x TCH 1233 and TCH 976 x TCH 1218 respectively.

4.2.2.4 Number of monopodia per plant

Expression of heterosis in hybrids has been presented in Table 18. Heterosis over mid-parental value was significant and negative in 22 hybrids and the range varied from -53.33 to -86.49 per cent. The estimates of heterobeltiosis was negatively significant in 25 hybrids. In these hybrids the expression varied

Table 16. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for plant height

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-16.01*	-23.57**	-1.67
MCU 5 x SVPR 2	-2.53	-16.27*	22.99*
MCU 5 x LRK 516	-8.11	-14.85	-10.18
MCU 5 x TCH 1569	-19.53**	-28.43**	-3.09
MCU 5 x TCH 1609	2.76	-4.61	17.47
MCU 7 x Surabhi	-2.58	-17.35*	6.34
MCU 7 x SVPR 2	-9.61	-27.22**	6.91
MCU 7 x LRK 516	-11.20	-11.38	-20.23**
MCU 7 x Sahana	12.07	-0.31	14.70
MCU 7 x TCH 1218	-15.27*	-30.81**	-2.03
MCU 7 x TCH 1223	-4.09	-22.23**	12.16
MCU 7 x TCH 1233	10.91	-3.14	16.30
MCU 7 x TCH 1452	7.72	-7.28	15.22
MCU 7 x TCH 1458	10.18	-6.05	19.41
MCU 7 x TCH 1569	-27.15**	-39.45**	-18.02
MCU 7 x TCH 1609	-14.51	-26.14**	-9.04
MCU 9 x TCH 1223	-26.63**	-33.52**	-4.12
MCU 9 x TCH 1233	-14.62*	-15.66*	1.26
MCU 9 x TCH 1452	-3.34	-6.12	16.67
MCU 9 x TCH 1458	-19.09**	-22.26**	-1.20
MCU 9 x TCH 1569	-17.07**	-22.66**	4.71
MCU 9 x TCH 1609	-29.54**	-31.26**	-15.34
MCU 11 x LRK 516	-30.48**	-41.54**	-22.83*
MCU 11 x TCH 1218	-9.08	-12.16	24.37*
MCU 11 x TCH 1223	-25.79**	-28.94**	2.49
MCU 11 x TCH 1233	-6.75	-10.96	17.53
MCU 11 x TCH 1452	-10.46	-13.08	14.74
MCU 11 x TCH 1609	27.41*	-29.84**	-7.40
TCH 976 x TCH 1218	3.71	-1.19	39.90**
TCH 976 x TCH 1233	9.44	5.96	35.85**
TCH 976 x TCH 1452	4.84	5.96	32.35**
TCH 976 x TCH 1458	11.93	11.44	42.88**
TCH 976 x TCH 1569	-19.91**	-22.03**	5.57
TCH 976 x TCH 1609	-8.99	-10.79	14.38
TCH 976 x Sahana	1.06	-4.12	22.93
TCH 1025 x Surabhi	-20.01**	-22.19**	0.11
TCH 1025 x SVPR 2	-5.48	-13.60*	26.92
TCH 1025 x LRK 516	-4.54	-16.95*	1.03
TCH 1025 x TCH 1458	-7.64	-9.62	14.87
TCHL 1028 x LRK 516	-11.50	-23.01**	-6.34
TCH 1028 x Sahana	-23.70**	-25.77**	-9.70
TCH 1028 x TCH 1218	6.92	-0.60	40.74**
TCH 1028 x TCH 1233	-26.78	-27.26**	-11.50
TCH 1028 x TCH 1458	-7.07	-9.06	15.58
TCH 1028 x TCH 1569	10.08	4.49	41.48**
LRA 5166 x TCH 1223	-35.02**	-39.98**	-13.43
LRA 5166 x TCH 1233	-4.34	-5.18	15.89
LRA 5166 x TCH 1452	9.18	8.29	35.46**
LRA 5166 x TCH 1609	-21.81**	-22.10**	-4.07
SE	3.25	3.75	3.75

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 17. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for number of sympodia per plant

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-28.48**	-28.63**	-6.78
MCU 5 x SVPR 2	-1.83	-3.97	31.17*
MCU 5 x LRK 516	3.61	-10.79	16.53
MCU 5 x TCH 1569	-31.01**	-35.27	-3.52
MCU 5 x TCH 1609	3.83	1.24	32.25
MCU 7 x Surabhi	-9.74	-20.83*	2.98
MCU 7 x SVPR 2	-0.85	-14.82	16.34
MCU 7 x LRK 516	-14.37	-16.02	-17.62
MCU 7 x Sahana	7.04	-6.94	23.58
MCU 7 x TCH 1218	-2.16	-19.79*	23.04
MCU 7 x TCH 1223	-7.26	-23.91**	15.99
MCU 7 x TCH 1233	-16.20	-31.21**	5.15
MCU 7 x TCH 1452	13.27	-0.83	29.54*
MCU 7 x TCH 1458	3.90	-12.90	26.29*
MCU 7 x TCH 1569	-22.37*	-35.64**	-4.07
MCU 7 x TCH 1609	0.00	-10.48	11.11
MCU 9 x TCH 1223	-26.06**	-29.95**	6.50
MCU 9 x TCH 1233	-12.76	-17.55*	26.02*
MCU 9 x TCH 1452	-14.23	-15.94	14.36
MCU 9 x TCH 1458	-28.25**	-30.47**	0.81
MCU 9 x TCH 1569	-15.70*	-19.38*	20.16
MCU 9 x TCH 1609	-41.02**	-43.61**	-23.28
MCU 11 x LRK 516	-26.65**	-39.65**	-11.84
MCU 11 x TCH 1218	-16.38*	-18.37*	25.20
MCU 11 x TCH 1223	-24.36**	-25.85**	12.74
MCU 11 x TCH 1233	-9.79	-11.79	34.82**
MCU 11 x TCH 1452	-9.89	-14.66	24.66
MCU 11 x TCH 1609	-29.79**	-35.06**	-5.15
TCH 976 x TCH 1218	2.50	-8.00	41.11**
TCH 976 x TCH 1233	-2.96	-12.77	33.33*
TCH 976 x TCH 1452	3.86	0.41	31.17*
TCH 976 x TCH 1458	-0.26	-8.19	33.12*
TCH 976 x TCH 1569	-32.80**	-38.91**	-8.94
TCH 976 x TCH 1609	0.22	-0.66	23.31
TCH 976 x Sahana	5.53	1.22	34.42**
TCH 1025 x Surabhi	-15.91	-17.40	7.45
TCH 1025 x SVPR 2	5.07	0.79	37.67**
TCH 1025 x LRK 516	-15.17	-25.70*	-6.78
TCH 1025 x TCH 1458	-15.43	-21.12*	14.36
TCHL 1028 x LRK 516	-8.00	-24.30**	10.57
TCH 1028 x Sahana	-31.20**	-34.32**	-4.07
TCH 1028 x TCH 1218	-9.41	-11.57	35.64**
TCH 1028 x TCH 1233	-19.22*	-21.01*	20.73
TCH 1028 x TCH 1458	-16.20*	-16.51	21.95
TCH 1028 x TCH 1569	-4.50	-5.45	40.92
LRA 5166 x TCH 1223	-36.06*	-40.11**	-8.94
LRA 5166 x TCH 1233	-20.06**	-25.30**	14.17
LRA 5166 x TCH 1452	-12.76	-13.47	14.91
LRA 5166 x TCH 1609	-10.34	-13.27	15.18
SE	0.97	1.12	1.12

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

between -53.85 to -89.13 per cent. Standard heterosis was not significant in any of the combinations.

4.2.2.5 Number of bolls per plant

Expression of heterosis is presented in Table 19. Significant positive heterosis over mid-parental values was noticed in 27 hybrids and the percentage of expression varied from 14.19 to 49.69 in the hybrids MCU 5 x Surabhi and MCU 7 x TCH 1218 respectively. Four hybrids expressed negative heterosis. In 14 hybrids heterobeltiotic values were positive ranging from 16.53 to 36.81 per cent, the lowest and highest values having been recorded in the hybrids TCH 1028 x TCH 1218 and MCU 11 x TCH 1609 respectively. Seven hybrids registered negative heterosis over the better parent. In respect of standard heterosis four hybrids namely MCU 5 x TCH 1569, MCU 9 x TCH 1223, TCH 976 x TCH 1569 and TCH 1028 x TCH 1458 displayed significant positive expression, the minimum and maximum values being 13.99 and 28.39 per cent respectively. Fifteen hybrids were negatively heterotic.

4.2.2.6 Boll weight

Expression of heterosis based on all the three criteria is presented in Table 20. Positive heterotic effect over mid parental values were discernible in 26 hybrids with a range of 14.40 to 48.87 recorded by the hybrids MCU 9 x TCH 1458 and LRA 5166 x TCH 1452 respectively. None of the hybrids were negatively heterotic over the mid parental values. The heterotic effect over better parent was in the postive direction in 13 hybrids. The range of expression varied

Table 18. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for number of monopodia per plant

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-66.04*	-67.86*	-55.00
MCU 5 x SVPR 2	-54.38**	-64.90**	-8.75
MCU 5 x LRK 516	-31.15	-36.36	5.00
MCU 5 x TCH 1569	-67.65**	-72.50**	-45.00
MCU 5 x TCH 1609	-39.68	-45.71	-5.00
MCU 7 x Surabhi	6.67	-4.00	20.00
MCU 7 x SVPR 2	-75.00**	-82.69**	-55.00
MCU 7 x LRK 516	-78.68*	-82.88**	-71.75
MCU 7 x Sahana	-13.51	-20.00	-20.00
MCU 7 x TCH 1218	-74.29	-77.50	-77.50
MCU 7 x TCH 1223	-53.33*	-65.00**	-30.00
MCU 7 x TCH 1233	-34.62	-46.88	-15.00
MCU 7 x TCH 1452	-50.88	-62.16*	-30.00
MCU 7 x TCH 1458	-32.00	-43.33	-15.00
MCU 7 x TCH 1569	-85.50**	-89.13**	78.25
MCU 7 x TCH 1609	-34.55	-48.57**	-10.00
MCU 9 x TCH 1223	-86.49**	-87.50**	-75.00
MCU 9 x TCH 1233	-60.61*	-61.76*	-35.00
MCU 9 x TCH 1452	-40.85	-43.24	5.00
MCU 9 x TCH 1458	-58.59*	-61.03*	-33.75
MCU 9 x TCH 1569	-68.51**	-70.88**	-41.75
MCU 9 x TCH 1609	-85.51**	-85.71**	-75.00
MCU 11 x LRK 516	-62.26*	-69.70*	-50.00
MCU 11 x TCH 1218	-20.00	-30.00	-30.00
MCU 11 x TCH 1223	-63.33*	-72.50*	-45.00
MCU 11 x TCH 1233	-63.08*	-70.00*	-52.00
MCU 11 x TCH 1452	-33.33	-48.65	-5.00
MCU 11 x TCH 1609	-41.82	-54.29*	-20.00
TCH 976 x TCH 1218	-17.11	-37.83	-6.75
TCH 976 x TCH 1233	-33.06	-35.16	3.75
TCH 976 x TCH 1452	-40.30	-45.95	0.00
TCH 976 x TCH 1458	-46.67	-46.67	-20.00
TCH 976 x TCH 1569	-57.14*	-62.50**	-25.00
TCH 976 x TCH 1609	-12.77	-19.00	41.75
TCH 976 x Sahana	-10.64	-30.00	5.00
TCH 1025 x Surabhi	-47.60	-47.60	-34.50
TCH 1025 x SVPR 2	-37.66	-53.85**	20.00
TCH 1025 x LRK 516	-79.31**	-81.82**	-70.00
TCH 1025 x TCH 1458	-49.09	-53.33	-30.00
TCHL 1028 x LRK 516	-83.33**	-84.03**	-71.25
TCH 1028 x Sahana	-4.72	-29.86	26.25
TCH 1028 x TCH 1218	8.82	-22.92	38.75
TCH 1028 x TCH 1233	-79.41**	-80.56**	-65.00
TCH 1028 x TCH 1458	-69.70**	-72.22**	-50.00
TCH 1028 x TCH 1569	-26.18**	-29.88	40.25
LRA 5166 x TCH 1223	-64.19**	-72.25**	-44.50
LRA 5166 x TCH 1233	-38.33	-47.97	-16.75
LRA 5166 x TCH 1452	6.44	-15.14	57.00
LRA 5166 x TCH 1609	-64.91*	-71.43**	-50.00
SE	0.38	0.44	0.44

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 19. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for number of bolls per plant

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	14.19*	1.02	-4.13
MCU 5 x SVPR 2	7.34	4.13	-1.18
MCU 5 x LRK 516	-9.94	-21.89**	-25.88**
MCU 5 x TCH 1569	24.61**	-3.25	-8.18
MCU 5 x TCH 1609	4.43	14.09	-16.71
MCU 7 x Surabhi	32.73**	0.81	-10.06
MCU 7 x SVPR 2	26.93**	20.82*	-15.79*
MCU 7 x LRK 516	37.82**	19.44	-21.39**
MCU 7 x Sahana	32.87**	19.44	-21.39**
MCU 7 x TCH 1218	49.69**	21.06*	2.93
MCU 7 x TCH 1223	28.23**	1.99	-9.35
MCU 7 x TCH 1233	31.37**	3.99	-6.37
MCU 7 x TCH 1452	8.12	-10.51	-28.32**
MCU 7 x TCH 1458	31.03**	4.89	-8.37
MCU 7 x TCH 1569	4.79	-18.38*	-23.17**
MCU 7 x TCH 1609	14.94	-5.26	-23.31**
MCU 9 x TCH 1223	50.08**	34.28**	19.35**
MCU 9 x TCH 1233	2.63	-8.70	-17.80*
MCU 9 x TCH 1452	-0.01	-6.21	-24.88**
MCU 9 x TCH 1458	-11.80	-20.48*	-30.53**
MCU 9 x TCH 1569	7.56	-6.13	-11.64
MCU 9 x TCH 1609	41.14**	31.74**	6.63
MCU 11 x LRK 516	23.80**	16.78	-8.18
MCU 11 x TCH 1218	16.71*	12.32	-4.50
MCU 11 x TCH 1223	31.32**	23.74**	9.98
MCU 11 x TCH 1233	-2.52	-8.70	-17.80*
MCU 11 x TCH 1452	27.83**	26.65**	1.44
MCU 11 x TCH 1609	38.79**	36.81**	10.73
TCH 976 x TCH 1218	-15.49*	-17.80*	-26.06**
TCH 976 x TCH 1233	-17.72**	-17.76*	-25.95**
TCH 976 x TCH 1452	1.14	-4.40	-14.00*
TCH 976 x TCH 1458	-0.32	-1.76	-11.62
TCH 976 x TCH 1569	39.49**	36.39**	28.39**
TCH 976 x TCH 1609	11.69	6.09	-4.56
TCH 976 x Sahana	14.35	-0.99	-10.93
TCH 1025 x Surabhi	21.31**	13.76	-5.14
TCH 1025 x SVPR 2	22.42**	18.42*	5.65
TCH 1025 x LRK 516	-20.69**	-27.20**	-39.30**
TCH 1025 x TCH 1458	10.15	7.65	-5.96
TCHL 1028 x LRK 516	25.09**	14.01	-3.42
TCH 1028 x Sahana	21.59**	8.03	-8.49
TCH 1028 x TCH 1218	16.75*	16.53*	-0.92
TCH 1028 x TCH 1233	-16.67*	-19.14*	-27.20**
TCH 1028 x TCH 1458	32.49*	20.11**	13.99*
TCH 1028 x TCH 1569	13.55*	7.86	1.54
LRA 5166 x TCH 1223	7.66	7.43	-4.12
LRA 5166 x TCH 1233	19.69**	19.17*	7.29
LRA 5166 x TCH 1452	25.86**	19.41*	6.57
LRA 5166 x TCH 1609	9.07	3.99	-7.19
SE	0.92	1.06	1.06

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

from 15.12 in MCU 11 x TCH 1233 to 46.19 per cent in LRA 5166 x TCH 1452. Negative expression was evident in three hybrids. Heterosis over the standard parent was significantly positive in 17 hybrids. The hybrids TCH 1025 x TCH 1458 and TCH 1028 x TCH 1218 recorded the lowest and highest values of 17.99 and 34.83 per cent respectively. Negative expression over the standard parent was not evident in the hybrids.

4.2.2.7 Seed cotton yield per plant

The expression of heterosis for seed cotton yield per plant is furnished in Table 21. Positive relative heterosis was displayed by 41 hybrids. The range was from 21.55 to 87.64 per cent. The lowest and highest values were recorded by the hybrids TCH 1028 x TCH 1458 and LRA 5166 x TCH 1452 respectively. Negative mid parental heterosis was not recorded. Twenty nine hybrids recorded positive heterobeltiosis with the lowest and highest values of 12.27 and 77.40 per cent recorded by the hybrids MCU 11 x TCH 1223 and LRA 5166 x TCH 1452 respectively. Heterosis over better parent was in the negative direction in three hybrids MCU 5 x LRK 516, MCU 7 x TCH 1569 and TCH 976 x TCH 1218. Twelve hybrids displayed significantly positive heterosis over the standard parent.The range of values varied from 15.15 to 37.04 per cent, and were registered by the hybrids LRA 5166 x TCH 1223 and LRA 5166 x TCH 1452 respectively. Negative expression of heterosis was observed in 12 hybrids.

Table 20. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for boll weight

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	19.76*	10.66	6.89
MCU 5 x SVPR 2	15.22*	11.43	15.22
MCU 5 x LRK 516	0.45	-7.41	-10.56
MCU 5 x TCH 1569	2.59	-4.04	6.45
MCU 5 x TCH 1609	25.09**	17.61	13.61
MCU 7 x Surabhi	6.92	2.09	-8.06
MCU 7 x SVPR 2	11.06	3.90	7.43
MCU 7 x LRK 516	12.63	7.26	-3.40
MCU 7 x Sahana	16.37*	11.63	0.54
MCU 7 x TCH 1218	-5.04	-17.27**	0.36
MCU 7 x TCH 1223	10.01	-5.24	18.08*
MCU 7 x TCH 1233	10.42	3.76	6.27
MCU 7 x TCH 1452	45.05**	38.27**	24.53**
MCU 7 x TCH 1458	6.32	-4.30	7.70
MCU 7 x TCH 1569	-2.27	-11.46	-1.79
MCU 7 x TCH 1609	22.29**	18.89*	7.07
MCU 9 x TCH 1223	-9.55	-15.30*	5.55
MCU 9 x TCH 1233	25.73**	22.06**	32.77**
MCU 9 x TCH 1452	35.12**	18.27*	28.65**
MCU 9 x TCH 1458	14.40*	12.49	26.59**
MCU 9 x TCH 1569	-5.30	-6.21	4.03
MCU 9 x TCH 1609	-2.45	-13.09	-5.46
MCU 11 x LRK 516	9.08	-5.34	4.83
MCU 11 x TCH 1218	15.05*	10.04	33.48**
MCU 11 x TCH 1223	-4.15	-9.48	12.80
MCU 11 x TCH 1233	19.61**	15.12*	27.48**
MCU 11 x TCH 1452	8.42	-5.82	4.30
MCU 11 x TCH 1609	10.20	-2.59	7.88
TCH 976 x TCH 1218	19.01**	1.18	22.74**
TCH 976 x TCH 1233	21.93**	11.54	14.23
TCH 976 x TCH 1452	44.76	41.94**	20.59*
TCH 976 x TCH 1458	28.56**	12.81	26.95**
TCH 976 x TCH 1569	-5.67	-16.71*	-7.61
TCH 976 x TCH 1609	27.86**	27.79**	8.68
TCH 976 x Sahana	33.80**	32.03**	12.18
TCH 1025 x Surabhi	16.33*	12.31	-1.16
TCH 1025 x SVPR 2	35.83**	25.71**	29.99**
TCH 1025 x LRK 516	30.16**	25.33**	10.30
TCH 1025 x TCH 1458	17.68*	4.85	17.99*
TCHL 1028 x LRK 516	7.76	-2.58	-1.79
TCH 1028 x Sahana	13.37	3.20	4.03
TCH 1028 x TCH 1218	21.40**	11.4	34.83**
TCH 1028 x TCH 1233	9.69	8.83	11.46
TCH 1028 x TCH 1458	3.32	-2.07	10.21
TCH 1028 x TCH 1569	17.46**	12.11	24.35**
LRA 5166 x TCH 1223	17.19**	-1.58	22.65**
LRA 5166 x TCH 1233	38.18**	26.22**	29.27**
LRA 5166 x TCH 1452	48.87**	46.19**	23.81**
LRA 5166 x TCH 1609	11.50	11.26	-5.37
SE	0.18	0.21	0.21

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 21. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for seed cotton yield per plant

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	35.70**	11.00	0.49
MCU 5 x SVPR 2	24.54**	23.55**	11.85
MCU 5 x LRK 516	-11.05	-28.59**	-35.35**
MCU 5 x TCH 1569	29.38**	22.40**	24.22**
MCU 5 x TCH 1609	31.19**	13.13	2.42
MCU 7 x Surabhi	43.96**	29.29**	-25.55**
MCU 7 x SVPR 2	42.33**	7.79	-3.97
MCU 7 x LRK 516	57.56**	44.67**	-20.69**
MCU 7 x Sahana	55.17**	44.91**	-23.44**
MCU 7 x TCH 1218	35.45**	-1.56	-0.48
MCU 7 x TCH 1223	34.92**	-3.92	3.82
MCU 7 x TCH 1233	43.69**	8.22	-2.02
MCU 7 x TCH 1452	56.93**	33.33**	-12.57*
MCU 7 x TCH 1458	34.99**	-0.74	-3.30
MCU 7 x TCH 1569	0.04	-27.38**	-26.30**
MCU 7 x TCH 1609	43.70**	22.06*	-19.92**
MCU 9 x TCH 1223	36.47**	15.34**	24.63**
MCU 9 x TCH 1233	28.22**	16.93*	5.86
MCU 9 x TCH 1452	34.11**	26.00**	-6.01
MCU 9 x TCH 1458	-0.06	-11.77	-14.04*
MCU 9 x TCH 1569	2.33	-11.22	-9.90
MCU 9 x TCH 1609	41.10**	32.60**	-1.09
MCU 11 x LRK 516	33.91**	9.64	-5.73
MCU 11 x TCH 1218	34.25**	24.22**	25.58**
MCU 11 x TCH 1223	25.04**	12.27*	21.31**
MCU 11 x TCH 1233	16.64**	13.70*	2.94
MCU 11 x TCH 1452	36.59**	20.37**	3.50
MCU 11 x TCH 1609	54.81**	36.46**	17.34**
TCH 976 x TCH 1218	0.83	-12.48*	-11.51
TCH 976 x TCH 1233	0.20	-8.72	-17.36**
TCH 976 x TCH 1452	46.04**	37.36**	2.22
TCH 976 x TCH 1458	28.26**	13.12*	10.20
TCH 976 x TCH 1569	31.79**	14.21*	15.91**
TCH 976 x TCH 1609	44.24**	35.70**	0.98
TCH 976 x Sahana	54.30**	31.92**	-1.83
TCH 1025 x Surabhi	41.24**	26.33**	-7.79
TCH 1025 x SVPR 2	67.56**	52.43**	35.79**
TCH 1025 x LRK 516	1.17	-11.43	-35.35**
TCH 1025 x TCH 1458	28.08**	12.02	9.13
TCHL 1028 x LRK 516	35.31**	12.34	-6.76
TCH 1028 x Sahana	39.46**	14.11	-5.29
TCH 1028 x TCH 1218	42.87**	30.08**	31.51**
TCH 1028 x TCH 1233	-9.07	-12.86	-21.10**
TCH 1028 x TCH 1458	21.55**	12.56*	9.65
TCH 1028 x TCH 1569	34.63**	22.37**	24.19**
LRA 5166 x TCH 1223	26.78**	6.57	15.15*
LRA 5166 x TCH 1233	66.98**	51.36**	37.04**
LRA 5166 x TCH 1452	87.64**	77.40**	30.57**
LRA 5166 x TCH 1609	24.25**	17.50*	-13.52*
SE	2.99	3.45	3.45

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

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4.2.2.8 Number of seeds per locule

The expression of heterosis is presented in Table. 22. The hybrids MCU 11 x TCH 1218, MCU 11 x TCH 1233, LRA 5166 x TCH 1233 and TCH 1028 x TCH 1218 displayed relative heterotic effect in the positive direction. The percentage of heterosis noticed in the above hybrids were 23.05, 18.80, 13.37 and 12.91 respectively for the hybrids in the order mentioned. Two hybrids exhibited negative values. The hybrids MCU 11 x TCH 1218 and MCU 11 x TCH 1233 recording the values of 22.12 and 16.67 respectively, have exhibited positive heterobeltiosis, while three hybrids were negatively heterobeltiotic. Standard heterosis was positive in two hybrids namely TCH 1025 x SVPR.2 and MCU 11 x TCH 1218 which registered 13.94 and 16.25 per cent increase respectively over the standard.

4.2.2.9 Ginning outturn

The expression of heterosis is presented in Table 23. Nine hybrid combinations were positively heterotic over the the respective mid parent values. The expression varied from 9.2 to 17.31 per cent, in MCU 9 x TCH 1458 and MCU 9 x TCH 1609 respectively. Two hybrids exhibited negative heterosis. Eight hybrids displayed positive better parental heterosis ranging from 8.56 to 13.78 per cent by LRA 5166 x TCH 1452 and MCU 9 x TCH 1609 respectively while four hybrids displayed negative values. In 14 hybrids the standard heterosis was significantly positive. The values in these hybrids ranged from 7.66 to 16.85 per cent in the hybrids TCH 1028 x TCH 1218 and MCU 5 x SVPR.2 respectively.

Table 22. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for number of seeds per locule

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-4.78	-5.24	-4.33
MCU 5 x SVPR 2	-11.33*	-18.63**	-2.60
MCU 5 x LRK 516	-5.31	-14.18*	-14.18*
MCU 5 x TCH 1569	-0.72	-0.72	-0.72
MCU 5 x TCH 1609	-0.35	-3.94	-3.94
MCU 7 x Surabhi	-5.00	-6.74	-2.26
MCU 7 x SVPR 2	-2.23	-8.31	-9.76
MCU 7 x LRK 516	5.06	-6.74	-2.26
MCU 7 x Sahana	8.87	1.38	6.25
MCU 7 x TCH 1218	-5.91	-10.23	-5.91
MCU 7 x TCH 1223	-0.05	-0.72	5.48
MCU 7 x TCH 1233	0.84	-6.10	-1.59
MCU 7 x TCH 1452	2.82	0.46	5.29
MCU 7 x TCH 1458	0.74	-0.18	4.62
MCU 7 x TCH 1569	-11.60*	-13.62*	-9.47
MCU 7 x TCH 1609	-3.89	-9.40	-5.05
MCU 9 x TCH 1223	-8.24	-9.28	-3.61
MCU 9 x TCH 1233	4.95	-1.85	1.92
MCU 9 x TCH 1452	-2.08	-3.89	-0.19
MCU 9 x TCH 1458	3.02	2.55	6.49
MCU 9 x TCH 1569	1.42	-0.46	3.37
MCU 9 x TCH 1609	-0.15	-5.46	-1.83
MCU 11 x LRK 516	8.63	1.38	-4.95
MCU 11 x TCH 1218	23.05**	22.12**	16.25*
MCU 11 x TCH 1223	1.54	-4.43	1.54
MCU 11 x TCH 1233	18.80**	16.67*	9.38
MCU 11 x TCH 1452	2.28	-0.91	-0.91
MCU 11 x TCH 1609	8.81	8.26	1.49
TCH 976 x TCH 1218	7.30	7.04	2.40
TCH 976 x TCH 1233	9.82	6.78	2.16
TCH 976 x TCH 1452	3.83	1.59	1.59
TCH 976 x TCH 1458	-2.76	-6.17	-3.46
TCH 976 x TCH 1569	5.80	3.51	3.51
TCH 976 x TCH 1609	3.57	2.01	-2.40
TCH 976 x Sahana	10.34	7.29	2.64
TCH 1025 x Surabhi	-0.73	-3.33	-2.40
TCH 1025 x SVPR 2	5.80	-4.82	13.94*
TCH 1025 x LRK 516	4.35	-3.52	-7.69
TCH 1025 x TCH 1458	-0.39	-3.88	-1.11
TCHL 1028 x LRK 516	4.64	-2.79	-7.93
TCH 1028 x Sahana	8.52	6.04	0.43
TCH 1028 x TCH 1218	12.91*	12.63	7.21
TCH 1028 x TCH 1233	3.58	1.22	-4.13
TCH 1028 x TCH 1458	-8.03	-11.68	-9.13
TCH 1028 x TCH 1569	-8.40	-10.82	-10.82
LRA 5166 x TCH 1223	4.11	-4.84	1.11
LRA 5166 x TCH 1233	13.37*	11.86	1.11
LRA 5166 x TCH 1452	7.52	1.06	1.06
LRA 5166 x TCH 1609	0.74	-1.87	-8.94
SE	0.28	0.32	0.32

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 23. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for ginning outturn

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	0.59	-3.43	-0.67
MCU 5 x SVPR 2	12.14**	10.71**	16.85**
MCU 5 x LRK 516	4.34	0.87	3.75
MCU 5 x TCH 1569	-0.11	-0.96	1.87
MCU 5 x TCH 1609	3.28	-2.52	0.27
MCU 7 x Surabhi	6.87	6.37	0.66
MCU 7 x SVPR 2	-5.68	-10.95**	-6.01
MCU 7 x LRK 516	3.68	2.45	-1.62
MCU 7 x Sahana	2.01	-6.20	4.82
MCU 7 x TCH 1218	5.82	-0.77	6.26
MCU 7 x TCH 1223	1.49	-4.77	1.84
MCU 7 x TCH 1233	2.74	-3.90	3.48
MCU 7 x TCH 1452	3.64	0.30	0.51
MCU 7 x TCH 1458	3.93	0.54	0.83
MCU 7 x TCH 1569	-3.50	-7.02	-5.98
MCU 7 x TCH 1609	12.94**	11.47**	4.50
MCU 9 x TCH 1223	2.68	-2.03	4.78
MCU 9 x TCH 1233	2.87	-2.15	5.36
MCU 9 x TCH 1452	11.15**	9.45*	9.68*
MCU 9 x TCH 1458	9.20**	7.49	7.80*
MCU 9 x TCH 1569	3.82	1.78	2.92
MCU 9 x TCH 1609	17.31**	13.78**	10.54**
MCU 11 x LRK 516	5.98	0.33	7.83*
MCU 11 x TCH 1218	-1.03	-1.21	6.17
MCU 11 x TCH 1223	1.17	0.93	8.47*

Contd...

Hybrids	d_i	d_{ii}	d_{iii}
MCU 11 x TCH 1233	0.60	0.50	8.22*
MCU 11 x TCH 1452	5.05	1.50	9.08*
MCU 11 x TCH 1609	3.73	-4.07	3.09
TCH 976 x TCH 1218	-4.97	-5.86	0.81
TCH 976 x TCH 1233	1.38	0.16	7.84*
TCH 976 x TCH 1452	1.25	-1.09	3.93
TCH 976 x TCH 1458	-0.76	-3.02	1.90
TCH 976 x TCH 1569	-10.23**	-11.92**	-7.44
TCH 976 x TCH 1609	4.70	-2.16	2.80
TCH 976 x Sahana	-1.13	-4.09	7.18
TCH 1025 x Surabhi	6.87	6.79	1.06
TCH 1025 x SVPR 2	3.63	-1.80	3.65
TCH 1025 x LRK 516	11.79**	10.90**	6.48
TCH 1025 x TCH 1458	16.40**	13.03**	13.36**
TCHL 1028 x LRK 516	4.61	-0.34	5.71
TCH 1028 x Sahana	3.14	0.52	12.33**
TCH 1028 x TCH 1218	1.01	0.54	7.66*
TCH 1028 x TCH 1233	3.85	3.08	10.99**
TCH 1028 x TCH 1458	0.19	-2.54	3.38
TCH 1028 x TCH 1569	-9.84**	-11.95**	-6.60
LRA 5166 x TCH 1223	5.65	-0.67	6.23
LRA 5166 x TCH 1233	-1.23	-7.88*	-0.81
LRA 5166 x TCH 1452	11.95**	8.56*	8.80*
LRA 5166 x TCH 1609	10.55**	8.88*	2.52
SE	0.84	0.97	0.97

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.2.2.10 Lint index

Twenty four hybrid combinations were positively heterotic over the respective mid parent values (Table.24). The mid parental heterosis for lint index varied from 13.52 per cent in TCH 1028 x TCH 1233 to 73.53 per cent in TCH 1025 x TCH 1458 respectively. Two hybrids displayed negative values. Twelve hybrids were heterobeltiotic, exhibiting a range of 16.95 to 55.85 per cent. In seven hybrids the heterobeltiosis was negative. Among the 49 hybrids, standard heterosis ranging from 18.87 to 39.52 per cent was registered by 11 hybrids. The hybrid TCH 976 x TCH 1569 registered the maximum value of -35.95 per cent in the negative direction.

4.2.2.11 Seed index

The data on the expression of heterosis for seed index are furnished in Table 25. Positive heterotic effect over the respective mid parental values was discernible in 15 hybrids. The range of expression varied from 9.21 to 27.82 per cent observed in MCU 9 x TCH 1452 and TCH 1025 x SVPR.2 respectively. The maximum negative values was - 14.76 per cent recorded in LRA 5166 x TCH 1223. Positive estimates for heterobeltiosis ranging from 11.97 to 22.76 per cent was encountered in six hybrids, MCU 11 x TCH 1233 and LRA 5166 x TCH 1233 recording the lowest and highest values respectively. Seven hybrids were negatively heterobeltiotic. Positive standard heterosis was noticed in 20 hybrids. The range was from 11.02 to 31.29 per cent displayed by MCU 7 x TCH 1233 and TCH 976 x TCH 1458, respectively. Negative expression over the standard parent was not observed in any of the combinations.

Table 24. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for lint index

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	3.95	-8.02	-15.83
MCU 5 x SVPR 2	30.57**	26.46**	15.72
MCU 5 x LRK 516	14.67	3.44	-5.35
MCU 5 x TCH 1569	2.14	0.33	-4.82
MCU 5 x TCH 1609	21.24*	10.19	0.84
MCU 7 x Surabhi	32.74**	21.88	-14.15
MCU 7 x SVPR 2	-7.10	-21.64*	-32.81**
MCU 7 x LRK 516	21.20	9.12	-19.71*
MCU 7 x Sahana	16.38	-10.09	-2.83
MCU 7 x TCH 1218	15.31	-10.14	-5.24
MCU 7 x TCH 1223	3.86	-20.77*	-11.22
MCU 7 x TCH 1233	26.05**	-1.31	2.73
MCU 7 x TCH 1452	18.85	-1.97	-11.11
MCU 7 x TCH 1458	12.29	-6.91	-16.67
MCU 7 x TCH 1569	-10.43	-27.40**	-31.13**
MCU 7 x TCH 1609	45.92**	30.39**	-2.41
MCU 9 x TCH 1223	2.18	-7.86	3.25
MCU 9 x TCH 1233	22.89**	14.60	19.29*
MCU 9 x TCH 1452	49.19**	48.67**	34.80**
MCU 9 x TCH 1458	36.02**	35.62**	22.12*
MCU 9 x TCH 1569	16.67*	13.70	7.86
MCU 9 x TCH 1609	39.10**	27.36**	14.68
MCU 11 x LRK 516	20.43*	3.04	6.60
MCU 11 x TCH 1218	2.36	1.39	6.92
MCU 11 x TCH 1223	10.31	6.08	18.87*
MCU 11 x TCH 1233	15.25*	14.90	19.60*
MCU 11 x TCH 1452	15.12	8.00	11.74
MCU 11 x TCH 1609	15.23	-0.71	2.73
TCH 976 x TCH 1218	-6.64	-7.06	-1.99
TCH 976 x TCH 1233	17.19*	16.95*	22.22*
TCH 976 x TCH 1452	18.69*	10.83	15.83
TCH 976 x TCH 1458	19.18*	10.63	15.62
TCH 976 x TCH 1569	-35.75**	-38.72**	-35.95**
TCH 976 x TCH 1609	37.00**	17.55*	22.85*
TCH 976 x Sahana	-1.68	-3.30	4.51
TCH 1025 x Surabhi	23.82*	23.09	-12.26
TCH 1025 x SVPR 2	42.72**	30.68**	12.05
TCH 1025 x LRK 516	52.24**	49.86**	10.27
TCH 1025 x TCH 1458	73.53**	55.85**	39.52**
TCHL 1028 x LRK 516	8.08	-13.45	5.87
TCH 1028 x Sahana	1.36	-4.54	16.77
TCH 1028 x TCH 1218	10.72	3.08	26.10**
TCH 1028 x TCH 1233	13.52*	5.06	28.51**
TCH 1028 x TCH 1458	-2.92	-15.94*	2.83
TCH 1028 x TCH 1569	-19.59**	-28.62**	-12.68
LRA 5166 x TCH 1223	-2.22	-19.64*	-9.96
LRA 5166 x TCH 1233	18.50*	0.30	4.40
LRA 5166 x TCH 1452	55.44**	39.54**	26.52**
LRA 5166 x TCH 1609	44.79**	42.16**	6.39
SE	0.17	0.20	0.20

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 25. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for seed index

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	3.09	2.77	3.45
MCU 5 x SVPR 2	7.52	0.31	0.98
MCU 5 x LRK 516	1.09	1.01	1.69
MCU 5 x TCH 1569	2.60	-1.85	8.20
MCU 5 x TCH 1609	11.73**	4.62	20.67**
MCU 7 x Surabhi	8.67	1.18	1.22
MCU 7 x SVPR 2	12.89*	12.28	-2.12
MCU 7 x LRK 516	8.65	0.94	1.45
MCU 7 x Sahana	14.11*	14.06	1.18
MCU 7 x TCH 1218	0.10	-7.71	-5.69
MCU 7 x TCH 1223	3.62	-7.17	1.10
MCU 7 x TCH 1233	20.24**	12.79**	11.02*
MCU 7 x TCH 1452	8.56	-2.53	5.65
MCU 7 x TCH 1458	-0.02	-9.71	-3.41
MCU 7 x TCH 1569	1.96	-9.14	0.16
MCU 7 x TCH 1609	1.21	-11.56*	2.00
MCU 9 x TCH 1223	-3.66	-5.38	6.86
MCU 9 x TCH 1233	14.92**	7.53	21.45**
MCU 9 x TCH 1452	9.21*	7.01	20.86**
MCU 9 x TCH 1458	5.39	2.60	15.88**
MCU 9 x TCH 1569	6.52	5.24	18.86**
MCU 9 x TCH 1609	-12.21**	-13.12**	0.20
MCU 11 x LRK 516	0.92	0.62	1.14
MCU 11 x TCH 1218	5.01	3.84	6.12
MCU 11 x TCH 1223	5.95	1.58	10.63
MCU 11 x TCH 1233	12.81**	11.97*	11.88*
MCU 11 x TCH 1452	-2.15	-5.97	1.92
MCU 11 x TCH 1609	4.28	-2.69	12.24*
TCH 976 x TCH 1218	10.83*	8.67	15.57**
TCH 976 x TCH 1233	11.03*	6.90	13.69*
TCH 976 x TCH 1452	14.50**	13.42**	22.94**
TCH 976 x TCH 1458	23.09**	22.73**	31.29**
TCH 976 x TCH 1569	-9.65*	-11.24*	-2.16
TCH 976 x TCH 1609	-1.68	-5.51	8.98
TCH 976 x Sahana	2.35	-4.98	1.06
TCH 1025 x Surabhi	1.52	0.81	2.27
TCH 1025 x SVPR 2	27.82**	18.82**	20.55**
TCH 1025 x LRK 516	7.81	7.31	8.86
TCH 1025 x TCH 1458	7.39	4.62	11.92*
TCHL 1028 x LRK 516	-3.96	-12.53**	7.02
TCH 1028 x Sahana	-9.42*	-20.99**	-3.33
TCH 1028 x TCH 1218	6.36	-2.40	19.41**
TCH 1028 x TCH 1233	0.46	-9.36*	10.90
TCH 1028 x TCH 1458	-2.74	-8.85	11.53*
TCH 1028 x TCH 1569	11.55**	6.03	29.73**
LRA 5166 x TCH 1223	-14.76**	-16.31**	-8.86
LRA 5166 x TCH 1233	26.69**	22.76**	28.82**
LRA 5166 x TCH 1452	9.30*	7.56	16.59**
LRA 5166 x TCH 1609	7.89	3.03	18.82**
SE	0.29	0.33	0.33

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.2.2.12 2.5 per cent span length

The manifestation of heterosis in different forms for this character is furnished in Table 26. Ten hybrids showed positive relative heterosis. The range of mid parental heterosis varied from 1.47 (MCU 9 x TCH 1569) to 8.86 (MCU 5 x SVPR.2) per cent. Thirty one hybrids showed negative expression. The hybrid LRA 5166 x TCH 1233 was the only hybrid which registered positive better parental heterosis (3.13 per cent) and 42 hybrids were negatively heterobeltiotic in effect. Five hybrids encountered positive values of standard heterosis and the maximum value was 3.65 per cent registered by MCU 5 x TCH 1609. Standard heterosis was negative in 39 hybrids.

4.2.2.13 Uniformity ratio

The expression of heterosis for this character is presented in Table 27.

Seven hybrids displayed positive relative heterosis which ranged from 3.45 to 8.88 per cent. The hybrids MCU 7 x TCH 1223 and TCH 976 x Sahana registered the lowest and highest values. Nineteen hybrids displayed negative relative heterosis and the hybrid TCH 1028 x LRK 516 registered negative heterosis of -9.89 per cent. Heterobeltiosis of 3.85 per cent was noticed in three hybrids namely MCU 5 x Surabhi, TCH 1025 x Surabhi and LRA 5166 x TCH 1223. Negative effect was registered by 26 hybrids. Standard heterosis was positive in only one hybrid TCH 976 x Sahana which expressed the value of 4.44 per cent and in 27 hybrids standard heterosis was in the negative direction.

Table 26. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for 2.5 per cent span length

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-7.18**	-7.91**	-3.32**
MCU 5 x SVPR 2	8.86**	-1.93**	1.33*
MCU 5 x LRK 516	4.27**	-3.22**	0.00
MCU 5 x TCH 1569	0.33	-3.54**	-0.33
MCU 5 x TCH 1609	4.23**	0.32	3.65**
MCU 7 x Surabhi	-9.78**	-14.87**	-10.63**
MCU 7 x SVPR 2	-2.96**	-8.32**	-14.62**
MCU 7 x LRK 516	-3.05**	-5.47**	-11.96**
MCU 7 x Sahana	2.71**	-0.83	-7.64**
MCU 7 x TCH 1218	-4.25**	-7.44**	-7.64**
MCU 7 x TCH 1223	-1.20	-4.85**	-4.32**
MCU 7 x TCH 1233	-2.87**	-4.17**	-8.31**
MCU 7 x TCH 1452	-5.59**	-7.43**	-1030**
MCU 7 x TCH 1458	-7.34**	-8.47**	-12.62**
MCU 7 x TCH 1569	0.12	-1.05	-5.65**
MCU 7 x TCH 1609	-1.06	-2.32**	-6.64**
MCU 9 x TCH 1223	-4.98**	-7.00**	-2.33**
MCU 9 x TCH 1233	0.31	-4.15**	0.66
MCU 9 x TCH 1452	-2.27**	-6.05**	-1.33*
MCU 9 x TCH 1458	-0.24	-4.79**	0.00
MCU 9 x TCH 1569	1.47**	-3.21**	1.66**
MCU 9 x TCH 1609	1.69**	-2.89**	1.99**
MCU 11 x LRK 516	-1.19*	-5.59**	-8.31**
MCU 11 x TCH 1218	-10.91**	-12.10**	-12.29**
MCU 11 x TCH 1223	-10.92**	-12.44**	-11.96**
MCU 11 x TCH 1233	-6.61**	-7.30**	-9.97**
MCU 11 x TCH 1452	-7.19**	-7.30**	-9.97**
MCU 11 x TCH 1609	-9.31**	-10.03**	-12.62**
TCH 976 x TCH 1218	-11.77**	-12.11**	-11.63**
TCH 976 x TCH 1233	-4.51**	-6.83**	-6.31**
TCH 976 x TCH 1452	-3.08**	-4.85**	-4.32**
TCH 976 x TCH 1458	-2.71**	-5.18**	-4.65**
TCH 976 x TCH 1569	-10.46**	-12.78**	-12.29**
TCH 976 x TCH 1609	-1.07	-3.52**	-2.99**
TCH 976 x Sahana	-6.68**	-13.11**	-12.62**
TCH 1025 x Surabhi	-12.23**	-15.19**	-10.96**
TCH 1025 x SVPR 2	-1.47*	-9.05**	-10.96**
TCH 1025 x LRK 516	-4.10**	-8.71**	-10.63**
TCH 1025 x TCH 1458	-2.06**	-3.28**	-5.32**
TCHL 1028 x LRK 516	-2.11**	-7.85**	-7.64**
TCH 1028 x Sahana	-7.94**	-14.14**	-13.95**
TCH 1028 x TCH 1218	-3.65**	-3.87**	-3.65**
TCH 1028 x TCH 1233	-0.96	-3.20**	-2.99**
TCH 1028 x TCH 1458	1.53**	-0.88	-0.66
TCH 1028 x TCH 1569	3.62**	1.10	1.33*
LRA 5166 x TCH 1223	-6.87**	-10.46**	-9.97**
LRA 5166 x TCH 1233	4.70**	3.13**	-1.33*
LRA 5166 x TCH 1452	1.58**	-0.57	-3.65**
LRA 5166 x TCH 1609	-0.88	-2.32**	-6.64**
SE	0.12	0.13	0.13

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 27. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for uniformity ratio

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	5.88**	3.85*	0.00
MCU 5 x SVPR 2	-6.67**	-13.10**	-6.67**
MCU 5 x LRK 516	-2.22	-8.97**	-2.22
MCU 5 x TCH 1569	-6.61**	-9.09**	-11.11**
MCU 5 x TCH 1609	0.78	-1.53	-4.44**
MCU 7 x Surabhi	-1.15	-1.53	-4.44**
MCU 7 x SVPR 2	-4.35**	-8.97**	-2.22
MCU 7 x LRK 516	-8.70**	-13.10**	-6.67**
MCU 7 x Sahana	-2.22	-5.04**	-2.22
MCU 7 x TCH 1218	-1.53	-1.53	-4.44**
MCU 7 x TCH 1223	3.45*	3.05	0.00
MCU 7 x TCH 1233	2.66	2.27	0.00
MCU 7 x TCH 1452	1.50	0.00	0.00
MCU 7 x TCH 1458	0.38	0.00	-2.22
MCU 7 x TCH 1569	-6.46**	-6.82**	-8.89**
MCU 7 x TCH 1609	0.76	0.76	-2.22
MCU 9 x TCH 1223	-6.82**	-8.21**	-8.89**
MCU 9 x TCH 1233	-3.01*	-3.73*	-4.44**
MCU 9 x TCH 1452	-8.55**	-8.89**	-8.89**
MCU 9 x TCH 1458	-5.26**	-5.97**	-6.67**
MCU 9 x TCH 1569	1.50	0.75	0.00
MCU 9 x TCH 1609	-4.91**	-5.97**	-6.67**
MCU 11 x LRK 516	-5.38**	-8.97**	-2.22
MCU 11 x TCH 1218	-0.38	-1.49	-2.22
MCU 11 x TCH 1223	4.55**	2.99	2.22
MCU 11 x TCH 1233	-5.26**	-5.97**	-6.67**
MCU 11 x TCH 1452	-1.86	-2.22	-2.22
MCU 11 x TCH 1609	1.89	0.75	0.00
TCH 976 x TCH 1218	7.57**	3.05	0.00
TCH 976 x TCH 1233	-4.76**	-9.09**	-11.11**
TCH 976 x TCH 1452	1.18	-4.44**	-4.44**
TCH 976 x TCH 1458	2.38	-2.27	-4.44**
TCH 976 x TCH 1569	2.38	-2.27	-4.44**
TCH 976 x TCH 1609	2.79	-1.53	-4.44**
TCH 976 x Sahana	8.88**	1.44	4.44**
TCH 1025 x Surabhi	4.25**	3.85*	0.00
TCH 1025 x SVPR 2	0.73	-4.83**	2.22
TCH 1025 x LRK 516	-1.46	-6.90**	0.00
TCH 1025 x TCH 1458	-1.15	-2.27	-4.44**
TCHL 1028 x LRK 516	-9.89**	-15.17**	-8.89**
TCH 1028 x Sahana	1.12	-2.88	0.00
TCH 1028 x TCH 1218	-2.70	-3.82*	-6.67**
TCH 1028 x TCH 1233	-3.08*	-4.55**	-6.67**
TCH 1028 x TCH 1458	-7.69**	-9.09**	-11.11**
TCH 1028 x TCH 1569	-7.69**	-9.09**	-11.11**
LRA 5166 x TCH 1223	5.06**	3.85*	0.00
LRA 5166 x TCH 1233	-2.70	-4.55**	-6.67**
LRA 5166 x TCH 1452	-1.53	-4.44**	-4.44**
LRA 5166 x TCH 1609	-4.65**	-6.11**	-8.89**
SE	0.46	0.53	0.53

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.2.2.14 Fibre fineness

Expression of heterosis for fibre fineness is furnished in Table 28. LRA.5166 x TCH 1223 and MCU 7 x TCH 1218 were the hybrids registering the minimum and maximum positive relative heterosis of 1.46 and 19.84 per cent respectively. Negative heterosis was noticed in 29 hybrids, in which the highest value of -24.83 per cent registered by LRA 5166 x TCH 1452. Heterobeltiosis was positive in seven hybrids and 36 hybrids were negativekt heterotic. Significant standard heterosis was recorded by 41 hybrids. The minimum and maximum values of 1.56 and 41.56 per cent were recorded by TCH 1025 x LRK 516 and MCU 7 x TCH 1218 respectively. Only four hybrids were negative in expression of heterosis over the standard parent.

4.2.2.15 Bundle strength

Expression of heterosis is presented in Table 29. Twenty two hybrids were positively heterotic over the mid parental values and the expression varied from 1.2 to 19.06 per cent, in TCH 1025 x SVPR 2 and MCU 11 x LRK 516 respectively. Twenty two hybrids showed negative effect for relative heterosis. Positive heterobeltiosis was noticed in 14 hybrids and 31 hybrids registered negative estimates of heterosis over the better parent value. Significant and positive standard heterosis was recorded by seven crosses with a range 1.44 to 15.31 per cent, hybrids LRA.5166 x TCH 233 and MCU 9 x TCH 1569 showing the lowest and highest estimates respectively. 36 hybrids encountered negative estimates.

Table 28. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for fibre fineness

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	1.79**	1.03	12.50**
MCU 5 x SVPR 2	-2.59**	-7.95**	13.44**
MCU 5 x LRK 516	-7.16**	-9.10**	4.06**
MCU 5 x TCH 1569	1.68**	0.57	10.31**
MCU 5 x TCH 1609	3.47**	0.81	16.56**
MCU 7 x Surabhi	-2.42**	-3.74**	7.19**
MCU 7 x SVPR 2	3.37**	-2.87**	19.69**
MCU 7 x LRK 516	10.24**	7.28**	22.81**
MCU 7 x Sahana	7.85**	0.58	25.94**
MCU 7 x TCH 1218	19.84**	10.67**	41.56**
MCU 7 x TCH 1223	-9.34**	17.34**	8.75**
MCU 7 x TCH 1233	-0.68	-5.55**	13.44**
MCU 7 x TCH 1452	-0.36	-7.21**	16.56**
MCU 7 x TCH 1458	13.15**	10.21**	25.94**
MCU 7 x TCH 1569	-0.58	-1.06	7.19**
MCU 7 x TCH 1609	12.47**	8.92**	25.94**
MCU 9 x TCH 1223	8.09**	0.48	32.19**
MCU 9 x TCH 1233	-2.68**	-5.55**	13.44**
MCU 9 x TCH 1452	-15.41**	-19.65**	0.94
MCU 9 x TCH 1458	-1.01	-1.55**	12.50**
MCU 9 x TCH 1569	4.40**	1.75**	15.00**
MCU 9 x TCH 1609	-7.06**	-8.11**	6.25**
MCU 11 x LRK 516	-15.07**	-18.09**	0.94
MCU 11 x TCH 1218	-16.63**	-18.16**	4.69**
MCU 11 x TCH 1223	-7.28**	-10.21**	-18.12**

Hybrids	d_i	d_{ii}	d_{iii}
MCU 11 x TCH 1233	-19.61**	-20.63**	-2.19**
MCU 11 x TCH 1452	-5.06**	-5.97**	18.12**
MCU 11 x TCH 1609	0.22	-2.87**	19.69**
TCH 976 x TCH 1218	-20.92**	-25.49**	-4.69**
TCH 976 x TCH 1233	-9.42**	-12.06**	5.63**
TCH 976 x TCH 1452	-21.73**	-25.62**	-6.56**
TCH 976 x TCH 1458	-8.20**	-8.66**	4.37**
TCH 976 x TCH 1569	-6.14**	-8.56**	3.44**
TCH 976 x TCH 1609	3.01**	1.89**	17.81**
TCH 976 x Sahana	-12.67**	-16.89**	4.06**
TCH 1025 x Surabhi	-14.21**	-15.38**	-3.13**
TCH 1025 x SVPR 2	1.75**	-1.86**	20.94**
TCH 1025 x LRK 516	-11.28**	-11.28**	1.56*
TCH 1025 x TCH 1458	-3.01**	-3.09**	10.94**
TCHL 1028 x LRK 516	-5.92**	-7.85**	10.00**
TCH 1028 x Sahana	-2.39**	-4.66**	19.37**
TCH 1028 x TCH 1218	-11.54**	-14.50**	9.3 7**
TCH 1028 x TCH 1233	-11.79**	-12.06**	5.63**
TCH 1028 x TCH 1458	-3.17**	-5.24**	13.12**
TCH 1028 x TCH 1569	-4.87**	-9.69**	7.81**
LRA 5166 x TCH 1223	1.46**	-6.65**	22.81**
LRA 5166 x TCH 1233	0.81	-3.21**	16.25**
LRA 5166 x TCH 1452	-24.83**	-29.35**	-11.25**
LRA 5166 x TCH 1609	-12.39**	-14.32**	-0.94
SE	0.01	0.02	0.02

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

Table 29. Expression of heterosis (percentage) in intra-*hirsutum* hybrids for bundle strength

Hybrids	d_i	d_{ii}	d_{iii}
MCU 5 x Surabhi	-5.47**	-6.95**	-6.22**
MCU 5 x SVPR 2	1.86**	-11.02**	0.48
MCU 5 x LRK 516	-1.52**	-13.14**	-1.91**
MCU 5 x TCH 1569	-8.21**	-13.14**	-1.91**
MCU 5 x TCH 1609	-12.43**	-17.37**	-6.70**
MCU 7 x Surabhi	14.67**	9.51**	2.87**
MCU 7 x SVPR 2	-11.45**	-15.96**	-21.05**
MCU 7 x LRK 516	-1.24**	-5.26**	-11.00**
MCU 7 x Sahana	-20.54**	-24.92**	-20.73**
MCU 7 x TCH 1218	-8.36**	-8.83**	-14.35**
MCU 7 x TCH 1223	11.99**	5.43**	-0.96
MCU 7 x TCH 1233	8.60**	2.89**	-3.35**
MCU 7 x TCH 1452	16.04**	10.53**	3.83**
MCU 7 x TCH 1458	-2.26**	-4.75**	-10.53**
MCU 7 x TCH 1569	-8.11**	-11.23**	-10.53**
MCU 7 x TCH 1609	-6.33**	-9.24**	-9.09**
MCU 9 x TCH 1223	6.04**	-2.73**	-3.35**
MCU 9 x TCH 1233	8.00**	-0.32	-0.96
MCU 9 x TCH 1452	6.40**	-1.28**	-1.91**
MCU 9 x TCH 1458	4.06**	-1.28**	-1.91**
MCU 9 x TCH 1569	15.22**	14.40**	15.31**
MCU 9 x TCH 1609	-0.24	-0.64	-0.48
MCU 11 x LRK 516	19.06**	12.94**	8.61**
MCU 11 x TCH 1218	3.20**	1.49**	-2.39**
MCU 11 x TCH 1223	11.69**	3.98**	0.00
MCU 11 x TCH 1233	-2.83**	-8.96**	-12.44**
MCU 11 x TCH 1452	-0.18	-5.97**	-9.57**
MCU 11 x TCH 1609	-3.49**	-5.41**	-5.26**
TCH 976 x TCH 1218	0.93	0.00	-5.26**
TCH 976 x TCH 1233	-1.52**	-7.07**	-11.96**
TCH 976 x TCH 1452	-2.04**	-7.07**	-11.96**
TCH 976 x TCH 1458	0.43	-2.53**	-7.66**
TCH 976 x TCH 1569	-19.25**	-21.68**	-21.05**
TCH 976 x TCH 1609	-10.15**	-12.58**	-12.44**
TCH 976 x Sahana	-7.80**	-12.54**	-7.66**
TCH 1025 x Surabhi	1.63**	-6.16**	-5.26**
TCH 1025 x SVPR 2	1.20**	-7.11**	-6.22**
TCH 1025 x LRK 516	-6.47**	-13.27**	-12.44**
TCH 1025 x TCH 1458	-5.37**	-10.90**	-10.05**
TCHL 1028 x LRK 516	4.07**	1.77**	-8.13**
TCH 1028 x Sahana	-6.19**	-12.99**	-8.13**
TCH 1028 x TCH 1218	-0.75	-2.23**	-9.09**
TCH 1028 x TCH 1233	9.79**	6.01**	-4.31**
TCH 1028 x TCH 1458	6.13**	5.48**	-4.78**
TCH 1028 x TCH 1569	5.18**	-0.32	0.48
LRA 5166 x TCH 1223	16.67**	9.23**	3.83**
LRA 5166 x TCH 1233	13.37**	6.71**	1.44**
LRA 5166 x TCH 1452	12.13**	6.21**	0.96
LRA 5166 x TCH 1609	-2.45**	-4.94**	-4.78**
SE	0.06	0.07	0.07

Contd...

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.3 Study of interspecific hybrids

4.3.1 Mean expression of different traits in the F1 hybrids

The mean expression of 14 characters recorded on 21 hybrids is presented in Table 30.

4.3.1.1 Days to first flowering

The range for days to first flowering was from 61.67 to 70.00. The minimum value was recorded in MCU 5 x EC 97631, MCU 7 x Bhaksh 5230 and the maximum value was observed in TCH 1025 x EC 9256. The mean value was 66.51 and three hybrids were lower than the mean value.

4.3.1.2 Plant height

The lowest (51.23) and highest (102.12 cm) values for plant height of were recorded in MCU 7 x Bhaksh 5230 and TCH 976 x Bhaksh 5230 respectively. The mean was 71.30cm and four hybrids surpassed the mean expression.

4.3.1.3 Number of sympodia per plant

The range for number of sympodia per plant varied from 10.80 to 19.69 in MCU 11 x TCB.15 and TCH 976 x Bhaksh 5230 respectively. The mean value was 14.18 and three hybrids exceeded the mean value.

Table 30. Mean expression of different character in the interspecific hybrids

Character / Hybrids	Days to first flowering	Plant height (cm)	No. of sympo-dia/ plant	No. of mono-podia /plant	No. of bolls / plant	Boll weight (g)	Seed cotton yield / plant (g)	No. of seeds/ locule	Ginning outturn (%)	Lint index (g)	Seed index (g)	2.5% span length (mm)	Uniformity ratio (%)	Bundle strength (1/8 gauge g/tex)
MCU 5 x TCB 7	68.33	66.52	14.40	0.82	14.13	3.24	45.43	6.20	30.10	1.93	10.42	33.10	41.00	24.60
MCU 5 x TCB 209	67.67	69.62	15.57	**2.78**	24.00	3.08	72.58	5.92	28.98	**1.82**	10.96	**34.00**	41.00	24.40
MCU 5 x EC 97631	61.67	93.73	15.20	1.33	27.27	3.28	88.28	5.72	28.27	1.60	10.32	32.63	41.00	26.00
MCU 5 x TCB 7	64.00	66.39	11.13	**0.73**	12.73	2.98	38.11	**6.97**	33.58	2.15	**8.40**	29.80	45.00	24.00
MCU 5 x TCB 209	64.33	65.07	12.43	1.87	11.60	2.75	31.14	6;60	29.86	1.72	9.46	29.20	45.00	23.90
MCU 7 x Bhaksh 5230	**61.67**	**51.23**	12.13	1.73	11.67	3.56	40.43	6.92	**36.66**	2.91	8.68	**26.20**	**48.00**	19.70
MCU 7 x EC 9256	65.33	67.62	12.40	1.58	11.58	3.33	38.79	5.78	32.20	2.12	9.41	30.80	45.00	24.00
MCU 7 x BCS 9-76	69.33	67.44	12.33	2.53	14.00	2.77	37.61	6.35	32.14	2.10	9.32	30.40	45.00	26.60
MCU 7 x Sudan G.45	64.33	64.45	13.08	0.95	**9.79**	3.55	34.61	6.92	30.26	1.98	10.49	29.70	45.00	24.60
MCU 7 X Suvin	63.00	54.92	13.91	1.33	17.33	2.65	44.73	6.24	28.97	1.53	9.24	31.10	41.00	24.20
MCU 7 x EC 111248	66.67	63.08	13.43	1.33	21.72	2.88	61.52	6.54	33.76	2.27	8.69	35.07	45.00	25.50
MCU 7 x TCB 15	65.67	53.56	**10.80**	1.58	10.56	**2.40**	**25.09**	**5.53**	35.12	2.65	9.05	29.50	45.00	**18.10**
MCU 7 x BCS 9-76	66.67	73.69	15.60	1.43	19.47	3.22	61.98	5.88	30.94	2.03	10.13	32.20	45.00	23.80
TCH 976 X Suvin	67.33	70.79	17.97	1.67	36.20	2.85	100.66	6.44	32.09	2.24	10.03	34.00	41.00	26.50
TCH 979 x Bhaksh 5230	69.67	**102.12**	**19.69**	2.20	31.13	3.47	**105.66**	6.04	27.16	**1.43**	10.32	33.70	**39.00**	25.90
TCH 1025 x Sudan G-45	66.67	82.59	15.20	1.87	20.33	3.51	70.05	6.47	31.53	2.41	11.41	34.00	43.00	25.50
TCH 1025 x Bhaksh 5-30	69.67	65.89	12.96	0.93	10.49	**3.72**	38.54	5.65	27.49	1.66	11.57	31.90	45.00	24.50
TCH 1025 x EC 9-56	**70.00**	74.07	12.67	2.67	**50.00**	3.47	50.08	5.60	**26.39**	**1.43**	9.68	33.70	42.00	**27.70**
TCH 1025 x BCS 9-76	68.67	68.94	14.08	1.45	25.60	2.86	70.00	5.56	31.07	2.01	9.88	32.87	41.00	27.60
TCH 1025 x Sudan G-45	69.00	92.45	18.50	2.00	18.89	2.81	51.79	5.85	26.70	1.65	**12.39**	**35.50**	40.00	27.00
TCH 1025 x EC 111248	**70.00**	77.40	14.41	1.50	18.13	3.40	59.64	5.97	32.05	2.25	10.08	31.50	45.00	25.00
TCHB 213 (Check)	68.67	97.50	17.73	1.40	19.14	3.52	66.73	6.20	32.70	**3.08**	8.47	32.93	42.67	24.80
Mean	66.51	71.03	14.18	1.63	18.17	3.13	55.56	6.15	30.73	2.00	10.00	31.95	43.24	24.76
SE	0.98	2.85	0.80	0.30	0.64	0.08	2.25	0.32	0.73	0.17	0.29	0.23	0.50	0.20
CD	2.76	8.03	2.25	0.85	1.80	0.23	6.34	0.90	2.06	0.48	0.82	0.65	1.41	0.56

4.3.1.4 Number of monopodia per plant

Number of monopodia per plant was minimum in MCU 7 x TCB.7 and the maximum in MCU 5 x TCB.209, the values being 0.73 and 2.78 respectively. Only one hybrid was lower to the mean expression of 1.63.

4.3.1.5 Number of bolls per plant

The range for number of bolls per plant was from 9.79 to 36.20. The lowest and highest number of bolls were registered by MCU 7 x Sudan G.45 and TCH 976 x Suvin respectively. Seven hybrids surpassed the mean value of 18.17.

4.3.1.6 Boll weight

The smallest (2.40g.) and biggest (3.72 g..) bolls were produced by the crosses MCU 11 x TCB.15 and TCH 1025 x Bhaksh 5230 respectively. The mean value was 3.13 and five hybrids exceeded the mean expression.

4.3.1.7 Seed cotton yield per plant

The lowest yield of 25.09 g. for single plant yield was recorded in MCU 11 x TCB. 15 and the highest yield of 105.66 g. was observed in TCH 976 x Bhaksh 5230. Seven hybrids were superior to the mean value of 55.56 g.

4.3.1.8 Number of seeds per locule

MCU 11 x TCB.15 and MCU 7 x TCB.7 recorded the lowest and highest number of seeds of 5.53 and 6.97 respectively. None of the hybrid exceeded the hybrid mean for this character.

4.3.1.9 Ginning outturn

The range for ginning outturn was from 26.39 to 36.66 registered by TCH 1025 x EC 9256 and MCU 7 x Bhaksh 5230 respectively. The ginning outturn was superior in four hybrids when compared to the mean value to 30.73.

4.3.1.10 Lint index

The mean lint index of the hybrids was 2.00g. The character had a range from 1.43 (TCH 976 x Bhaksh 5230 and TCH 1025 x EC 9256) to 2.91 g.(MCU 7 x Bhaksh 5230). Two hybrids had higher lint index as compared to the general mean.

4.3.1.11 Seed index

The seed index displayed a range of 8.40 g. in MCU 7 x TCB. 7 and 12.39 g. in TCH. 1025 x Sudan G.45 respectively. The mean value was 10.00 g. and four hybrids were superior to this value.

4.3.1.12 2.5 per cent span length

The hybrids MCU 7 x Bhaksh 5230 and TCH 1028 x Sudan G 45 recorded the minimum and maximum values of 26.20 mm and 35.50 respectively for 2.5 per cent span length. Ten hybrids exceeded the mean expression of 31.95 mm.

4.3.1.13 Uniformity ratio

Uniformity ratio was found to be minimum in TCH 1028 x Sudan G.45 (40.0 per cent), and maximum in MCU 7 x Bhaksh 5230 (48.00 per cent). Eleven hybrids exceeded the mean expression of 43.24 per cent.

4.3.1.14 Bundle strength

The mean bundle strength in the hybrids was 24.76 g./tex, and the range was from 18.10 to 27.70 gram per tex in MCU 11 x TCB.15 and TCH 1025 x EC 9256 respectively. Nine hybrids surpassed the hybrid mean value.

4.3.2 Expression of heterosis

4.3.2.1 Days of first flowering

The heterotic expression for days to first flowering is presented in Table 31.

Significant negative heterosis over mid parental value was noticed in 10 hybrids. The expression had a range from -4.31 to -12.74 per cent. Twelve hybrids exhibited negative heterobeltiosis and the values varied from -5.21 to -13.95 per cent. Standard heterosis was found to be significantly negative in eight hybrids. Positive expression of relative heterosis, heterobeltiosis and standard heterosis was not evident in all the hybrids.

4.3.2.2 Plant height

The manifestation of heterosis over the mid parental value, better parental value and best check has been presented in Table 31.

Eighteen hybrid combinations were heterotic over the respective mid parental values in the positive direction and the expression varied from 15.91 to 71.85 per cent. None of the hybrids were negatively heterotic. Positive

Table 31. Expression of heterosis (percentage) in interspecific hybrids for days to first flowering and plant height

Hybrids	Days to first flowering			Plant height		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	-1.91	-1.91	-0.49	30.22**	11.32	-31.77**
MCU 5 x TCB 209	-1.93	-2.87	-1.46	25.83**	16.50*	-28.59**
MCU 5 x EC 97631	-12.74**	-13.95**	-10.19**	71.85**	56.85**	-3.86
MCU 7 x TCB 7	-7.47**	-8.13**	-6.80**	42.46**	30.71**	-31.90**
MCU 7 x TCB 209	-6.08**	-6.31**	-6.31**	27.97**	27.83**	-33.26**
MCU 7 x Bhaksh 5230	-10.63**	-11.06**	-10.19**	-0.95	-2.68	-47.46**
MCU 7 x EC 9256	-6.00**	-7.11**	-4.85*	24.65**	17.19*	-30.65**
MCU 7 BCS 9-76	1.22	0.97	0.97	44.34**	32.78**	-30.83**
MCU 7 x Sudan G.45	-6.08**	-6.31**	-6.31**	26.98**	26.89**	-33.90**
MCU 7 x Suvin	-7.80**	-8.25**	-8.25**	18.42**	8.13	-43.67**
MCU 9 x EC 111248	-4.53*	-5.21**	-2.91	15.91*	-4.96	-35.31**
MCU 11 x TCB 15	-1.01	-5.29**	-4.37*	-8.68	-28.38**	-45.06**
MCU 11 x BCS 9-76	1.27	-2.44	-2.91	25.49**	-1.46	-24.42**
TCH 976 x Suvin	-0.74	-0.98	-1.94	23.54**	-2.54	-27.39**
TCH 976 x Bnhaksh 5230	1.70	0.48	1.46	63.03**	40.58**	4.74
TCH 1025 x Sudan G.45	-4.31*	-6.10**	-2.91	38.07**	19.84**	-15.29**
TCH 1025 x Bhaksh 5230	-0.71	-1.88	1.46	8.41	-4.39	-32.42**
TCH 1025 x EC 9256	-0.94	-1.41	1.94	16.99**	7.47	-24.03**
TCH 1028 x BCS 9-76	-1.90	-4.19*	0.00	23.57**	0.02	-29.29**
TCH 1028 x Sudan G.45	-1.43	-3.72	0.49	54.54**	34.13**	-5.18
TCH 1028 x EC 111248	-4.96**	-6.51**	-2.43	38.97**	12.29*	-20.62**
SE	0.85	0.98	0.98	2.47	2.85	2.85

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

expression for heterobeltiosis ranged between 12.29 to 56.85 per cent exhibited in 11 hybrids and the hybrids MCU 11 x TCB 15 registered negative heterosis, the value being -28.38 per cent. The estimates of standard heterosis was found to be negatively significant in 18 hybrids. The expression was found to vary from -15.29 to -47.46 per cent.

4.3.2.3 Number of sympodia per plant

Expression of heterosis in hybrids has been presented in Table 32. Heterosis over mid parental value was positive in 10 hybrids and the range varied from 17.39 to 61.39 per cent. The hybrids MCU 5 x TCB.7 and TCH 976 x Bhaksh 5230 respectively displayed the lowest and highest values. Negative expression (-23.67 per cent) was recorded in the hybrid MCU 11 x TCB 15. The estimates of heterobeltiosis was positive in the hybrids TCH 976 x Suvin (19.78 per cent) and TCH 976 x Bhaksh 5230 (31.27 per cent). Seven hybrids were negatively heterobeltiotic. None of the hybrids showed positive standard heterosis.

4.3.1.4 Number of monopodia per plant

Expression of heterosis based on all the three criteria is furnished in Table 32. Seven hybrids were heterotic when compared to their mid parental values. Three hybrids were positively heterotic over the better parental values and four hybrids had negative heterobeltiosis. Three hybrids MCU 5 x TCB 209, MCU 7 x BCS 9-76 and TCH 1025 x EC 9256 were positively heterotic over the standard check.

Table 32. Expression of heterosis (percentage) in interspecific hybrids for number of sympodia per plant and number of monopodia per plant

Hybrids	Number of sympodia per plant			Number of monopodia per plant		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	17.39*	-10.37	-18.80**	-29.43	-55.89*	-41.19
MCU 5 x TCB 209	17.63*	-3.11	-12.22	51.45*	48.75*	98.33*
MCU 5 x EC 97631	23.91**	-5.39	-14.29*	29.03	-28.57	-4.76
MCU 7 x TCB 7	8.44	-7.73	-37.22**	-18.52	-45.00	-47.62
MCU 7 x TCB 209	10.39	2.76	-30.08**	19.15	3.70	33.33
MCU 7 x Bhaksh 5230	13.04	0.55	-31.58**	116.67*	30.00	23.81
MCU 7 x EC 9256	31.68**	2.76	-30.08**	50.16	18.25	12.62
MCU 7 BCS 9-76	3.79	2.21	-30.45**	145.16**	90.00**	80.95**
MCU 7 x Sudan G.45	26.04**	8.43	-26.22**	23.91	-28.75	-32.14
MCU 7 x Suvin	24.94**	15.28	-21.56**	17.65	0.00	-4.76
MCU 9 x EC 111248	3.73	-19.72**	-24.25**	9.59	-41.18*	-4.76
MCU 11 x TCB 15	-23.67**	-39.89**	-39.10**	115.45*	18.50	12.86
MCU 11 x BCS 9-76	5.17	-13.17*	-12.03	38.71	7.50	2.38
TCH 976 x Suvin	42.59**	19.78*	1.32	13.64	-16.67	19.05
TCH 976 x Bnhaksh 5230	61.39**	31.27**	11.03	94.41**	10.17	57.38
TCH 1025 x Sudan G.45	26.00**	-1.51	-14.29*	100.00*	12.00	33.33
TCH 1025 x Bhaksh 5230	4.38	-16.03*	-26.92**	-3.45	-44.00	-33.33
TCH 1025 x EC 9256	14.11	-17.93*	-28.57**	119.18**	60.00*	90.48**
TCH 1028 x BCS 9-76	-5.06	-21.61**	-20.58**	-7.66	-39.72*	3.33
TCH 1028 x Sudan G.45	38.78**	2.97	4.32	53.85	-16.67	42.86
TCH 1028 x EC 111248	6.24	-19.78**	-18.72**	16.88	-37.50*	7.14
SE	0.69	0.80	0.80	0.26	0.30	0.30

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.3.2.5 Number of bolls per plant

The expression of heterosis for number of bolls per plant is furnished in Table 33. Positive relative heterosis was displayed by 16 hybrids. The range varied from 30.51 to 180.04 per cent. The lowest and highest values were recorded by the hybrids MCU 7 x EC 9256 and TCH 976 x Suvin respectively. Negative mid parental heterosis was recorded in TCH 1025 x Bhaksh 5230 (-13.89 per cent). Ten hybrids recorded positive heterobeltiosis which ranged from 12.34 to 85.39 per cent. The lowest and highest values were recorded by the hybrids TCH 1025 x Sudan G.45 and TCH 976 x Suvin respectively. Heterosis over the better parent was in the negative direction in four hybrids. Six hybrids displayed positive heterosis over the standard parent. The range of values varied from 13.52 (in MCU 9 x EC 111248) to 89.17 (TCH 976 x Suvin) per cent. Negative expression of heterosis was observed in 10 hybrids.

4.3.2.6 Boll weight

Expression of heterosis is presented in Table 33. Significant positive heterosis over mid parental values was noticed in nine hybrids and the percentage of expression varied from 6.99 to 36.26 per cent in the hybrids MCU 5 x TCB.7 and TCH 1025 x Bhaksh 5230 respectively. Five hybrids had negative expression. Heterobeltiotic value was positive (13.53 per cent) in TCH 1025 x Bhaksh 5230. Fourteen hybrids registered negative heterosis over the better parent. In respect of standard heterosis none of the hybrids displayed positive expression and 13 were negatively heterotic.

Table 33. Expression of heterosis (percentage) in interspecific hybrids for number of bolls per plant and boll weight

Hybrids	Number of bolls per plant			Boll weight		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	11.98	-31.39**	-26.15**	6.99*	-9.92**	-8.04*
MCU 5 x TCB 209	59.33**	16.50**	25.41**	-2.58	-14.37**	-12.58**
MCU 5 x EC 97631	104.09**	32.36**	42.48**	-1.85	-8.90**	-7.00*
MCU 7 x TCB 7	58.77**	11.73	-33.46**	2.64	-11.03	-15.33**
MCU 7 x TCB 209	10.88	1.78	-39.38**	-9.54**	-17.99**	-21.95**
MCU 7 x Bhaksh 5230	32.18**	2.37	-39.04**	28.48**	6.06	0.95
MCU 7 x EC 9256	30.51**	1.58	-39.51**	19.31**	-0.80	-5.58
MCU 7 BCS 9-76	57.95**	22.84**	-26.84**	0.24	-17.50**	-21.48**
MCU 7 x Sudan G.45	10.49	-14.07	-48.82**	24.52**	5.77	0.66
MCU 7 x Suvin	95.60**	52.09**	-9.42*	-12.15**	-20.97**	-24.79**
MCU 9 x EC 111248	126.13**	42.64**	13.52**	-10.92**	-28.81**	-18.16**
MCU 11 x TCB 15	-6.99	-38.14**	-44.84**	-28.57**	-41.79**	-31.88**
MCU 11 x BCS 9-76	66.41**	14.06**	1.72	2.28	-21.99**	-8.70**
TCH 976 x Suvin	180.04**	85.39**	89.17**	-2.34	-9.80**	-19.02**
TCH 976 x Bnhaksh 5230	141.50**	59.44**	62.69**	29.68**	9.59**	-1.61
TCH 1025 x Sudan G.45	66.46**	12.34*	6.25	25.03**	7.22*	-0.28
TCH 1025 x Bhaksh 5230	-13.89*	-42.06**	-45.20**	36.26**	13.53**	5.58
TCH 1025 x EC 9256	22.73**	-17.63**	-21.62**	26.06**	5.80	-1.61
TCH 1028 x BCS 9-76	107.15**	39.23**	33.77**	-3.27	-23.71**	-18.73**
TCH 1028 x Sudan G.45	52.85**	2.74	-1.29	-7.82*	-25.13**	-20.25**
TCH 1028 x EC 111248	62.12**	-1.38	-5.24	10.20**	-9.33**	-3.41
SE	0.55	0.64	0.64	0.07	0.08	0.08

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.3.2.7 Seed cotton yield per plant

Expression of heterosis based on all the three criteria is presented in Table 34. Positive heterotic effect over mid parental values was discernible in 17 hybrids with a range of 28.35 to 192.02 per cent recorded by the hybrids TCH 1028 x Sudan G.45 and TCH 976 x Bhaksh 5230 respectively. The hybrid MCU 11 x TCB 15 was negatively heterotic. The heterotic effect over better parent was in the positive direction in five hybrids. The range of expression varied from 19.55 in TCH 1025 x Sudan G.45 to 76.88 per cent in TCH 976 x Bhaksh 5230. Negative expression was noted in seven hybrids. Heterosis over the standard parent was positive in MCU 5 x EC 97631, TCH 976 x Suvin and TCH 976 x Bhaksh 5230, the values registered being 32.29, 50.83 and 58.34 per cent respectively. Thirteen hybrids displayed negative standard heterosis.

4.3.2.8 Number of seeds per locule

The expression of heterosis is presented in Table 34.

The hybrids MCU 7 x TCB.7 (13.88 per cent) and TCH 976 x Suvin (14.80 per cent) displayed relative heterotic effect in the positive direction. The hybrid MCU 5 x EC 97631 displayed negative heterosis Heterobeltiosis was not evident in the positive direction in all the hybrids while nine hybrids displayed better parental heterosis in the negative direction. Heterosis over the standard parent was not observed in any of the hybrid combinations.

4.3.2.9 Ginning outturn

Expression of heterosis for ginning outturn is furnished in Table 35. Positive heterotic effect over the respective mid parental values was discernible

Table 34. Expression of heterosis (percentage) in interspecific hybrids for seed cotton yield per plant and number of seeds per locule

Hybrids	Seed cotton yield per plant			Number of seeds per locule		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	8.67	-37.48**	-31.92**	4.09	-10.58	0.00
MCU 5 x TCB 209	50.62**	-0.12	8.77	-7.00	-14.66*	-4.57
MCU 5 x EC 97631	96.04**	21.48**	32.29**	-12.72*	-17.55**	-7.80
MCU 7 x TCB 7	59.65**	3.55	-42.89**	13.88*	-4.04	12.47
MCU 7 x TCB 209	2.91	-15.40	-53.34**	1.10	-9.17	6.45
MCU 7 x Bhaksh 5230	63.57**	9.85	-39.42**	3.85	-4.82	11.56
MCU 7 x EC 9256	56.45**	5.40	-41.87**	-8.66	-20.46**	-6.77
MCU 7 BCS 9-76	51.35**	2.18	-43.65**	6.04	-12.61*	2.42
MCU 7 x Sudan G.45	36.02**	-5.97	-48.14**	11.82	-4.72	11.67
MCU 7 x Suvin	69.83**	21.55*	-32.97**	5.29	-14.13*	0.65
MCU 9 x EC 111248	78.68**	2.74	-7.81	3.43	-9.17	5.48
MCU 11 x TCB 15	-39.20**	-63.65**	-62.40**	-7.85	-14.87*	-10.75
MCU 11 x BCS 9-76	51.33**	-10.20*	-7.12	4.85	-9.59	-5.22
TCH 976 x Suvin	166.24**	68.50**	50.83**	14.80*	-2.91	3.87
TCH 976 x Bnhaksh 5230	192.02**	76.88**	58.34**	-4.73	-8.89	-2.53
TCH 1025 x Sudan G.45	92.78**	19.55**	4.98	10.07	-2.51	4.30
TCH 1025 x Bhaksh 5230	8.23	-34.22**	-42.24**	-10.98	-14.87*	-8.92
TCH 1025 x EC 9256	40.33**	-14.53**	-24.95**	-6.85	-15.58**	-9.68
TCH 1028 x BCS 9-76	76.06**	5.06	4.90	-1.39	-15.33*	-10.32
TCH 1028 x Sudan G.45	28.35**	-22.26**	-22.39**	0.09	-10.96	-5.70
TCH 1028 x EC 111248	57.75**	-10.49*	-10.63*	-0.67	-9.14	-3.76
SE	1.95	2.25	2.25	0.28	0.32	0.32

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

in MCU 7 x Bhaksh 5230 (6.79 per cent). Negative expression was recorded in 15 hybrids. The range of expression varied from -7.05 to -25.82 per cent in TCH 1025 x sudan G45 and TCH 1028 x sudan G 45 respectively. Positive expression of heterobeltiosis over the better parent was not evident in all the hybrids and 16 of them displayed negative heterosis. Positive standard heterosis was noticed in MCU 11 x TCB 15 and MCU 7 x Bhaksh 5230, the values registered being 7.40 and 12.12 per cent respectively. Ten hybrids were negative in expression.

4.3.2.10 Lint index

The expression of heterosis is presented in Table 35.

MCU 7 x Bhaksh 5230 (34.0 per cent) registered positive relative heterosis while twelve were negatively heterotic. Hetorobeltiosis in the positive direction was not observed in any of the hybrids. However, fifteen hybrids displayed negative heterosis which ranged from -19.45 to-57.67 per cent. Heterosis over the standard parent was negative in 19 hybrid combinations.

4.3.2.11 Seed index

Fourteen hybrids were positively heterotic over the respective mid parent values (Table 36). Mid parental heterosis for seed index varied from 10.23 in MCU 7 x Bhaksh 5230 to 35.86 per cent in TCH 1025 x Bhaksh 5230 respectively. Negative expression was discernible in MCU 7 x TCB.7. Eight hybrids were heterobeltiotic. The range of heterobeltiosis was from 12.25 to 34.21 per cent . Among the 21 hybrids, standard heterosis was positive in six

Table 35. Expression of heterosis (percentage) in interspecific hybrids for ginning outturn and lint index

Hybrids	Ginning outturn			Lint index		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	-13.31**	-18.22**	-7.96*	-32.79**	-33.79**	-37.45**
MCU 5 x TCB 209	-16.55**	-21.26**	-11.39**	-28.50**	-37.34**	-40.80**
MCU 5 x EC 97631	-16.44**	-23.17**	-13.54**	-32.63**	-45.02**	-48.05**
MCU 7 x TCB 7	1.50	0.13	2.70	-8.45	-23.85**	-30.19**
MCU 7 x TCB 209	-9.77**	-10.97**	-8.69**	-15.50	-21.61	-44.26**
MCU 7 x Bhaksh 5230	6.79*	4.37	12.12**	34.00**	17.81	-5.52
MCU 7 x EC 9256	-4.28	-4.56	-1.52	1.87	-7.55	-31.06**
MCU 7 BCS 9-76	-2.35	-4.16	-1.70	4.74	-1.72	-31.82**
MCU 7 x Sudan G.45	-10.44**	-11.09**	-7.47*	-6.76	-16.48	-35.82**
MCU 7 x Suvin	-11.53**	-13.64**	-11.42**	-24.78*	-30.41**	-50.22**
MCU 9 x EC 111248	-4.06	-5.22	3.24	-15.56	-20.72*	-26.30**
MCU 11 x TCB 15	-3.19	-8.66**	7.40*	-6.14	-19.45*	-13.96
MCU 11 x BCS 9-76	-12.53**	-19.53**	-5.38	-25.06**	-38.20**	-33.98**
TCH 976 x Suvin	-7.71**	-14.65**	-1.88	-19.06*	-32.70**	-27.38**
TCH 976 x Bnhaksh 5230	-25.31**	-27.76**	-16.95**	-50.52**	-56.87**	-53.46**
TCH 1025 x Sudan G.45	-7.05**	-7.36*	-3.59	4.17	1.97	-21.65**
TCH 1025 x Bhaksh 5230	-20.23**	-21.73**	-15.92**	-29.77**	32.66**	-46.00**
TCH 1025 x EC 9256	-21.86**	-21.93**	-19.29**	-37.47**	-37.88**	-53.68**
TCH 1028 x BCS 9-76	-11.55**	-18.14**	-4.99	-33.30**	-48.33**	-34.74**
TCH 1028 x Sudan G.45	-25.82**	-29.65**	-18.36**	-47.36**	-57.67**	-46.54**
TCH 1028 x EC 111248	-12.86**	-15.54**	-1.98	-29.72**	-42.16**	-26.95**
SE	0.63	0.73	0.73	0.15	0.17	0.17

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

hybrids and the expression ranged from 10.12 to 46.34 per cent. Negative expression was not observed in any of the hybrid combinations.

4.3.2.12 2.5 per cent span length

Expression of heterosis is presented in Table 36.

Seventeen hybrids expressed positive relative heterosis which ranged from 2.05 to 15.32 per cent. The hybrids MCU 7 x TCB 7 and TCH 1028 x Sudan G 45 registered the lowest and highest values. Two hybrids (MCU 7 x TCB 209 and MCU 7 x Bhaksh 5230) were negatively heterotic. Fourteen hybrids were positively heterotic over the better parental value which ranged from 2.72 to 13.06 per cent in MCU 5 x TCB 209 and TCH 1028 x Sudan G.45 respectively while four hybrids displayed negative values. Standard heterosis was positive in seven hybrids. The range of standard heterosis varied from 2.33 (TCH 976 x Bhaksh 5230, TCH 1025 x EC 9256) to 7.79 per cent (TCH 1028 x Sudan G 45). Eleven hybrids were heterotic in the negative direction.

4.3.2.13 Uniformity ratio

Expression of heterosis for uniformity ratio is furnished in Table 37. Six hybrids expressed positive relative heterosis. The range varied from 3.45 to 10.77 per cent. The hybrids MCU 7 x EC 9256 and MCU 7 x Bhaksh 5230 registered the lowest and highest values. Six hybrids displayed negative relative heterosis. Three hybrids (TCH 1025 x Bhaksh 5230, TCH 1028 x EC 111248 and MCU 7 x Bhaksh 5230) were positively heterobeltiotic, the values registered by

Table 36. Expression of heterosis (percentage) in interspecific hybrids for seed index and 2.5 per cent span length

Hybrids	Seed index			2.5 per cent span length		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	1.25	-13.34**	23.03**	7.70**	6.43**	0.51
MCU 5 x TCB 209	22.56**	17.52**	29.41**	5.92**	2.72**	3.24**
MCU 5 x EC 97631	16.30**	12.25**	21.93**	6.01**	4.93**	-0.91
MCU 7 x TCB 7	-13.14**	-30.09**	-0.75	2.05*	-1.87	-9.51**
MCU 7 x TCB 209	13.57**	1.43	11.69*	-4.47**	-11.78**	-11.34**
MCU 7 x Bhaksh 5230	10.23*	3.13	2.48	-9.50**	-12.28**	-20.45**
MCU 7 x EC 9256	16.72**	6.97	11.18*	5.24**	0.98	-6.48**
MCU 7 BCS 9-76	11.55**	-0.67	10.12*	7.48**	6.54**	-7.69**
MCU 7 x Sudan G.45	29.31**	17.96**	23.86**	-0.06	-5.41**	-9.82**
MCU 7 x Suvin	6.60	-7.63	9.09	2.47**	-4.80**	-5.57**
MCU 9 x EC 111248	-2.43	-9.51*	2.60	14.88**	10.92**	6.48**
MCU 11 x TCB 15	4.69	2.92	6.85	-1.28	-3.38**	-10.43**
MCU 11 x BCS 9-76	13.35**	7.95	19.69**	11.48**	10.15**	-2.23*
TCH 976 x Suvin	5.36	0.30	18.46**	8.05**	4.08**	3.24**
TCH 976 x Bnhaksh 5230	18.26**	14.16**	21.89**	12.08**	11.34**	2.33*
TCH 1025 x Sudan G.45	30.26**	28.31**	34.72**	11.72**	8.28**	3.24**
TCH 1025 x Bhaksh 5230	35.86**	34.21**	36.69**	7.53**	6.81**	-3.14**
TCH 1025 x EC 9256	11.12**	10.00*	14.33**	12.40**	10.49**	2.33*
TCH 1028 x BCS 9-76	-0.13	-5.00	16.69**	11.98**	8.95**	-0.20
TCH 1028 x Sudan G.45	28.46**	19.13**	46.34**	15.32**	13.06**	7.79**
TCH 1028 x EC 111248	8.38*	-3.04	19.09**	5.70**	4.42**	-4.35**
SE	0.25	0.29	0.29	0.20	0.23	0.23

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

the hybrids were 4.65, 5.47 and 9.92 per cent respectively. Expression of heterosis over the better parent was negative in seven hybrids. Heterosis over the standard parent was positive in 11 hybrids. Ten crosses displayed the value of 5.47 per cent and MCU 7 x Bhaksh 5230 registered 12.50 per cent heterotic effect. In nine hybrids standard heterosis was in the negative direction.

4.3.2.14 Bundle strength

Expression of heterosis based on relative heterosis, heterobeltiosis and standard heterosis is furnished in Table 37.

Ninteen hybrids were positively heterotic over the mid parental values and the expression varied from 4.53 to 34.09 per cent. MCU 5 x TCB 7 and TCH 1028 x BCS 9-76 exhibited the minimum and maximum heterotic values respectively. The hybrids MCU 7 x Bhaksh 5230 and MCU 11 x TCB 15 were negatively heterotic. Eighteen hybrids showed positive expression over the better parental value. The highest value of 32.51 per cent was registered by TCH 1028 x EC 111 248. Two hybrids displayed negative heterosis. Positive standard heterosis was recorded by nine crosses with a range of 2.82 to 11.69 per cent. Hybrids MCU 9 x EC 111248 and TCH 1025 x Sudan G 45 registered the lowest values and TCH 1025 x EC 9256 displayed the highest expression respectively. Negative estimates of heterosis was encountered in six hybrids.

Table 37. Expression of heterosis (percentage) in interspecific hybrids for uniformity ratio and bundle strength

Hybrids	Uniformity ratio			Bundle strength		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
MCU 5 x TCB 7	-5.75**	-9.56**	-3.91*	4.53**	4.24**	-0.81
MCU 5 x TCB 209	-0.81	-1.60	-3.91*	11.42**	3.39**	-1.61
MCU 5 x EC 97631	-3.15*	-4.65**	-3.91*	17.65**	10.17**	4.84**
MCU 7 x TCB 7	1.12	-0.74	5.47**	11.37**	2.27	-3.23**
MCU 7 x TCB 209	6.30**	3.05	5.47**	20.00**	18.32**	-3.63**
MCU 7 x Bhaksh 5230	10.77**	9.92**	12.50**	-6.49**	-12.44**	-20.56**
MCU 7 x EC 9256	3.45*	3.05	5.47**	16.89**	8.77**	0.00
MCU 7 BCS 9-76	0.75	-1.46	5.47**	26.87**	19.28**	7.26**
MCU 7 x Sudan G.45	0.00	-2.88	5.47**	15.95**	7.89**	-0.81
MCU 7 x Suvin	-2.38	-6.11**	-3.91*	17.38**	12.04**	-2.42*
MCU 9 x EC 111248	5.88**	0.75	5.47**	29.88**	22.79**	2.82*
MCU 11 x TCB 15	1.12	0.75	5.47**	-18.10**	-24.90**	-27.02**
MCU 11 x BCS 9-76	-0.37	-1.46	5.47**	12.26**	6.73**	-4.03**
TCH 976 x Suvin	2.07	1.65	-3.91*	28.02**	22.69**	6.85**
TCH 976 x Bnhaksh 5230	-6.02**	-9.30**	-8.59**	22.46**	15.11**	4.44**
TCH 1025 x Sudan G.45	-3.73**	-7.19**	0.78	16.17**	11.84**	2.82*
TCH 1025 x Bhaksh 5230	4.65**	4.65**	5.47**	12.39**	8.89**	-1.21
TCH 1025 x EC 9256	-2.70	-3.08	-1.56	26.20**	21.49**	11.69**
TCH 1028 x BCS 9-76	-7.17**	-10.22**	-3.91*	34.09**	23.77**	11.29**
TCH 1028 x Sudan G.45	-10.11**	-13.67**	-6.25**	29.60**	18.42**	8.87**
TCH 1028 x EC 111248	8.43**	5.47**	5.47**	33.81**	32.51**	0.81
SE	0.43	0.50	0.50	0.18	0.20	0.20

d_i = relative heterosis d_{ii} = heterobeltiosis d_{iii} = standard heterosis

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

4.4 Biochemical studies

4.4.1 Isozymes

To study the biochemical diversity existing between the genotypes based on isozyme pattern, attempts were made to study the peroxidase and super oxide dismutase enzymes in 13 accessions of *G.hirsutum* (MCU 5, MCU 7, MCU 9, MCU 11, TCH 976, TCH 1025, TCH 1028, TCH 1218, TCH 1223, TCH 1233, TCH 1452, TCH 1458 and TCH 1569) and 10 accessions of *G. barbadense* (TCB.7, TCB.15, TCB 209, Bhaksh 5230, EC 9256, EC 97631, EC 111248, BCS 9-76, Sudan G-45 and Suvin) group. Both the enzymes expressed two electromorphs and they were monomorphic. They did not show any variation within the genotypes of the same species.

4.4.2 Estimation of soluble protein

The total soluble protein ranged from 4.1 to 13.1 per cent in *G. hirsutum* parents and the mean protein content was 7.37 per cent. Parents featured higher protein content in this group. In *G. barbadence* group, the total soluble protein varied from 3.4 to 9.03 per cent with the mean value of 6.04 per cent. Parents exceeded the mean protein (Table 37a).

Table 37a. Soluble protein content in cotton seeds

Genotypes	Soluble protein content (%)	Genotypes	Soluble protein content (%)
G. hirsutum		*G. barbadense*	
MCU 5	5.1	TCB 7	6.2
MCU 7	5.1	TCB 15	8.2
MCU 9	5.4	TCB 209	6.2
MCU 11	8.8	Bhaksh 5230	6.7
TCH 976	4.4	EC 9256	5.5
TCH 1025	8.8	EC 97631	4.3
TCH 1028	5.2	EC 111248	9.0
TCH 1218	13.1	BCS 9-76	7.3
TCH 1223	4.1	Sudan G-45	3.4
TCH 1233	11.8	Suvin	3.5
TCH 1452	6.2		
TCH 1458	7.4		
TCH 1569	8.7		
TCH 1609	5.9		
LRA 5166	4.5		
LRK 516	6.3		
Sahana	10.6		
Surabhi	13.1		
SVPR 2	5.6		
Mean	7.37		6.04

Discussion

CHAPTER V

DISCUSSION

The area under cotton in India is the largest and constitutes nearly one-fourth of the world's cotton area in which 70 per cent of the area is rainfed and 30 per cent irrigated . In India the period between 1980-1997 can be considered as a "golden era" in respect of cotton production. During this period, production of cotton has gone up from 75 lakh bales in 1983-84 to 160 lakh bales during 1996-97 (Kairon, 1997). This achievement was possible primarily because of the evolution of high yielding varieties and heterotic hybrids.

Eventhough the genus *Gossypium* contains 45 (Endrizzii *et al.,* 1985 and Percival Kohel, 1991) species which encompasses diploids and tetraploids of enormous genetic diversity, only four of them are under cultivation. India grows stable varieties of all the four cultivated species of cotton viz., *Gossypium hirsutum, Gossypium barbadense, Gossypium arboreum* and *Gossypium herbaceum* and F1 hybrid cottons of intra-*hirsutum*, *hirsutum x barbadense* and *herbaceum x arboreum* crosses. Among the cultivated cottons, *Gossypium hirsutum* is considered as the most important species because of its wide adaptability, high yielding ability and better spinning capacity while the species *Gossypium barbadense* is capable of spinning to high counts due to its finer, longer and stronger lint.

India is not only the first, but perhaps the only country in the world to grow hybrid cottons on a commercial scale. The efficient and successful exploitation of heterosis in cotton was marked by the release of intra-*hirsutum* hybrid, Hybrid 4 (Patel, 1971) in Gujarat during early seventies. The successful exploitation of heterosis was continued with the development of high yielding intra and inter specific crosses. With the growing demand for cotton due to ever increasing population and technological improvement in the cotton mills, the production for 2000 AD has been projected at 20 million bales. Thus, there is an immense need for the development of improved cotton varieties and hybrids to meet the further requirement of the cotton mills.

For the development of superior and heterotic hybrids in cotton, it is essential to evaluate a large number of available germplasm for different characters in order to identify the most potential parents. In this context, estimation of genetic and geographic diversity in the crop species is of utmost importance as it forms the basic prerequisite for an efficient selection programme.

The result of Cheng and Zhao (1992) confirms that cluster divergence and performance of the parents to be considered together while selecting the parent materials. Eventhough lot of work has been done in the evaluation of the yield and quality characters in cotton, it is known that the expression of the characters varies from material to material and with the environment in which they are

evaluated (Mather,1949). Hence, it is imperative to evaluate the genotypes selected for hybridisation in a particular environment to unravel their genetic and breeding values.

For the selection of superior parents for hybridization programme, it is necessary to measure the genetic diversity among the set of genotypes as, genetic diversity plays an important role in generating heterosis in hybrids between genotypes. Selection of parents based on inter and intra-cluster divergence was suggested by Cheng and Zhao, 1992. It is also important to know the information regarding the relationship among the different economic characters so that a suitable breeding programme can be formulated for the improvement of yield and / or quality traits.

With a view to investigate the genetic diversity as related to expression of heterosis, the present study was attempted using 19 genotypes of *G. hirsutum* and 10 genotypes of *G. barbadense*, 49 intra *hirsutum* hybrids generated from selected *hirsutum* parents and 21 interspecific hybrids involving *hirsutum* and *barbadense* parents.

Progress in any crop improvement programme depends mainly on the variability existing in the metric traits of the base population. In the present study, there was a close correspondence between the phenotypic and genotypic

variances, indicating the stable expression of the attributes of seed cotton yield and the absence of high environmental influence. This was also confirmed by the narrow differences between GCV and PCV values particularly for the number of bolls per plant, boll weight, seed cotton yield per plant, seed oil content, 2.5 per cent span length, uniformity ratio, fibre fineness, maturity coefficient and bundle strength indicating the characters to be free from environmental influence. On the contrary, number of monopodia per plant was vulnerable to the environmental influence as indicated by the wider differences between GCV and PCV values.

Heritability and genetic advance are the two important selection criteria considered in the crop improvement. Heritability estimates along with genetic advance are normally used as indices for predicting the gain under selection than heritability estimates alone. The narrow differences between GCV and PCV values also reflected in high heritability values invariably for all the characters. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson et al. 1955). In the present study a combination of high heritability with low genetic advance was noticed for number of bolls per plant, boll weight, seed oil content, 2.5 per cent span length and fibre fineness. On the contrary, high heritability with high genetic advance was noticed for seed cotton yield which is in confirmation with the reports by Kalsy *et al* (1977) and Patil and Chopde (1983). Thus, there is much scope for yield improvement using the present set of materials which is an encouraging inference obtained from the present study.

In plant breeding, correlation coefficients are used as a tool to measure the mutual relationship between various characters on which selection is based for genetic improvement in yield. The association studies revealed that plant height, number of sympodia per plant, number of bolls per plant, boll weight and number of seeds per locule had highly significant positive correlation with seed cotton yield. Since all the yield contributing characters have been positively correlated with seed cotton yield, rational improvement of seed cotton yield is possible through selection for these component characters also. This conforms to the results of Sridar (1997).

Among the fibre quality characters, bundle strength registered negative association with seed cotton yield per plant. Earlier report of Cheng and Zhao (1992) also indicated a negative relationship between these two important characters, although such finding is detrimental for simultaneous improvement of yield and quality.

In order to know the information on the cause and effect relationship between yield contributing characters and yield, seven yield related characters were subjected to path analysis. The analysis revealed that number of bolls per plant and boll weight directly influenced the yield followed by number of seeds per locule and number of sympodia per plant. Singh *et al.* (1979) and Tyagi *et al.* (1988), reported the number of bolls per plant and boll weight to be the important contributors to yield while Sridar (1997) noticed number of sympodia per plant to the primary component of yield.

As the knowledge of genetic diversity between the parental genotypes is an essential pre-requisite for realising heterosis of a high order in the hybrids, the extent of diversity in the parental genotypes was estimated by D^2 statistics. The concept of D^2 statistics was originally developed by Mahalonobis (1928). The application of D^2 statistic as a tool for the assessment of genetic diversity in plant breeding was suggested by Rao (1952). This technique provides variable information on the degree of diversity the relative contribution of each character to the total divergence.

In the present study, the 29 cotton parental genotypes selected from *G. hirsutum* and *G. barbadense* speices came under six clusters based on their genetic divergence, reflecting the existence of sufficient genetic diversity among these genotypes. Cluster I included genotypes from India and Russia which are , the two ecologically divergent countries. Similarly cluster II included one from Sudan, two from Russia and five from India. This clustering pattern indicated that there was no relationship between the genetic diversity and geographical origin of the genotype. The absence of relationship between the ecogeographic origin and genetic divergence has been reported by Cheng and Zhao (1992), Sumathi and Nadarajan (1994). Sambamurthy *et al.* (1995a and b), Carvalho *et al.* (1995) and Sandhu and Boparai (1997).

Among the different yield and quality characters studied, boll weight, seed oil content, 2.5 per cent span length, fibre fineness and bundle strength accounted for nearly 99 per cent of the total divergence. Maximum contribution

of fibre characters towards divergence was also reported by Sambamurthy *et al.* (1995a and b). This goes to show that plant morphological characters are more susceptible to environmental variations than fibre properties.

The five important characters which contributed a large share to divergence, viz. number of bolls for plant, boll weight, seed cotton yield per plant, ginning outturn, 2.5 per cent span length and bundle strength were used to study the relationship between the heterotic expression in the hybrids and genetic diverisity of the parental genotypes..

Among the 49 intra-*hirsutum* hybrid combinations evaluated 12, MCU 5 x TCH 1569, MCU 9 x TCH 1223, MCU 11 x TCH 1218, MCU 11 x TCH 1223, MCU 11 x TCH 1609, TCH 976 x TCH 1569, TCH 1025 x SRPR-2, TCH 1028 x TCH 1218, TCH 1028 x TCH 1569, LRA 5166 x TCH 1223, LRA 5166 x TCH 1233, and LRA LRA 5166 x TCH 1452 exhibited yield heterosis based on the standard parent. The mean yield ranged from 92.44 g. to 105.57 g.. in these 12 hybrids. Out of this 10 hybrids excluding MCU.11x TCH 1223 and MCU.11 x TCH 1609 were heterotic for either number of bolls per plant or boll weight which are the most important yield components identified in the present study. These 10 hybrids are likely to be highly stable in their performance as they combined high values for yield and also for its important yield components. Six of the above hybrids MCU.9 x TCH 1223, MCU.11 x TCH 1218, TCH 1025 x SVPR.2, TCH 1028 x TCH 1218, LRA 5166 X TCH 1223 and LRA 5166 x TCH 1452 had high ginning outturn of more than 37 per cent and these hybrids will be

economically useful. Particularly, the combinations TCH 1028 X TCH 1218 and LRA 5166 X TCH 1452 which are heterotic for ginning outturn are of great interest to crop improvement.

In respect of fibre quality MCU.9 x TCH1223, MCU.11 x TCH 1218, LRA 5166 x TCH 1233, LRA 5166 x TCH 1452 recorded high bundle strength values exceeding 20 g./tex and LRA 5166 x TCH 1233 recorded relative heterosis for this parameter. Thus, among all the intra-*hirsutum* hybrid combinations evaluated in the present study, five superior hybrids MCU. 9 x TCH 1223, MCU.11 x TCH 1218, LRA 5166 x TCH1223, LRA 5166 x TCH 1233 and LRA 5166 x TCH 1452 (Table 38) which could be identified for yield, one of the yield components, ginning outturn and fibre properties. The mean expression for the economic characters of these hybrids is presented in Fig.4. These hybrids need to the evaluated under different situations for assessing the G x E interaction and stability for their performance. In earlier studies, reports on the negative relationship between yield and quality parameters was common. Kerr (1966), and Valarmathi (1996) reported negative association between yield and strength fibres while Thompson (1972), Kalsy *et al.* (1977) noticed a negative relationship between yield and fibre length. The present study has brought out that yield, ginning and quality parameters can be combined together to obtain economically useful hybrids.

In respect of the inter specific combinations, three out of 21 hybrids evaluated, exhibited yield heterosis based on the standard parent (Table 38). The seed

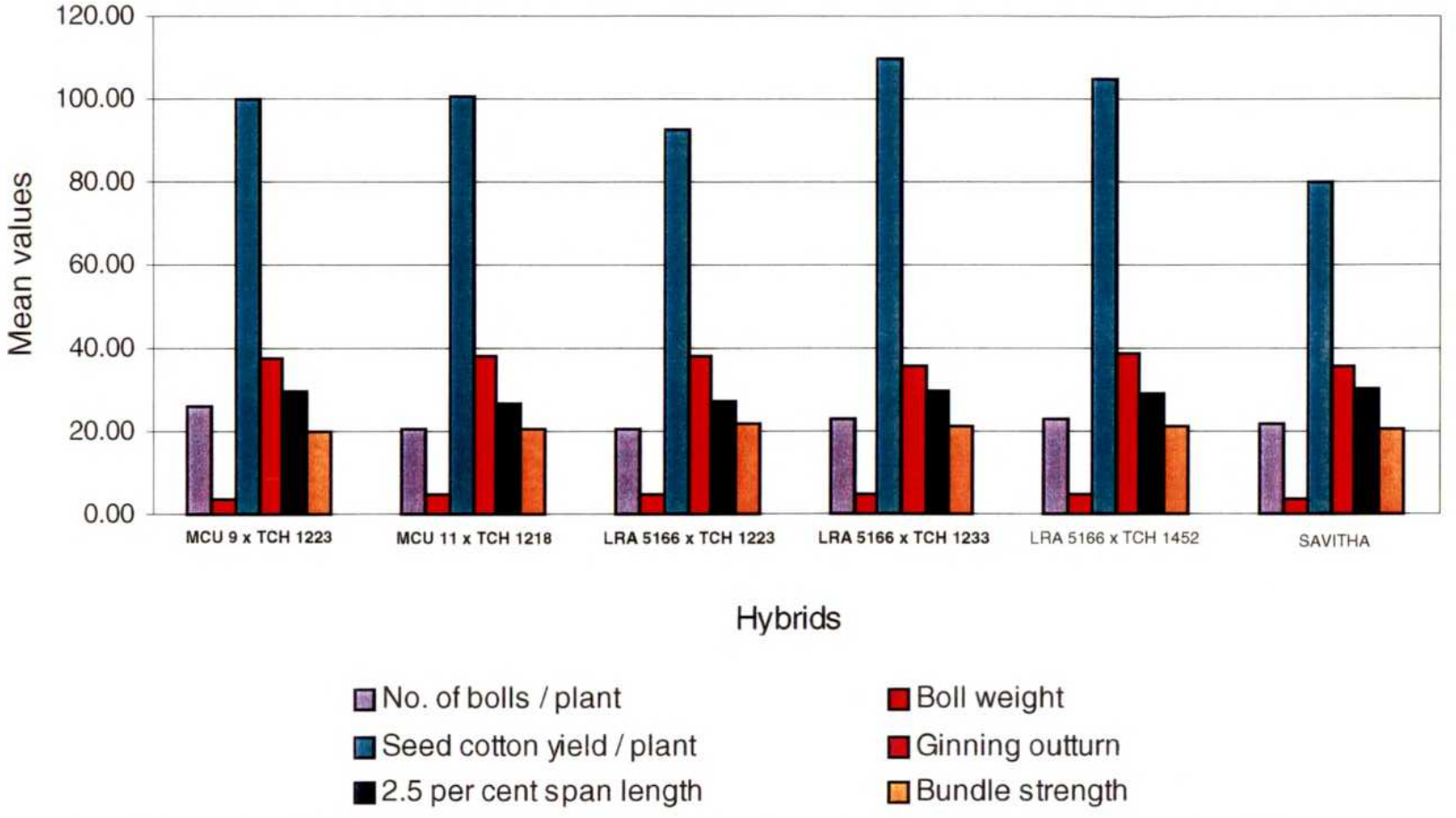


Fig. 4 Mean expression of superior intra *hirsutum* hybrids for the six economic characters

cotton yield was 88.28 g., 100.66 g. and 105.66 g. for MCU.5 x EC 97631, TCH 976 x Suvin and TCH 976 x Bhaksh 5230 respectively. The mean expression these hybrids along with the check is depicted in Fig.5. All the three hybrids exhibited positive heterosis for number of bolls per plant also, although heterosis for boll weight could not be discernible in any of the combinations. Considering the fibre quality traits namely 2.5 per cent span length and bundle strength two out of the three interspecific hybrids (TCH 976 x Suvin, and TCH 976 x Bhaksh, 5230) were heterotic, for both the quality parameters while the hybrid MCU.5 x EC 97631 was heterotic for bundle strength only. Generally interspecific hybrids show poor ginning outturn as compared to the intra-*hirsutum* hybrids or *hirsutum* parents. In the present study also, the three interspecific hybrids showed absence of heterosis for ginning outturn. Nevertheless TCH 976 x Suvin gave relatively higher value of 32.09 per cent ginning outturn which is a welcome feature in breeding interspecific hybrids.

When compared with intra *hirsutum* hybrids interspecific hybrids were superior for fibre quality characters as revealed by their heterotic expression for 2.5 per cent span length and bundle strength. The mean bundle strength ranged from 25.90 g./tex to 26.50 g./tex in the interspecific hybrids which were also superior to intra-*hirsutum* hybrids. This results conform to the results reported by Krishnadoss (1991).

Contradictory reports have been made by deifferent authors on the relationship between heterosis and the diversity of parents. Wang and Pan

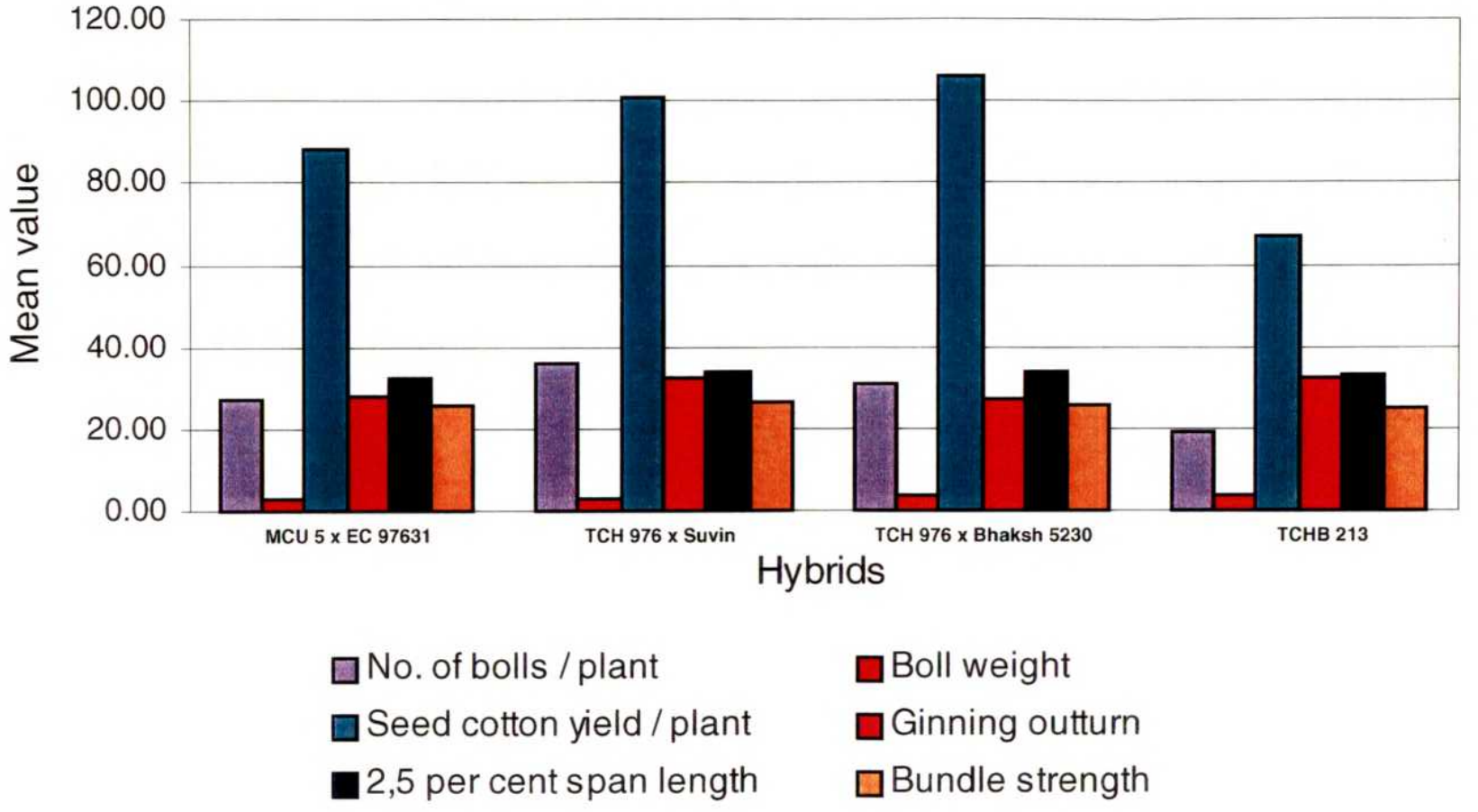


Fig. 5 Mean expression of superior interspecific hybrids for the six economic characters

Table 38. Expression of heterosis by superior hybrids

Hybrid	Mean yield/ plant		Number of bolls/ plant		Boll weight		Ginning outturn		2.5% span length		Bundle strength	
	Mean (g)	Standard heterosis	Mean	Standard heterosis	Mean (g)	Standard heterosis	Mean (%)	Standard heterosis	Mean (mm)	Standard heterosis	Mean (1/8 gauge g/tex)	Standard heterosis
Intra *hirsutum*												
MCU 9 x TCH 1223	100.04	24.63**	25.91	19.35**	3.93	5.55	37.49	4.78	29.4	-2.33**	20.2	-3.35**
MCU 11 x TCH 1218	100.81	25.58**	20.73	-4.50	4.97	33.48**	37.98	6.17	26.4	-12.29**	20.4	-2.39**
LRA 5166 x TCH 1223	92.44	15.15**	20..81	-4.12	4.57	22.65**	38.01	6.23	27.1	-9.97**	21.7	3.83**
LRA 5166 x TCH 1233	110.00	37.04**	23.29	7.29	4.81	29.27**	35.49	-0.81	29.7	-1.33**	21.2	1.44**
LRA 5166 x TCH 1452	104.81	30.57**	23.13	6.57	4.61	23.81**	38.92	8.80*	29.0	-3.65**	21.1	0.96
Savitha	80.27		21.71		3.72		35.78		30.10		20.90	
Interspecific												
MCU 5 x EC 97631	88.28	32.29**	27.27	42.48**	3.28	-7.00*	28.27	-13.54**	32.63	-0.91	26.00	4.84**
TCH 976 x Suvin	100.66	50.83**	36.20	89.17**	2.85	-19.02**	32.09	-1.88	34.00	3.24**	26.50	6.85**
TCH 976 x Bhaksh 5230	105.66	58.34**	31.13	62.69**	3.47	-1.61	27.16	-16.95**	33.70	2.33**	25.90	4.44**
TCHB 213	66.73		19.14		3.52		32.70		32.93		24.80	

(1990) have reported existence of association between hybrid vigour in the divergent parental combination while the reports of Amalraj and Gawande (1986) indicate the abscence of such a relationship. Hence a critical analysis was made using the genetic meterials studied in the present investigation to understand the above relationship.

All the 70 hybrids including 49 intra-*hirsutum* and 21 inter-specific were scored for their heterotic expression based on standard heterosis for the six important characters viz., Number of bolls per plant, boll weight, seed cotton yield per plant, ginning outturn, 2.5 per cent span length and bundle strength. A score of -1 was given for negative heterosis and 1 for positive heterosis. Out of the 70 hybrids, 17 hybrids (11 intra*hirsutum* and six interspecific) received overall scores of 1 and above. Hence, the results pertaining to these 17 hybrids are discussed critically to bring out the relationship between heterosis and genetic diversity.

Based on the inter cluster distances, the clusters were classified as less divergent, divergent and highly divergent if the cluster distances were less than 51.17, 51.17 to 61.17 and above 61.17 respectively. Between the two groups of hybrids (intra *hirsutum* and interspecific), more number of the latter group recorded scores for heterotic expression. Six out of 21 hybrids in this group registered the scores for heterotic expression. The parents of three hybrids TCH 976 x Bhaksh 5230, TCH 1025 x Sudan G 45 and TCH 1028 x BCS 9-76 belonged to the diversity groups less divergent x less divergent. One of the

Table 39. Criteria for selection of parents based on genetic diversity and heterosis

Hybrid	Cluster number	Classification	Score	Number of bolls/ plant	Boll weight	Seed cotton yield/ plant	Ginning outturn	2.5% span length	Bundle strength
Intra-*hirsutum*									
Less divergent									
MCU 5 x TCH 1569	III x I		1	17.78* (1)	6.42 (0)	24.22** (1)	1.87 (0)	-0.33 (0)	-1.91** (-1)
Divergent									
MCU 5 x SVPR 2	III x V		2	-1.18 (0)	15.22 (0)	11.85 (0)	16.85** (1)	1.33* (1)	0.48 (0)
Interspecific									
Less divergent									
TCH 976 x Suvin	I x II		3	89.17** (1)	-19.02** (-1)	50.83** (1)	-1.88 (0)	3.24** (1)	6.85** (1)
TCH 976 x Bhaksh 5230	I x II		3	62.69** (1)	-1.61 (0)	58.34** (1)	-16.95** (-1)	2.33* (1)	4.44** (1)
TCH 1025 x Sudan G45	I x II		2	6.25 (0)	-0.28 (0)	4.98 (0)	-3.59 (0)	3.24** (1)	2.82* (1)
MCU 9 x EC 111248	I x IV		2	13.52** (1)	-18.16** (-1)	-7.81 (0)	3.24 (0)	6.48** (1)	2.82* (1)
MCU 5 x EC 97631	III x I		1	42.48** (1)	-7.00* (-1)	32.29** (1)	-13.54** (-1)	-0.91 (0)	4.84** (1)
TCH 1028 x BCS 9-76	I x II		1	33.77** (1)	-18.73** (-1)	4.90 (0)	-4.99 (0)	-0.20 (0)	11.29** (1)
Intra-cluster (*hirsutum*)									
TCH 1028 x TCH 1569	I	LD x LD	3	1.54 (0)	24.35** (1)	24.19** (1)	-6.60 (0)	1.33* (1)	0.48 (0)
MCU 9 x TCH 1569	I	D x LD	2	-7.64 (0)	4.03 (0)	-9.90 (0)	2.92 (0)	1.66** (1)	15.31** (1)
MCU 9 x TCH 1609	I	D x LD	2	6.63 (0)	-5.46 (0)	-1.09 (0)	10.54** (1)	1.99** (1)	-0.48 (0)
LRA 5166 x TCH 1223	I	LD x D	2	-4.12 (0)	22.65** (1)	15.15* (1)	6.23 (0)	-9.97** (-1)	3.83** (1)
LRA 5166 x TCH 1233	I	LD X D	2	7.29 (0)	29.27** (1)	37.04** (1)	-0.81 (0)	-1.33 (-1)	1.44** (1)
LRA 5166 x TCH 1452	I	LD x D	2	6.57 (0)	23.81** (1)	30.57** (1)	8.80* (1)	-3.65** (-1)	0.96 (0)
MCU 11 x LRK 516	I	LD x HD	1	-8.18 (0)	4.83 (0)	-5.73 (0)	7.83* (1)	-8.31** (-1)	8.61** (1)
MCU 11 x TCH 1223	I	LD x D	1	9.98 (0)	12.80 (0)	21.31** (1)	8.47* (1)	-11.96** (-1)	0.00 (0)
TCH 1028 x TCH 1218	I	LD x LD	1	-0.92 (0)	34.83** (1)	31.51** (1)	7.66* (1)	-3.65** (-1)	-9.09** (-1)

LD = Less divergent D = Divergent HD = Highly divergent

Values in the brackets indicate the score given based on the significance of the standard heterosis.

(-1) = Negatiely significant (0) = Non significant (1) = Positively significant

parents, Suvin, of the hybrid TCH 976 x Suvin, and EC 97631 of the F_1 MCU.5 x EC 97631 were highly divergent while the other parent TCH 976 and MCU.5 belonged to less divergent and divergent clusters respectively. In the last combination, MCU 9 x EC 111248 both the parents came under the cluster which are divergent based on the intercluster distance.

Out of the two intra-*hirsutum* hybrids, the parents of MCU.5 x TCH 1569 belonged to divergent (MCU.5) and less divergent (TCH 1569) clusters. Both the parents of the cross MCU.5 x SVPR 2 were from clusters which are divergent. The above results go to show that there is no relationship between genetic divergence and expression of heterosis in the above materials studied in the present investigation. Use of common parents for hybridisation ensuring common gene flow, general criteria for selection, aclimatisation in a common environment and more or less similar objective of breeding would have tended to result in common genotypes which may show genetic identity among themselves and narrow down the genetic diversity. Such similarities should have resulted in poor expression of heterosis. On the other hand, genotypes belonging to the two different species, *G. hirsutum* and *G. barbadense* combine to result in heterotic hybrids showing spcies diversity can contribute to heterosis. The allelic diversity between these two species is also evident from the hybrid breakdown in F_2 derived from the above two interspecific hybrid combinations. Earlier studies by Stephens (1947) and Krishnadoss (1991) also conforms this result. However such recombinants would be of no use in a pedigree breeding programme.

Among the intra-*hirsutum* combinations, nine hybrids were heterotic which obtained the scores from 1 to 3. In these hybrids also, one of the parents was less divergent as seen from the dendrogram score for these parents. The other parent may be either less divergent, divergent or highly divergent. Thus there was no relationship between the diversity and heterotic expression in this group also and conforms to the earlier reports of Sumathi and Nadarajan, 1994.

Another important feature, is that when one of the parent is divergent or highly divergent, the hybrid exhibits positive heterosis for both yield and quality traits. The heterotic effect was more pronounced for quality traits than yield components. Such phenomenon may be due to the fact that the quality characters contributed more to the total divergence (Table 39). The earlier studies by Wang and Pan (1990) also states that, within a restricted range, increased genetic distance was associated with increased heterosis.

The realisation of high yielding heterotic hybrids is high in the present investigation. The characters evaluated among the genotypes revealed very little influence of the environment which discloses the stability of their expression. The hybrids involving highly diverse parents will be superior for quality characters whereas the maximum heterosis for both yield and quality characters occurs at an optimal or intermediate level of genetic diversity. In the hybrids involving parents of less divergent group, F_2 seeds can also be used for cultivation if the inbreeding depression is very minimum as the expression of characters are likely to be stable. Since, the yield contributing characters have positive correlation

with yield and yield heterosis is also associated with the heterotic expression of boll number and boll weight, it is possible to improve yield through the improvement of these characters with the set of parental genotypes evaluated in the present investigation.

In the present study an attempt was made to assess the diversity using biochemical markers. Isozyme analysis for (two enzymes peroxidase and superoxidase dismutase) was done in the 23 parental genotypes. From the banding patterns obtained for the two isozymes, it was clear that there was no polymorphic bands between the genotypes of the same species. Eventhough the genotypes could be grouped into six different clusters based on morphological characters, the polymorphic banding was not found for both the isozymes. Similar results were obtained by Wang Zhillong et al. (1995) for peroxidase and Zhou-Bao Liang (1995) for superoxide enzymes. This may be due to free flow of genes between the genotypes over the years because of their extensive use in the breeding programmes with similar objectives or common ancestry among the genotypes.

The total soluble protein content was generally higher in *Gossypium hirsutum* genotypes as compared to *Gossypium barbadense* varieties. Although a clear cut relationship between protein content and yield could not be brought out, there is an indication that high yielding genotypes could be short listed based on the soluble protein content in the *hirsutum* group. This could be exemplified by the genotypes MCU 11, TCH 1218, TCH 1223, TCH 1233, TCH 1458 and TCH 1569 which combined generally a higher protein content and

higher seed cotton yield. These results conform to the earlier findings of Raja (1996). However, further conformation is needed in this study.

Thus, the study disclosed number of bolls, boll weight to be the chief components of yield. Presence of adequate diversity in the genetic material could also evident from the clustering pattern. It further indicated absence of parallalism between diversity and heterosis. The hybrids identified in the present investigation MCU.9 x TCH 1223, MCU. 11 x TCH 1218, LRA 5166 x TCH 1223, LRA 5166 x TCH 1233 and LRA 5166 x TCH 1452, MCU 5 X EC 97631, TCH 976 x Suvin and TCH 976 x Bhaksh 5230 are worthy of further evaluation and release.

Summary

CHAPTER VI

SUMMARY

An investigation was taken up using cotton genotypes belonging to *Gossypium hirsutum* and *Gossypium barbadense* to identify the desirable diverse parents for heterosis breeding. The study was also aimed to identify the best hybrids with high heterotic potential by evaluating the synthesized intra-*hirsutum* and inter-specific hybrids using the above parental genotypes.

Nineteen genotypes of *G.hirsutum* and 10 genotypes of *G.barbadense* were subjected to genetic diversity analysis based on morphological as well as biochemical characters. Simultaneously, the parental genotypes were evaluated for their variability, heritability and genetic advance for all the characters and character association and path relationship were also studied.

The 49 intra-*hirsutum* and 21 interspecific hybrids were evaluated for their mean performance and heterosis.

Observations on yield and yield component characters such as days to first flowering, plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, number of seeds per locule and seed cotton yield and the economic traits seed index, lint index, ginning outturn and the quality characters 2.5 per cent span length, fibre fineness, maturity

coefficient, uniformity ratio and bundle strength were recorded. The seed oil content, total soluble protein content and isozyme banding pattern for the enzymes peroxidase and superoxide dismutase bio-chemical parameters.

The results of the present investigation are summarised hereunder :

- A close correspondence between the phenotypic and genotypic variances was noticed indicated the stable expression of the attributes of seed cotton yield and the absence of high environmental influence.

- A combination of high heritability with high genetic advance was noticed for seed cotton yield while number of bolls per plant, boll weight, seed oil content, 2.5 per cent span length and fibre fineness exhibited high heritability and low genetic advance.

- The association studies revealed that plant height, number of sympodia per plant, number of bolls per plant, boll weight and number of seeds per locule displayed highly significant positive correlation with seed cotton yield.

- The path analysis disclosed that number of bolls per plant and boll weight directly influenced the yield followed by number of seeds per locule and number of sympodia per plant.

- The 29 cotton genotypes selected from *G.hirsutum* and *G.barbadense* species came under six clusters based on their genetic divergence, reflecting the existence of sufficient genetic diversity among the genotypes.

- Among the different yield and quality characters studied, boll weight, seed oil content, 2.5 per cent span length, fibre fineness and bundle strength accounted for nearly 99 per cent of the total divergence.

- Among all the intra-*hirsutum* hybrids evaluated, five hybrids MCU 9 x TCH 1223, MCU 11 x TCH 1218, LRA 5166 x TCH 1223, LRA 5166 x TCH 1233 and LRA 5166 x TCH 1452 were superior as judged by high *per se* value for yield, one of the two yield components, ginning outturn and fibre properties.

- In respect of interspecific combinations, three out of 21 hybrids were high yielding and heterotic for yield and number of bolls per plant. Two out of three interspecific hybrids (TCH 976 x Suvin and TCH 976 x Bhaksh 5230) were heterotic for both 2.5 per cent span length and bundle strength.

- The interspecific hybrids were superior to intra-*hirsutum* hybrids for fibre characters as revealed by their higher heterotic expression for 2.5 per cent span length and bundle strength.

- No relationship could be established between genetic divergence and expression of heterosis.

- Among the intra-*hirsutum* combinations, nine hybrids were heterotic in which one of the parent belonged less divergent group while the other parent was either less divergent, divergent or high divergent. The hybrids involving highly diverse parents were superior for quality characters whereas the maximum heterosis for both yield and quality characters occurred at an optimal or intermediate level at genetic diversity.

- Eventhough the genotypes could be grouped into six different clusters based on morphological diversity, polymorphism was not found for the two isozymes viz., peroxidase and superoxide dismutase indicating the absence of diversity of subgenic level.

- The hybrids identified in the present investigation namely, MCU 9 x TCH 1223, MCU 11 x TCH 1218, LRA 5166 x TCH 1223, LRA 5166 x TCH 1233, LRA 5166 x TCH 1452, MCU 5 x EC 97631, TCH 976 x Suvin and TCH 976 x Bhaksh 5130 are worthy of further evaluation and release.

Plates

Plate 1.

Intra - *hirsutum* hybrids

A. MCU 9 x TCH 1223

B. MCU 11 x TCH 1218

Plate 2.

Intra - *hirsutum* hybrids

A. LRA 5166 x TCH 1223

B. LRA 5166 x TCH 1233

Plate 3.

Intra - *hirsutum* hybrid

LRA 5166 x TCH 1452

Plate 4.
Interspecific hybrids

A. MCU 5 x EC 97631

B. TCH 976 x Suvin

Plate 5.
Interspecific hybrid

TCH 976 x Bhaksh 5230

Genotypes used in the Study

1. MCU 5
2. MCU 7
3. MCU 9
4. MCU 11
5. TCH 976
6. TCH 1025
7. TCH 1028
8. TCH 1218
9. TCH 1223
10. TCH 1233
11. TCH 1452
12. TCH 1458
13. TCH 1569

Plate 6.

1 2 3 4 5 6 7 8 9 10 11 12 13

A. Peroxidase banding pattern of *G. hirsutum* genotypes

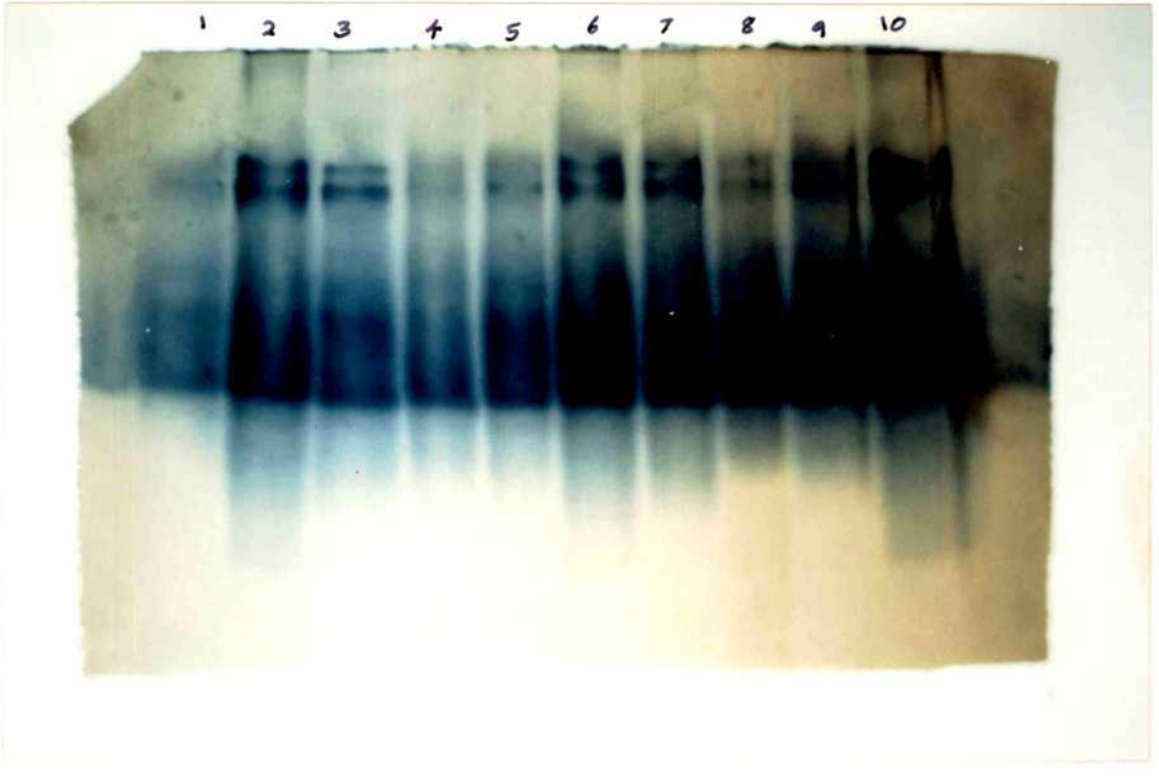
1 2 3 4 5 6 7 8 9 10 11 12 13

B. Superoxide dismutase banding pattern of *G. hirsutum* genotypes

Genotypes used in the Study

1. TCB 7
2. TCB 15
3. TCB 209
4. Bhaksh 5230
5. EC 9256
6. EC 97631
7. EC 111248
8. BCS 9-76
9. Sudan G.45
10. Suvin

Plate 7.



Peroxidase banding pattern of *G. barbadense* genotypes

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