Available online at www.ijpab.com
DOI: http://dx.doi.org/10.18782/2320-7051.2934
ISSN: 2320 – 7051
Int. J. Pure App. Biosci. **5 (3):** 169-186 (2017)
Research Article
International Journal of Pure & Applied Bioscience
OPEN ACCESS

Heterosis Studies for Yield and Fibre Quality Traits in Upland Cotton (*Gossypium hirsutum* L.)

C. Monicashree[1*], P. Amala Balu[2] and M. Gunasekaran[3]
[1]Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India
[2]Department of Cotton, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India
[3]Cotton Research Station, Tamil Nadu Agricultural University, Srivilliputtur – 626 125, Tamil Nadu, India
*Corresponding Author E-mail: cmshree92@gmail.com
Received: 1.05.2017 | Revised: 9.05.2017 | Accepted: 10.05.2017

ABSTRACT
A line x tester analysis was designed aiming towards the identification of best heterotic crosses for yield, fibre quality and economically important traits in upland cotton (Gossypium hirsutum L.). The present study was conducted in Department of cotton, Tamil Nadu Agricultural University, Coimbatore during kharif 2014-15 in a randomized block design. Eighty four crosses obtained by crossing 12 lines with seven testers in line x tester fashion were evaluated for 16 biometric traits. The line F 2617 and the tester TCH 1608 recorded significantly high per se performance for single plant yield. The hybrids viz., TCH 1705-101 x COD 5-1-2, VS-9-S11-1 x KC3, African I-2 x TCH 1705-250, F-2617 x TCH 1608 and VS-9-S11-1 x TCH 1608 registered high mean performance and significant standard heterosis for single plant yield and were identified as the best heterotic crosses. The hybrid VS-9-S11-1 × KC3 manifested highest positive significant relative heterosis and heterobeltiosis, while the hybrid TCH 1705-101 × COD 5-1-2 recorded highest positive significant standard heterosis for single plant yield. Furthermore, four hybrids viz., TCH 1705-101 x COD 5-1-2, TCH 1705-101 × Surabhi, TCH 1705-152 × BS-1 and TCH 1705-152 × TCH 1608 could well be exploited for crop improvement programme as they registered high per se performance combined with significant standard heterosis for most of the yield and fibre quality traits and hence, could well be exploited for crop improvement programme.

Key words: *Cotton, Line X Tester Analysis, Heterosis, Single Plant Yield.*

INTRODUCTION

Cotton, almost pure cellulose, with softness and breathability is the world's most popular natural fibre and always remain as the undisputed "king" of the global textiles industry. Cotton is the crop of Indian history, civilization, commerce and industry and the most important commercial crop contributing up to 70% of total raw material needs of textile industry in our country. The cotton fibre grows on the seed of a variety of plants of the genus *Gossypium*.

Cite this article: Monicashree, C., Amala Balu, P. and Gunasekaran, M., Heterosis Studies for Yield and Fibre Quality Traits in Upland Cotton (*Gossypium hirsutum* L.), *Int. J. Pure App. Biosci.* **5(3):** 169-186 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2934

Majority of the world's cotton is produced from *G. hirsutum* (90%) and *G. barbadense* (5%). In India, more than 85% of area is covered by hybrid cotton and the cultivation of hybrids in turn has helped in gaining self-sufficiency in cotton production. The yield of cotton hybrids is about 50% higher than straight varieties. India was the first country to introduce commercial cultivation of intra *hirsutum* hybrids, and then inter specific hybrids and thus, achieved a distinctive victory in hybrid cotton technology.

Cotton is one of the few crops which is accessible to the development of genotypes as varieties and at the same time amenable for commercial exploitation of heterosis. Heterosis is the increased vigour of the F1 generation over the mean of the parents or over the better parent. Heterosis is a phenomenon (cause), while hybrid vigour is the phenotypic expression (effect) of the genetical phenomenon. The chief intention of any hybridization programme is to congregate the desirable genes present in two or more parents into a single genetic background resulting in novel variability. These hybrids are utilized by either directly exploiting the hybrid vigour or forwarding to further generations and selecting the superior individuals after attaining homozygosity. Commercial exploitation of hybrid vigour in cotton has been successful in India with the release of first cotton hybrid, Hybrid 4 (intraspecific) in 1969 and Varalaxmi (interspecific) in 1971. The magnitude of heterosis can be maximized if the parents are genetically diverse from each other. Parents should differ for maximum number of yield influencing loci so that F1 exhibits the dominance effect at as many of the yield influencing loci as possible.

A long-term challenge faced by cotton breeders is the simultaneous improvement of yield and fibre quality to meet the demands of the cotton cultivators as well as the modernized textile industry. In the last few decades, sufficient improvement has been achieved in yield and its quality traits after the release of cotton hybrids for commercial cultivation. Besides, there is a constant need to develop more potential hybrids and adopt novel approaches for improving hybrid performance.

To know whether new cross combinations are suitable for exploitation of heterosis or whether these can be used to isolate useful and transgressive segregants from subsequent generations to develop a variety, evaluation of heterosis and inbreeding effects is essential. Identification of parents which show high magnitude of heterosis on crossing and production of hybrid seed with low cost is considered as a very important aspect for commercial exploitation of heterosis in cotton. India is pioneer in commercialization of heterosis in cotton and many researchers have reported heterosis or hybrid vigour in cotton. The magnitude of heterosis provides a basis for diversity and a guide to the choice of desirable parents for developing superior F1 hybrids, therefore to exploit hybrid vigour and/ or building better gene pools to be employed in population improvement.

In the current investigation, line × tester analysis has been used to study the quantitatively inherited characteristics of upland cotton, with a view to identify the best heterotic crosses for single plant yield, its attributing traits and fibre quality parameters. The prime objective of the present research was to estimate the extent of heterosis for yield and fibre quality traits among eighty-four crosses obtained by crossing 12 lines with seven testers in line x tester fashion in *Gossypium hirsutum* L.

MATERIALS AND METHODS

The present research work was carried out during *kharif* 2014-15 in the experimental field of Department of Cotton, Centre for Plant Breeding and Genetics (CPBG), Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India under irrigated conditions.

Plant materials

The experimental material used in the present study comprised of 19 parents and 84 crosses along with one standard check (**Table 1**). The genetic population was developed by crossing 12 lines (female) with seven testers (male) in a Line × Tester mating design. Genotypes of lines and testers were raised and each of the twelve lines was crossed with seven testers individually in a line × tester model[10] to obtain 84 cross combinations. The intraspecific crosses among the *G. hirsutum* genotypes were effected using conventional hand emasculation and pollination method developed by Doak[4]. Hybridization programme was continued for 45 days to get sufficient quantity of crossed bolls and they were collected separately and ginned to obtain F1 seeds. Simultaneously, parental seeds were also produced by selfing selected plants by adopting clay smear method[16].

Field layout

The F1 seed of 84 hybrids along with 19 parents and a standard check hybrid (Mallika, Non-Bt) were raised during *Rabi* 2014-15. Eighty four crosses were raised in three replications in a randomized block design (RBD) with each cross in two rows of 6 m length and spacing of 90 cm x 60 cm (row x plant) so as to maintain 10 plants in each row. The parents were also raised in the adjacent block with four rows for each entry and spacing of 90 cm x 45 cm along with the standard check hybrid for evaluating their combining ability. Recommended agronomic practices and need based plant protection measures were followed under irrigated condition to obtain good crop stand.

Data analysis

In the parents and F1's, five competitive plants from each genotype were selected at random per replication and were labelled with tags for recording the biometrical observations of 16 yield and fibre quality traits. The average values of the observations from these five plants represented the mean of that genotype per replication. Thus, a total of 103 genotypes were evaluated for all the 16 characters *viz*., days to first flowering, plant height (cm), number of monopodial branches per plant, number of sympodial branches per plant, number of fruiting nodes per plant, number of bolls per plant, Boll weight (g), need index, lint index, single plant yield (g), ginning out turn (%), fibre fineness (µg/inch), 2.5 % span length (mm), uniformity ratio (%), bundle strength (g/tex) and elongation per cent (%). Observations on fibre quality traits in each replication were recorded with ten grams of lint sample in High Volume Instrument (HVI).

Statistical analysis

The mean data of the hybrids in each replication and their parents for each quantitative character were analysed for analysis of variance, estimation of standard error and critical difference by adopting the method suggested by Panse and Sukhatme[14]. Heterosis was estimated as per cent deviation of the mean performance of F1 over the mean performance of the mid parent (MP), better parent (BP) of a cross and standard check (SC) as per the method suggested by Gowen[7]. The standard error and significance pertaining to relative heterosis, heterobeltiosis and standard heterosis of hybrids was calculated as suggested by Turner[22] and Wynne *et al.*[26] respectively.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance for randomized block design was carried out to test the significant differences among the genotypes studied. The data revealed that the sources of variation *viz*., genotypes, parents and crosses showed highly significant differences for all the traits indicating the presence of sufficient variability in the experimental materials (**Table 2**). The lines obtained significance for all the characters except boll weight, while the testers showed highly significant differences for a majority of yield components and fibre quality traits except ginning outturn. This uncovers the choice of exploiting these traits for heterosis. Solanki *et al.*[20] and Kencharaddi *et al*.[11] reported significant differences among the cotton genotypes for the entire yield and yield related traits. Significant differences among the genotypes for fibre quality traits were reported by Ashokkumar *et al.*[1] and Usharani *et al.*[25].

Mean performance

Mean performance acts as the main criterion in selecting better hybrids as it reveals their real value. Shimna and Ravikesavan[18] suggested that the *per se* performance of hybrids appeared to be a useful index in judging them and Gilbert[6] reported that parents with good *per se* performance would result in good hybrids. Parents and hybrids showing high mean performance with positive significance were considered for all the traits except days to first flowering, plant height, number of monopodial branches per plant and fibre fineness for which negatively significant mean values were taken into consideration. **Table 3** and **Table 4** depict the range of mean performance of 19 parents and 84 hybrids for 16 traits respectively.

Earliness and dwarf stature of the crop are most preferred. Therefore, earlier flowering and short plants were taken into consideration. Among the 19 parents under study, the tester TCH 1705-250 was the earliest to flower with a mean of 50.33 days. Three lines and two testers were inferiorly significant than the grand mean of 54.18 days. The hybrid VS-9-S11-1 × CD-98955 was earlier to flower (50.33 days), while no hybrid recorded significantly lower mean than the grand mean of 51.96 days. Plant height was minimum in the line C 11-19 (76.20 cm). Six lines and two testers depicted significantly lower mean value than the grand mean value of 92.97 cm. Lowest mean for plant height among the hybrids was obtained by C 10-3 × KC3 (82.47 cm). The grand mean for the hybrids was 108.71 cm and two hybrids recorded significantly inferior mean.

Monopodial branches are vegetative branches and large number of monopodia makes the plant look bushy; occupies more space and usually results in a slow rate of boll formation when compared to sympodial branches or fruiting branches. Thereby, lesser monopodial branches were taken into consideration. The line DSC-1302 and the tester COD 5-1-2 had the least number of monopodial branches per plant (0.60) while, six lines and one tester unveiled significantly lower monopodial branches than grand mean (1.07). Within the hybrids, African I-2 × KC3 (0.87) exhibited lowest number of monopodial branches per plant. The hybrids obtained a grand mean of 1.55 monopodial branches per plant and 39 hybrids exhibited significantly lower mean values than the grand mean. The line African I-2 recorded maximum number of sympodial branches per plant of 23.00 and none of the parents recorded significantly higher values than overall mean of 19.42. The cross combinations exhibited a highest mean of 25.07 (TCH 1705-101 × Surabhi) with 4 hybrids significantly superior than the grand mean (20.04). The trait fruiting nodes per plant expressed a high mean of 62.80 (TCH 1705-250) and two parents were significantly superior than the grand mean (41.20). The hybrid TCH 1705-152 × BS-1 had the highest number of fruiting nodes with a mean of 72.67 and 24 hybrids were significantly higher than grand mean (47.77).

In cotton, number of bolls per plant and boll weight are the important yield attributing components which are positively associated with single plant yield. Yield in cotton is one of the most important economic characters and is the final product of multiplicative interaction of its contributing traits. Number of bolls per plant was higher in KC3 with a mean of 38.80 bolls. Three lines and two testers showed significantly higher boll number per plant than the overall grand mean of 30.12. Among the hybrids, TCH 1705-152 × Surabhi unveiled a maximum of 52.07 bolls. With a mean value of 33.21 bolls, 31 hybrids had significantly higher number of bolls per plant. The tester, TCH 1608 had the biggest boll with a mean weight of 5.39 g. The parents obtained a grand mean of 4.58 g and three lines and two testers depicted significantly higher boll weight than the grand mean. The hybrid, F-2617 × CD-98955 recorded the highest mean for boll weight (5.85 g). Three hybrids exhibited significantly higher boll weight than the overall hybrid mean value of 4.43 g. The trait single plant yield observed the tester TCH 1608 superiorly significant among the parents with a high mean of 133.00 g. Four lines and three testers had significantly higher mean value than overall mean (101.34 g). Within the hybrids, TCH 1705-101 × COD 5-1-2 registered highest single plant yield (198.27 g) and five hybrids obtained significantly higher mean than the grand mean of 138.22 g.

The tester Surabhi recorded maximum seed index with significantly high mean of 12.01. Two testers were significantly superior to the overall mean (10.20) expression of the parents. The hybrid, TCH 1705-169 × COD 5-1-2 recorded the maximum seed index of 12.70 and two hybrids obtained significantly higher than the overall mean (10.32). The tester BS-1 exhibited the highest lint index of 10.47 while, one line and two testers were significantly superior to the overall mean (8.34). In case of hybrids, the extent of lint index was highest in the hybrid C 11-19 × COD 5-1-2 showing significantly superior mean of 10.29. The mean lint index value for hybrids was 8.24 and two hybrids revealed significantly higher mean expression than the grand mean. Ginning percentage had DSC-1302 as the only parent registering significantly superior mean (40.11%) to the overall mean of 34.84%. Amidst the hybrid, F-2617 × KC3 recorded a high mean of 39.14% with two hybrids having significantly superior mean than the overall mean of 34.35 %.

Fibre fineness, uniformity, length and strength affect spinning efficiency. Fibre length is critical for textile processing and varies greatly for different cottons due to genetic differences. The fibres of long staple lengths produce smoother and stronger fabrics as cotton fibres of long staple lengths are finer, stronger and also more flexible than fibres of short staple length. The tester BS-1 showed the lowest micronaire value of 4.20 μg/inch but, none of the accessions registered significant lower mean among the parents. The hybrid, VS-9-S11-1 × Surabhi possessed a finer fibre with a mean of 3.70 μg/inch. Five hybrids depicted significantly lower mean values for fibre fineness than the grand mean (4.50 μg/inch). With a grand mean of 29.51 mm for the trait 2.5 per cent span length, the tester Surabhi recorded a high mean value of 34.50 mm and three lines and two testers revealed significantly superior mean value. A high mean value of 33.90 mm was obtained by the hybrid African I-2 × Surabhi with 19 hybrids significant over the grand mean (29.97 mm). The trait uniformity ratio obtained the highest mean for the tester TCH 1705-250 (55.10%). Four lines and two testers had significantly exceeded the parental mean expression of 49.63%. The hybrid, F-2617 × TCH 1705-250 (54.50%) observed the highest mean for this trait while, 15 hybrids were significantly superior to the grand mean (49.36%).

Fibre strength is one of the most important fibre properties and it is quantitatively inherited. Stronger, longer, finer, and more uniform cotton fibres are desired for modern textile industries. Mean performance among the parents for bundle strength observed TCH 1705-101 (21.40 g/tex) as the only entry significant over the grand mean of 19.71 g/tex. The mean value among the hybrids for bundle strength was maximum in VS-9-S11-1 × Surabhi (23.00 g/tex) with nine hybrids significantly superior than the overall mean (19.30 g/tex). The maximum elongation percentage was manifested by the tester TCH 1705-250 (8.90%) whereas, one line and one tester each were significantly higher than the parental mean of 5.40%. In case of hybrids, F-2617 × TCH 1705-250 showed the maximum (7.50%) elongation percentage with 17 hybrids significant over the grand mean (5.33%).

Expression of heterosis

Heterosis for 16 quantitative traits are grouped into plant morphological traits, yield and yield attributing traits, economic traits and fibre quality traits. **Table 5** represents relative heterosis, heterobeltiosis and standard heterosis for all the characters. The results indicated that the phenomenon of heterosis was of a general occurrence for almost all the characters, under study. However, the magnitude of heterosis varied with traits.

Plant morphological traits

For days to first flowering, the hybrid VS-9-S11-1 × CD-98955 recorded the minimum negative significant relative heterosis (–9.31%) and heterobeltiosis (–10.12%) and minimum negative standard heterosis (–1.31%). The hybrids TCH 1705-152 × TCH 1705-250 and TCH 1705-101 × Surabhi exhibited maximum positive relative heterosis (2.19%) and heterobeltiosis (0.00%) respectively. The maximum positive significant standard heterosis (6.54%) was recorded by two hybrids *viz*., TCH 1705-152 × TCH 1705-250 and TCH 1705-169 X Surabhi. Fifty one and 70 hybrids showed significantly negative relative heterosis and heterobeltiosis respectively while, none of the hybrids recorded significant negative standard heterosis for days to first flowering. Significant negative heterosis for days to first flowering in desirable direction has been reported by Haleem *et al*.[8] and Solanke *et al*.[19].

The hybrid C 10-3 × KC3 displayed the minimum negative relative heterosis (–9.49%) and minimum negative significant heterobeltiosis of –21.93% and standard heterosis of –32.81% for plant height. The hybrids C 11-19 × Surabhi and VS-9-S11-1 × Surabhi exhibited highest positive significant relative heterosis (43.95%) and heterobeltiosis (38.62%) respectively. The hybrid TCH 1705-152 × TCH 1608 recorded maximum positive standard heterosis (10.86%). None of the hybrids registered significant negative relative heterosis whereas, two and 32 hybrids revealed significantly negative heterobeltiosis and standard heterosis for plant height in desirable direction. Choudhary *et al*.[3], Kencharaddi *et al*.[11] and Solanke *et al*.[19] observed similar results for plant height.

For number of monopodial branches per plant, the hybrid African I-2 × TCH 1608 exhibited minimum negative significant relative heterosis of –20.00% and heterobeltiosis of –41.18%. The hybrids DSC-1302 × BS-1 and DSC-1302 × COD 5-1-2 recorded maximum positive significant relative heterosis and heterobetiosis of 167.04% and 155.56% respectively. The range of standard heterosis varied from 0.38% (African I-2 × KC3) to 192.31% (VS-9-S11-1 × Surabhi). Four and 11 hybrids depicted significant negative relative heterosis and heterobeltiosis respectively while, none of the hybrids recorded significant negative values for standard heterosis. Geddam *et al.*[5], Choudhary *et al.*[3] and Kencharaddi *et al.*[11] reported significant negative heterosis in desirable direction for this trait.

The extent of relative heterosis for number of sympodial branches per plant exhibited a range from –12.96% (C 10-3 × KC3) to 32.28% (TCH 1705-152 × BS-1). Heterobeltiosis varied from –19.09% (TCH 1705-152 × CD-98955) to 20.22% (G.cot.100 × CD- 98955) and standard heterosis ranged from –33.99% (C 10-3 × KC3) to 5.62% (TCH 1705-101 × Surabhi). Only seven hybrids revealed significant positive relative heterosis while, none of the hybrids showed significant positive heterobeltiosis and standard heterosis. Positive and significant heterosis in desirable direction were reported by Choudhary *et al.*[3], Solanki *et al.*[20], Solanke *et al.*[19] and Kencharaddi *et al.*[11] for number of sympodial branches per plant.

Yield and yield attributing characters

The hybrid C 12-2 × TCH 1705-250 recorded the minimum negative significant relative heterosis of –20.60% and heterobeltiosis of –35.14% whereas, the hybrids TCH 1705-101 × COD 5-1-2 (89.19%) and TCH 1705-101 × Surabhi (76.61%) exhibited highest positive significant mid parent and better parent heterosis respectively for number of fruiting nodes per plant. The range of standard heterosis varied from –24.45% (VS-9-S11-1 × CD-98955) to 70.85% (TCH 1705-152 × BS-1). Significant positive values for relative heterosis, heterobeltiosis and standard heterosis were manifested by 55, 37 and 45 hybrids respectively. Similar results have been reported by Ranganatha *et al.*[17] and Kencharaddi *et al.*[11].

For number of bolls per plant, the hybrid VS-9-S11-1 × COD 5-1-2 recorded both highest positive significant relative heterosis (54.20%) and heterobeltiosis (47.78%) whereas, the hybrid G.cot.100 ×

TCH 1608 exhibited minimum negative significant relative heterosis of –24.97% and heterobeltiosis of –31.11%. Forty-six and 32 hybrids unveiled significant positive relative heterosis and heterobeltiosis respectively. Standard heterosis ranged from –44.88% (VS-9-S11-1 × CD-98955) to 35.82% (TCH 1705-152 × Surabhi). Ten hybrids exhibited significant positive standard heterosis. The results obtained by Geddam *et al.*[5] and Solanke *et al.*[19] supported our findings.

With regard to boll weight, the hybrid DSC-1302 × TCH 1705-250 obtained lowest negatively significant relative heterosis, heterobeltiosis and standard heterosis of –22.77%, –28.78% and –24.94% respectively. The hybrid TCH 1705-101 × COD 5-1-2 registered highest positive significant relative heterosis (18.47%) whereas, C 11-19 × COD 5-1-2 showed maximum positive heterobeltiosis (11.27%). Three hybrids revealed significant positive relative heterosis in desirable direction whereas, none of the hybrids recorded significant positive heterobeltiosis. Two hybrids ARBC-1301 × TCH 1705-250 and African –I-2 × CD-98955 recorded highest positive significant standard heterosis (26.22%). Only three hybrids showed significant positive standard heterosis for boll weight. Our results were in parallel with the findings obtained by Tuteja and Agarwa[23], Solanki *et al.*[20] and Solanke *et al.*[19]. `

For single plant yield, the hybrid VS-9-S11-1 × KC3 manifested highest positive significant relative heterosis (132.39%) and heterobeltiosis (130.96%) while the hybrid TCH 1705-101 × COD 5-1-2 recorded highest significant positive standard heterosis (44.02%). The hybrid C11-19 × BS-1 displayed lowest negative relative heterosis (–3.37%) whereas, VS-9-S11-1 × CD-98955 recorded minimum negative heterobeltiosis (–18.22%) and minimum negative significant standard heterosis (–27.65%). Fifty-nine, 34 and five hybrids recorded significantly positive relative heterosis, heterobeltiosis and standard heterosis values respectively for this trait. Our results for the trait single plant yield were in accordance with the findings reported by Jyotiba *et al.*[9], Choudhary *et al.*[3] and Kencharaddi *et al.*[11].

Economic traits

Relative heterosis for seed index in the positive direction was registered by five hybrids and the values ranged from –21.58% (TCH 1705-101 × Surabhi) to 24.50% (F-2617 × CD-98955). Heterobeltiosis in the positive direction was observed in two hybrids and the extent of lowest (–32.92%) and highest (20.21%) heterosis values for heterobeltiosis was recorded in F-2617 × Surabhi and ARBC-1301 × KC3 respectively. Eleven hybrids had significantly positive expression for standard heterosis and the values ranged from –18.68% (C 10-3 × KC3) to 29.87% (TCH 1705-169 × COD 5-1-2). The results for seed index were supported by earlier researchers Geddam *et al.*[5], Solanki *et al.*[20] and Kencharaddi *et al.*[11].

In case of lint index, the relative heterosis ranged from –24.08% (G.cot.100 × TCH 1705-250) to 26.15% (F-2617 × CD-98955) and three hybrids recorded positively significant mid parent heterosis. The extent of heterobeltiosis and standard heterosis for lint index ranged from –33.91% (C 12-2 × BS-1) to 11.34% (F-2617 × TCH 1705-250) and –28.43% (C 10-3 × KC3) to 19.20% (C 11-19 × COD 5-1-2) respectively. None of the hybrids displayed significant positive heterobeltiosis and standard heterosis for this trait. Our findings were in parallel with the reports made by Jyotiba *et al.*[9] and Mehta *et al*.[13] for lint index.

The hybrid TCH 1705-101 × Surabhi exhibited maximum positive significant relative heterosis (17.09%) and heterobeltiosis (16.88%) for ginning outturn. The hybrid C 12-2 × BS-1 observed minimum negative significant relative heterosis of –13.80% and heterobeltiosis of –17.35%. Two hybrids *viz.*, TCH 1705-101 × Surabhi and F-2617 × KC3 showed positive significance for relative heterosis whereas, TCH 1705-101 × Surabhi exhibited positive significant expression for heterobeltiosis in desirable direction. The variation for standard heterosis ranged from –

18.30% (G.cot.100 × TCH 1705-250) to 8.56% (F-2617 × KC3). None of the hybrids showed significant positive standard heterosis for ginning percentage. Geddam *et al.*[5], Tuteja[24] and Kencharaddi *et al.*[11] observed significant positive heterosis for ginning outturn and this is in conformity to our results.

Fibre quality traits

Micronaire value is an important fibre quality trait in judging lint quality of cotton. The relative heterosis for fibre fineness ranged from –21.90% (ARBC-1301 × KC3) to 13.95% (VS-9-S11-1 × BS-1) and 11 hybrids expressed significant negative relative heterosis in desirable direction. Nineteen hybrids observed significant negative heterobeltiosis which ranged from –29.82% (TCH 1705-101 × KC3) to 11.36% (VS-9-S11-1 × BS-1). Negative significant standard heterosis was noticed in five hybrids and the values ranged from –17.78% (VS-9-S11-1 × Surabhi) to 17.78% (TCH 1705-169 × KC3). A decrease in micronaire value is always considered since, it indicates good fibre fineness. Many researchers[12,1,25] have reported varying degrees of heterosis for micronaire.

The trait 2.5 per cent span length had the hybrid ARBC-1301 × KC3 exhibiting the highest positive significant values for relative heterosis (22.14%) and heterobeltiosis (19.93%). The hybrids VS-9-S11-1 × BS-1 and DSC-1302 × Surabhi recorded the lowest negatively significant relative heterosis and heterobeltiosis of –9.45% and –16.52% respectively. Twenty-five hybrids displayed significant positive relative heterosis while four hybrids showed positive significance for heterobeltiosis. Standard heterosis had significant positive expression for two hybrids and the heterosis values ranged from –17.98% (DSC-1302 × KC3) to 6.94% (African I-2 × Surabhi). Similar results were obtained by Ashokkumar *et al.*[1], Patel *et al.*[15] and Usharani *et al.*[25].

Uniformity ratio observed two hybrids F-2617 × TCH 1608 and G.cot.100 × Surabhi recording the lowest negative significant relative heterosis (–7.86%) whereas, the hybrid DSC-1302 × COD 5-1-2 manifested highest positive significant relative heterosis of 11.69%. Thirteen hybrids expressed positive significance for mid parent heterosis. The hybrids F-2617 × TCH 1608 and C 12-2 × COD 5-1-2 displayed lowest negative significant heterobeltiosis (–10.96%) and standard heterosis (–6.50%) respectively. The highest positive significant values of heterobeltiosis (10.92%) was exhibited by the hybrid C 11-19 × CD-98955 and standard heterosis (14.26%) by F-2617 × TCH 1705-250. Positive significant heterobeltiosis was unveiled by six hybrids while, 40 hybrids recorded significant positive standard heterosis. Our results were in accordance with the findings of Ashokkumar *et al.*[1], Geddam *et al.*[5] and Usharani *et al.*[25].

The hybrid VS-9-S11-1 × BS-1 displayed the minimum negative significant relative heterosis (–17.31%), heterobeltiosis (–17.70%) and standard heterosis (–11.79%) for bundle strength. The hybrid G.cot.100 × COD 5-1-2 exhibited highest positive significant relative heterosis (13.32%) while, the hybrid VS-9-S11-1 × Surabhi manifested highest positive significance for both heterobeltiosis (10.05%) and standard heterosis (17.95%). Among the eighty-four hybrids, seven, two and seven hybrids recorded a positive significant expression for mid parent, better parent and standard heterosis respectively. Similar results have been reported by Kumar[12], Ashokkumar *et al.*[1] and Usharani *et al.*[25].

With respect to elongation percentage, the extent of relative heterosis ranged from –24.83% (DSC-1302 × TCH 1705-250) to 21.35% (C 12-2 × Surabhi) and eight hybrids unveiled positive significance over mid parent heterosis. No hybrids showed positive significant heterobeltiosis and the values ranged from –37.08% (DSC-1302 × TCH 1705-250, ARBC-1301 × TCH 1705-250, C 12-2 × TCH 1705-250) to 8.20% (TCH 1705-152 × BS-1). Fifty-nine hybrids displayed positive standard heterosis which ranged from –15.56% (G.cot.100 × COD 5-1-2) to 66.67% (F-2617 × TCH 1705-250). Our results for elongation per cent were in parallel with the findings made by Ashokkumar *et al.*[1] and Usharani *et al.*[25].

Superior crosses

Top most superiorly significant crosses (**Table 6)** were identified among the eighty-four hybrids for yield and fibre quality traits on the basis of *per se* performance with their per cent heterosis. With respect to mean performance, the hybrid TCH 1705-101 x COD 5-1-2 was considered as a superior cross as they showed significant high *per se* performance for the traits, number of sympodial branches per plant, number of fruiting nodes per plant, number of bolls per plant, single plant yield and fibre fineness. Similarly, the hybrid TCH 1705-101 × Surabhi was superior for five traits *viz*., number of monopodial branches per plant, number of sympodial branches per plant, number of fruiting nodes per plant, number of bolls per plant and ginning out turn. The third hybrid that topped the list was TCH 1705-152 × BS-1 showing superiority for number of monopodial branches per plant, number of sympodial branches per plant, number of fruiting nodes per plant, number of bolls per plant and elongation percentage. These hybrids were followed by TCH 1705-152 × TCH 1608 which was superior for four traits *viz*., number of monopodial branches per plant, number of sympodial branches per plant, number of fruiting nodes per plant and number of bolls per plant.

The hybrids, TCH 1705-101 x COD 5-1-2, VS-9-S11-1 x KC3, African I-2 x TCH 1705-250, F-2617 x TCH 1608 and VS-9-S11-1 x TCH 1608 were identified as the top promising hybrids for single plant yield with respect to mean performance. On the basis of fibre quality, VS-9-S11-1 × Surabhi was superior exhibiting significant *per se* performance for three traits *viz*., fibre fineness, 2.5% span length and bundle strength. Therefore, the aforementioned hybrids are suitable for compromising the demand in high speed spinning mills as they registered superiority for yield and fibre quality traits.

The scope for exploiting the hybrid vigour depends on high *per se* performance of the hybrids over the standard variety or the local check; the magnitude of heterosis and the biological feasibility for large scale production of hybrid seeds. Over dominance is attributed towards heterobeltiosis, while commercial superiority of the hybrid may be assessed by evaluating with a standard commercial check[21]. Among the three kinds of heterosis, the interpretation of test hybrids based on standard, useful or economic heterosis reflecting the actual superiority over the best existing cultivar to be replaced appears to be more relevant and practical[2]. Therefore, the hybrid(s) expressing heterosis over the standard hybrid Mallika was chosen as the best hybrid from the present study.

The analysis revealed that the hybrid TCH 1705-152 x BS-1 topped the list for standard heterosis with significant values for four traits *viz*., number of monopodial branches per plant, number of fruiting nodes per plant, number of bolls per plant and elongation percentage. Similarly, the hybrid TCH 1705-101 x COD 5-1-2 showed significant values for number of fruiting nodes per plant, number of bolls per plant, single plant yield and fibre fineness. Moreover, the hybrids TCH 1705-101 × Surabhi and TCH 1705-152 × TCH 1608 observed significant heterosis for three similar characters *viz*., number of monopodial branches per plant, number of fruiting nodes per plant and number of bolls per plant. Six hybrids *viz*., C10-3 x TCH 1705-250, C11-19 × TCH 1705-250, F-2617 x KC3, F-2617 × TCH 1705-250, TCH 1705-101 × TCH 1705-250 and TCH 1705-169 x TCH 1705-250 showed significant heterosis for uniformity ratio and elongation percentage. Subsequently, the hybrid VS-9-S11-1 × Surabhi obtained significant heterosis for bundle strength and fibre fineness. The five promising hybrids with high *per se* performance for single plant yield *viz*., TCH 1705-101 x COD 5-1-2, VS-9-S11-1 x KC3, African I-2 x TCH 1705-250, F-2617 x TCH 1608 and VS-9-S11-1 x TCH 1608 showed positive significance for standard heterosis and thus, these hybrids were found to be the best heterotic crosses over standard check for single plant yield. Therefore, the aforesaid hybrids could be used for improvement in yield and fibre quality traits.

Table 1: List of lines, testers and check used in the present investigation

S. No.	**Code**	**Genotype**	**Source**
Lines			
1.	L 1	TCH 1705 - 101	TNAU, Coimbatore
2.	L 2	TCH 1705 – 152	TNAU, Coimbatore
3.	L 3	TCH 1705 – 169	TNAU, Coimbatore
4.	L 4	DSC – 1302	UAS, Dharwad
5.	L 5	F-2617	Faridkot, Punjab (AICRIP Trial)
6.	L 6	ARBC-1301	UAS, Dharwad
7.	L 7	G.cot.100	MCRS, Surat
8.	L 8	VS – 9 – S11- 1	Germplasm collection from CRS, Srivilliputtur
9.	L 9	African I – 2	Germplasm collection from CRS, Srivilliputtur
10.	L 10	C 10 - 3	Germplasm collection from Dept. of Cotton, TNAU
11.	L 11	C 11 – 19	Germplasm collection from Dept. of Cotton, TNAU
12.	L 12	C 12 - 2	Germplasm collection from Dept. of Cotton, TNAU
Testers			
13.	T 1	TCH 1705 - 250	TNAU, Coimbatore
14.	T 2	TCH 1608	TNAU, Coimbatore
15.	T 3	BS-1	Bavanipatna, Orissa
16.	T 4	KC 3	ARS, Kovilpatty
17.	T 5	CD-98955	Germplasm collection from CRS, Srivilliputtur
18.	T 6	COD – 5 – 1 – 2	Germplasm collection from CRS, Srivilliputtur
19.	T 7	Surabhi	CICR, Coimbatore
20.	Check	Mallika (Non-Bt)	Nuziveedu, Telangana (Private sector)

Table 2: Analysis of variance for yield components and fibre quality traits among parents and crosses

Source	Mean squares																
	df	**DFF**	**PH**	**NM**	**NS**	**NFN**	**NB**	**BW**	**SPY**	**SI**	**LI**	**GOT**	**FF**	**SL**	**UR**	**BS**	**EP**
Replication	2	3.15	3613.33	0.01	41.48	1.56	13.20	6.70	1872.26	7.67	10.44	14.87	2.09	4.33	11.32	5.79	3.78
Genotypes	102	6.19**	455.43**	0.47**	12.29**	202.26**	96.04**	0.76**	1570.86**	3.79**	2.33**	11.30**	0.37**	9.56**	13.62**	3.75**	1.70**
Parents	18	10.31**	433.41**	0.31**	12.44**	175.03**	92.72**	0.77**	896.30**	5.44**	2.87**	10.44**	0.43**	18.11**	19.28**	3.41**	3.68**
Lines	11	7.89**	283.98**	0.26**	10.08*	99.15**	106.59**	0.40	685.14*	5.28**	2.36*	11.96**	0.31*	10.52**	11.10**	3.54**	2.42**
Testers	6	15.52**	505.51**	0.35**	12.39*	342.54**	81.99**	1.55**	1322.36**	3.18*	3.08**	8.49	0.71**	34.63**	3.46**	3.41**	5.98**
Line vs Testers	1	5.69	1644.57	0.53	38.65	4.59	4.55	0.15	662.65	20.84	7.24	5.34	0.01	2.37	6.19	2.11	3.84
Crosses	83	2.60**	326.92**	0.38**	12.19**	186.39**	92.55**	0.75**	974.24**	3.47**	2.24**	11.49**	0.34**	7.70**	12.51**	3.77**	1.29**
Cross vs Parents	1	228.91	11517.78	10.63	17.74	2009.23	445.20	1.04	63232.80	0.68	0.51	11.31	1.54	9.83	3.38	7.68	0.19
Error	204	1.48	104.63	0.01	5.42	4.06	2.05	0.32	312.09	1.20	1.06	4.74	0.15	0.70	1.06	0.72	0.13

** Significant (5 % level)*
*** Significant (1 % level)*
DFF-Days to first flowering, PH-Plant height, NM-Number of monopodial branches per plant, NS-Number of sympodial branches per plant, NFN-Number of fruiting nodes per plant, NB-Number of bolls per plant, BW-Boll weight, SI-Seed index, LI-Lint index, GOT-Ginning outturn, FF-Fibre fineness, SL-2.5% span length, UR-Uniformity ratio, BS-Bundle strength, EP-Elongation per cent, SPY-Single plant yield

Table 3: Ranges for mean performance of single plant yield and fibre quality traits in parents

Traits	Range		Lines		Range		Testers		Grand Mean
	Min	Max	Lowest	Highest	Min	Max	Lowest	Highest	
Days to first flowering	52.00	56.00	TCH 1705-101 C 11-19 C 12-2	TCH 1705-152 TCH 1705-169 DSC-1302 ARBC-1301	50.33	56.00	TCH 1705-250	BS-1 CD-98955	54.18
Plant height	76.20	104.03	C 11-19	ARBC-1301	84.00	117.60	CD-98955	TCH 1608	92.27
No. of monopodial branches per plant	0.60	1.60	DSC-1302	G.cot.100	0.60	1.70	COD 5-1-2	TCH 1608	1.07
No. of sympodial branches per plant	17.20	23.00	C 10-3	African I-2	15.80	22.00	BS-1	TCH 1705-250	19.42
No. of fruiting nodes per plant	31.40	52.80	TCH 1705-169	F-2617	29.20	62.80	COD 5-1-2	TCH 1705-250	41.20
No. of bolls per plant	20.40	38.40	C 12-2	TCH 1705-152	22.00	38.80	COD 5-1-2	KC3	30.12
Boll weight	4.11	5.17	C 10-3	F-2617	3.41	5.39	KC3	TCH 1608	4.58
Single plant yield	78.60	129.80	DSC-1302	F-2617	81.80	133.00	KC3	TCH 1608	101.34
Seeds index	7.38	11.39	F-2617	TCH 1705-101 VS-9-S11-1	8.95	12.01	KC3	Surabhi	10.20
Lint index	6.44	9.66	F-2617	VS-9-S11-1	7.61	10.47	TCH 1705-250	BS-1	8.34
Ginning out turn	32.64	40.11	TCH 1705-169	DSC-1302	32.64	36.14	Surabhi	BS-1	34.84
Fibre fineness	4.30	5.20	C 10-3	TCH 1705-152 TCH 1705-169	4.20	5.70	BS-1	KC3	4.68
2.5% span length	26.10	31.50	TCH 1705-152 DSC-1302	C 11-19	24.50	34.50	TCH 1705-250	Surabhi	29.51
Uniformity ratio	46.70	52.50	C 11-19	TCH 1705-152	45.00	55.10	COD 5-1-2	TCH 1705-250	49.63
Bundle strength	17.90	21.40	TCH 1705-169	TCH 1705-101	17.80	20.80	COD 5-1-2	Surabhi	19.71
Elongation per cent	3.80	6.70	C 12-2	F-2617	4.77	8.90	COD 5-1-2	TCH 1705-250	5.40

Table 4: Ranges for mean performance of single plant yield and fibre quality traits in hybrids

Traits	Range		Mean	Hybrids	
	Minimum	Maximum		Lowest	Highest
Days to first flowering	50.33	54.33	51.96	VS-9-S11-1 × CD-98955	TCH 1705-152 × TCH 1705-250 TCH 1705-169 × Surabhi
Plant height (cm)	82.47	136.07	108.71	C 10-3 × KC3	TCH 1705-152 × TCH 1608
No. of monopodial branches per plant	0.87	2.53	1.55	African I-2 × KC3	VS-9-S11-1 × Surabhi
No. of sympodial branches per plant	15.67	25.07	20.04	C 10-3 × KC3	TCH 1705-101 × Surabhi
No. of fruiting nodes per plant	32.13	72.67	47.77	VS-9-S11-1 × CD-98955	TCH 1705-152 × BS-1
No. of bolls per plant	21.13	52.07	33.21	VS-9-S11-1 × CD-98955	TCH 1705-152 × Surabhi
Boll weight	3.34	5.85	4.43	DSC-1302 × TCH 1705-250	F-2617 × CD-98955
Single plant yield	99.60	198.27	138.22	VS-9-S11-1 × CD-98955	TCH 1705-101 × COD 5-1-2
Seeds index	7.95	12.70	10.32	C 10-3 × KC3	TCH 1705-169 × COD 5-1-2
Lint index	6.18	10.29	8.24	C 10-3 × KC3	C 11-19 × COD 5-1-2
Ginning out turn	29.46	39.14	34.35	G.cot.100 × TCH 1705-250	F-2617 × KC3
Fibre fineness	3.70	5.30	4.50	VS-9-S11-1 × Surabhi	TCH 1705-169 × KC3
2.5% span length	26.00	33.90	29.97	DSC-1302 × KC3	African I-2 × Surabhi
Uniformity ratio	44.80	54.50	49.36	VS-9-S11-1 × COD 5-1-2	F-2617 × TCH 1705-250
Bundle strength	17.20	23.00	19.30	VS-9-S11-1 × BS-1	VS-9-S11-1 × Surabhi
Elongation per cent	3.80	7.50	5.33	G.cot.100 × COD 5-1-2	F-2617 × TCH 1705-250

Table 5: Ranges of Relative heterosis, Heterobeltiosis and Standard heterosis with number of significant crosses in desirable direction for different characters in cotton

Character	Relative heterosis (RH)	Heterobeltiosis (H)	Standard heterosis (SH)	No. of significant crosses in desirable direction		
				RH(%)	H(%)	SH(%)
Days to first flowering	–9.31 to 2.19	–10.12 to 0.00	–1.31 to 6.54	51	70	0
Plant height (cm)	–9.49 to 43.95	–21.93 to 38.62	–32.81 to 10.86	0	2	32
Number of monopodial branches per plant	–20.00 to 167.04	–41.18 to 155.56	0.38 to 192.31	4	11	0
Number of sympodial branches per plant	–12.96 to 32.28	–19.09 to 20.22	–33.99 to 5.62	7	0	0
Number of fruiting nodes per plant	–20.60 to 89.19	–35.14 to 76.61	–24.45 to 70.85	55	37	45
Number of bolls per plant	–24.97 to 54.20	–31.11 to 47.78	–44.88 to 35.82	46	32	10
Boll weight (g)	–22.77 to 18.47	–28.78 to 11.27	–24.94 to 26.22	3	0	3
Single plant yield (g)	–3.37 to 132.39	–18.22 to 130.96	–27.65 to 44.02	59	34	5
Seed index	–21.58 to 24.50	–32.92 to 20.21	–18.68 to 29.87	5	2	11
Lint index	–24.08 to 26.15	–33.91 to 11.34	–28.43 to 19.20	3	0	0
Ginning outturn (%)	–13.80 to 17.09	–17.35 to 16.88	–18.30 to 8.56	2	1	0
Fibre fineness (Mic.)	–21.90 to 13.95	–29.82 to 11.36	–17.78 to 17.78	11	19	5
2.5 per cent span length (mm)	–9.45 to 22.14	–16.52 to 19.93	–17.98 to 6.94	25	4	2
Uniformity ratio	–7.86 to 11.69	–10.96 to 10.92	–6.50 to 14.26	13	6	40
Bundle strength	–17.31 to 13.32	–17.70 to 10.05	–11.79 to 17.95	7	2	7
Elongation percentage	–24.83 to 21.35	–37.08 to 8.20	–15.56 to 66.67	8	0	59

Table 6: Superior crosses based on mean performance and per cent heterosis for yield and fiber quality traits

Characters	Superior Crosses	Per se performance of crosses	Heterosis over mid parent	Heterosis over better parent	Heterosis over standard check
Plant height	C 10-3 x KC3	82.47*	-9.49	-21.93 **	-32.81 **
	C 10-3 x COD 5-1-2	88.93*	8.46	1.75	-27.54 **
No. of monopodial branches per plant	TCH 1705-101 × BS-1	1.47*	46.67 **	22.22 **	69.23 **
	TCH 1705-101 × SURABHI	1.47*	33.33 **	4.76	69.23 **
	TCH 1705-152 × BS-1	1.47*	46.67 **	22.22 **	69.23 **
	DSC-1302 × SURABHI	1.47*	46.33 **	4.52	68.85 **
	ARBC-1301 × KC3	1.47*	12.82 **	4.76	69.23 **
	G.cot.100 × TCH 1608	1.47*	-11.11 **	-13.73 **	69.23 **
	AFRICAN -I-2 × SURABHI	1.47*	33.33 **	4.76	69.23 **
	C 11-19 × KC3	1.47*	33.64 **	22.50 **	69.62 **
	C 12-2 × TCH 1608	1.47*	17.33 **	-13.73 **	69.23 **
	TCH 1705-152 × TCH 1608	1.40*	12.00 **	-17.65 **	61.54 **
Number of sympodial branches per plant	TCH 1705-101 x Surabhi	25.07*	21.68 **	14.98	5.62
	TCH 1705-152 x BS-1	25.00*	32.28 **	13.64	5.34
	TCH 1705-152 x TCH 1608	24.47*	21.12 **	11.21	3.09
	TCH 1705-101 x COD 5-1-2	24.40*	25.77 **	11.93	2.81
Number of fruiting nodes per plant	TCH 1705-152 × BS-1	72.67*	72.20 **	61.48 **	70.85 **
	TCH 1705-152 × Surabhi	70.60*	79.18 **	56.88 **	65.98 **
	TCH 1705-101 × TCH 1608	64.67*	64.55 **	52.52 **	52.04 **
	TCH 1705-101 × Surabhi	63.93*	82.67 **	76.61 **	50.31 **
	TCH 1705-101 × COD 5-1-2	61.87*	89.19 **	70.90 **	45.45 **
	TCH 1705-152 × TCH 1608	61.67*	41.11 **	37.04 **	44.98 **
	TCH 1705-101 × BS-1	61.20*	61.90 **	55.32 **	43.88 **
	TCH 1705-152 × TCH 1705-250	61.13*	13.42 **	-2.65	43.73 **
	TCH 1705-152 × KC3	60.73*	41.24 **	34.96 **	42.79 **
	TCH 1705-101 × CD-98955	59.47*	62.03 **	59.86 **	39.81 **
Number of bolls per plant	TCH 1705-152 × Surabhi	52.07*	50.91 **	35.58 **	35.82 **
	TCH 1705-152 × BS-1	49.53*	36.83 **	28.99 **	29.22 **
	TCH 1705-101 × Surabhi	44.53*	44.12 **	42.74 **	16.17 **
	TCH 1705-152 × TCH 1608	43.60*	32.12 **	13.54 **	13.74 **
	TCH 1705-101 × TCH 1608	42.60*	44.90 **	36.54 **	11.13 **
	TCH 1705-152 × KC3	42.47*	10.02 **	9.45 **	10.78 **
	TCH 1705-152 × CD-98955	41.27*	22.10 **	7.47 *	7.66 **
	TCH 1705-101 × TCH 1705-250	40.60*	30.14 **	30.14 **	5.92 **
	TCH 1705-101 × COD 5-1-2	40.33*	51.63 **	29.27 **	5.22 *
	C 11-19 × Surabhi	40.13*	45.40 **	31.14 **	4.69 *
Boll weight	F-2617 x CD-98955	5.85*	-3.08	-13.42	4.87
	African I-2 x CD-98955	5.62*	17.14 *	4.98	26.22 *
	C 12-2 x CD-98955	5.44*	7.09	1.68	22.25 *
Single plant yield	TCH 1705-101 x COD 5-1-2	198.27*	124.29 **	116.45 **	44.02 **
	VS-9-S11-1 x KC3	188.93*	132.39 **	130.96 **	37.24 **
	African I-2 x TCH 1705-250	178.80*	64.79**	43.96**	29.88**
	F-2617 x TCH 1608	170.07*	29.43 **	27.87 *	23.54 *
	VS-9-S11-1 x TCH 1608	168.33*	57.47 **	26.57 *	22.28 *
Seed index	TCH 1705-169 x COD 5-1-2	12.70*	18.79 **	16.73 *	29.87 **
	ARBC-1301 x BS-1	12.65*	18.23 *	7.24	29.36 **
Lint index	C 11-19 x COD 5-1-2	10.29*	12.77	7.60	19.20
	TCH 1705-152 x COD 5-1-2	10.03*	12.72	4.92	16.22
Ginning	F-2617 x KC3	39.14*	8.75 *	8.42	8.56

outturn	TCH 1705-101 x Surabhi	38.28*	17.09 **	16.88 **	6.19
Fibre fineness	TCH 1705-101 × COD 5-1-2	3.90*	-12.36 *	-13.33	-13.33 *
	AFRICAN -I-2 × BS-1	3.90*	-10.34	-13.33	-13.33 *
	C 12-2 × BS-1	3.90*	-10.34	-13.33	-13.33 *
	VS-9-S11-1 × COD 5-1-2	3.80*	-13.64 *	-13.64	-15.56 *
	VS-9-S11-1 × SURABHI	3.70*	-16.85 **	-17.78 *	-17.78 **
2.5 % Span length	AFRICAN -I-2 × Surabhi	33.90*	3.04	-1.74	6.94 **
	ARBC-1301 × KC3	33.10*	22.14 **	19.93 **	4.42 *
	AFRICAN -I-2 × BS-1	32.80*	3.36	1.97	3.47
	VS-9-S11-1 × Surabhi	32.50*	0.93	-5.80 **	2.52
	AFRICAN -I-2 × CD-98955	32.50*	4.67 *	3.83	2.52
	C 11-19 × COD 5-1-2	32.10*	6.29 **	1.90	1.26
	G.cot.100 × COD 5-1-2	31.90*	7.23 **	4.25	0.63
	AFRICAN -I-2 × TCH 1608	31.90*	2.41	1.92	0.63
	ARBC-1301 × BS-1	31.80*	6.41 **	-1.14	0.32
	C 12-2 × CD-98955	31.70*	2.42	1.93	0.00
Uniformity ratio	F-2617 × TCH 1705-250	54.50*	1.77	-1.09	14.26 **
	DSC-1302 × TCH 1705-250	54.00*	1.12	-2.00	13.21 **
	DSC-1302 × COD 5-1-2	54.00*	11.69 **	4.45 **	13.21 **
	C 10-3 × TCH 1705-250	53.60*	2.39	-2.72	12.37 **
	TCH 1705-169 × TCH 1705-250	53.50*	0.66	-2.90	12.16 **
	TCH 1705-101 × TCH 1705-250	52.80*	0.00	-4.17 **	10.69 **
	F-2617 × KC3	52.70*	0.86	0.38	10.48 **
	C 11-19 × TCH 1705-250	52.10*	2.36	-5.44 **	9.22 **
	C 11-19 × CD-98955	51.80*	11.28 **	10.92 **	8.60 **
	C 10-3 × BS-1	51.70*	5.73 **	4.23 *	8.39 **
Bundle strength	VS-9-S11-1 x Surabhi	23.00*	10.31 **	10.05 **	17.95 **
	G.cot.100 x CD-98955	21.80*	8.46 **	6.34	11.79 **
	G.cot.100 x COD 5-1-2	21.70*	13.32 **	5.85	11.28 **
	TCH 1705-101 x BS-1	21.60*	2.61	0.93	10.77 **
	TCH 1705-152 x Surabhi	21.20*	7.61 *	1.92	8.72 *
	African I-2 x TCH 1608	21.00*	3.70	2.44	7.69 *
	G.cot.100 x TCH 1705-250	20.90*	1.70	1.46	7.18 *
	G.cot.100 x BS-1	20.80*	0.97	0.48	0.48
	C 11-19 x CD-98955	20.70*	5.88	5.08	6.15
Elongation per cent	F-2617 x TCH 1705-250	7.50*	-3.85	-15.73 **	66.67 **
	TCH 1705-169 x TCH1705-250	6.90*	-6.12	-6.12	53.33 **
	C 10-3 x TCH 1705-250	6.70*	-5.63	-24.72 **	48.89 **
	TCH 1705-152 x BS-1	6.60*	14.78 **	8.20	46.67 **
	F-2617 x BS-1	6.40*	5.79	-4.48	42.22 **
	VS-9-S11-1 x TCH 1705-250	6.30*	-8.03 *	-29.21 **	40.00 **
	TCH 1705-152 x CD-98955	6.30*	10.53 *	3.28	40.00 **
	TCH 1705-101 x TCH1705-250	6.20*	-10.14 **	-30.34 **	37.78 **
	C 11-19 x TCH 1705-250	6.20*	-6.06	-30.34 **	37.78 **
	F-2617 x KC3	6.20*	3.33	-7.46	37.78 **

CONCLUSION

Under the light of present study, none of the crosses registered superiority for both *per se* and standard heterosis for the traits studied. However, considering the hybrids with *per se* performance and significant heterosis over mid parent, better parent and standard check, four crosses *viz.*, TCH 1705-101 x COD 5-1-2, TCH 1705-101 × Surabhi, TCH 1705-152 × BS-1 and TCH 1705-152 × TCH 1608 exhibited high significant mean performance and higher standard heterosis over standard check for yield, fibre quality and economically important traits. Furthermore, five crosses *viz*., TCH 1705-101 x COD 5-1-2, VS-9-S11-1 x KC3, African I-2 x TCH 1705-250, F-2617 x TCH 1608 and VS-9-S11-1 x TCH 1608 showed high mean performance and higher standard heterosis for single plant yield. The hybrids which were considered as the best heterotic crosses can be exploited for yield and fibre quality improvement as they exhibited superior yield performance coupled with superior fibre properties.

REFERENCES

1. Ashokkumar, K., Senthil Kumar, K. and Ravikesavan, R. Heterosis studies for fibre quality of upland cotton in line x tester design. *Afr. J. Agric. Res.* **8(48):** 6359-6365 (2013).
2. Basu, A.K., Narayanan, S.S. and Bhat, N.G. Hybrid cottons: Historical development, present status and future perspectives in Indian context. In Hybrid research and development. M. Rai and S. Mauria (eds.), Indian Society of Seed Technology. pp `63–80 (1995).
3. Choudhary, R., Solanki, B. G., Choudhary, R., Singh, A. K. and Vikaskhandelwal. Heterosis in single cross inter and intra-specific hybrids of desi cotton in relation to seed cotton yield and it'scontributing characters. *The Bioscan.* **9(2):** 839-843 (2014).
4. Doak, C.C. A new technique in hybridizing suggested changes in existing methods of emasculation and bagging cotton flowers. *J. Hered.*, **25:** 201–204 (1934).
5. Geddam, S. B., Khadi, B. M., Mogali, S., Patil, R. S., Katageri, I. S., Nadaf, H. L. and Patil, B. C. Study of heterosis in genetic male sterility based diploid cotton hybrids for yield, yield component and fibre quality characters. *Karnataka J. Agric. Sci.* **24(2):** 118-124 (2011).
6. Gilbert, N.E. Diallel cross in plant breeding. *Heredity*, **13:** 477–492 (1958).
7. Gowen, J.W. Heterosis, Iowa state college press, Ames, Iowa, pp. 1-522 (1952).
8. Haleem, S.H.M., Metwali, M.R. and Felaly, M.M. Genetic analysis of yield and its Components of some Egyptian Cotton (*Gossypium barbadense* L.) Varieties. *World Journal of Agricultural Science.*, **6(5):** 615-620 (2010).
9. Jyotiba, S. S., Patil, B. R., Deshpande, S. K., Patil, S. S. and Patil. R. S. Heterosis studies in GMS based diploid Cotton. *Electronic J. Plant Breeding.* **1(4):** 685-688 (2010).
10. Kempthorne, O. An introduction to genetic statistics. John Wiley and Sons, Inc. New York (1957).
11. Kencharaddi, H. G., Hianchinal, R.R., Patil, S.S., Manjula, S.M., Pranesh, K.J. and Rajeev, S. Studies on heterosis in inter heterotic group derived cotton hybrids for lint yield and its components. *Plant archives*, **15(1):** 323-333 (2015).
12. Kumar, K.S. Diallel analysis in cotton (*Gossypium hirsutum* L.). M.Sc.(Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore (2007).
13. Mehta, D., Solanki, H.V., Rathodand, V.B. and Valu, M.G. Heterosis for seed cotton yield and its contributing characters in cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*, **5(1):**124-130 (2014).
14. Panse, V.G. and Sukhatme, P.V. Statistical methods for agricultural workers. 2nd Ed., ICAR, New Delhi, pp. 1-361 (1985).
15. Patel, D.H., Patel, D. U. and Kumar, V. Heterosis and combining ability analysis in tetraploid cotton (G.hirsutum L. and G.barbadense L.). *Electronic J. Plant Breed.* **5(3):** 408-414 (2014).
16. Ramanatha Iyer. An inexpensive method of selfing cotton flowers. *Emp. Cott. Grow. Rev.*, **13:** 28–30 (1936).
17. Ranganatha, H. M., Patil, S. S., Manjula, S. M. and Patil, B. C. Studies on heterosis in Cotton (Gossypium hirsutum L.) for seed cotton yield and its components. *Asian J. Bio. Sci.*, **8(1):** 82-55 (2013).

18. Shimna, B. and Ravikesavan. R. Combining ability analysis of yield related traits and fibre quality traits in cotton (*Gossypium* spp.). *J. Cotton Res. Dev.*, **22(1):** 23–27 (2008).
19. Solanke A., Deshmukh, S.B., Mhasal, G.S. and Marawar, M.W. Heterosis and combining ability in genetic male sterility based diploid cotton hybrids for yield, yield component, fibre quality characters and oil content. *Electronic Journal of Plant Breeding,* **6(1):**150-156 (2015).
20. Solanki, H.V., Mehta, D.R., Rathod ,V.B. and Valu, M.G. Heterosis for seed cotton yield and its contributing characters in cotton (*Gossypium hirsutum* L.). *Electronic J. Plant Breed.*, **5(1):** 124-130 (2014).
21. Swaminathan, M.S., Siddiq, E.A. and Sharma, M.S. Outlook for hybrid rice in India. In: Rice breeding, IRRI, Phillipines. pp109–113 (1972).
22. Turner, J.H. A study of heterosis in upland cotton. I. Yield of hybrids compared with varieties, combining ability and inbreeding effects. *Agron. J.*, **45:** 484-490 (1953).
23. Tuteja, O.P. and Agarwal, M. Heterosis for seed cotton yield and other traits in GMS based hybrids of American cotton (*Gossypium hirsutum* L.). *Cotton res. J*., **5(2):**131-141 (2014).
24. Tuteja, O.P. Studies on heterosis for yield and fibre quality traits in GMS hybrids of upland cotton (*Gossypium hirsutum* L.). *J.Cotton Res. Dev.*, **28(1):**1-6 (2014).
25. Usharani, K.S., Vindhiyavarman, P., Amala Balu, P. and Boopathi, N.M. Heterosis studies for fibre quality traits in diallel crosses of upland cotton (*Gossypium hirsutum* L.). *The Bioscan,* **10(2):** 793-799 (2015).
26. Wynne, J.C., Emery, D.A. and Rice, P.W. Combining ability estimates in *Arachis hypogaea* L. and field performance of F1 hybrids. *Crop Sci.*, **10:** 713-715 (1970).