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Studies on Recombinational Variability for Combining Ability Among F4 Barbadense Lines

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Abstract The present study was aimed at evaluating recombinational variability for combining ability in F_4 generation. To assess variability for combining ability, twenty eight F_4 (*Gossypium barbadense L.*) lines were crossed with four common diverse testers (*Gossypium hirsutum L.*) *viz.,* DH 98-27 (T_1), ZCH8 (T_2), 178-24 (T_3) and DH 18-31 (T_4) for use in assessing the variability for combining ability. The entire experimental material was planted on a medium black soil at College of Agriculture, Dharwad under irrigated condition. All the 53 F_5 (included Suvin variety as check) barbadense lines, four hirsutum testers and derived F_1 crosses along with the straight crosses (Bench Mark Crosses (BMC)) and ruling commercial checks (MRC 6918 *Bt* check and DCH 32 non *Bt* check) were sown during *kharif* 2011 in a Randomized Block Design with two replications and a spacing of 90 cm between rows and 60 cm between the plants within a row. Among the barbadense lines (males), the mean sum of squares (MSS) were not significant for all the characters except mean boll weight, reproductive points on sympodia and seed cotton yield which showed highly significant differences, while number of bolls per plant and ginning outturn exhibited significant differences. Among the hirsutum testers (females) exhibited not significant difference for all the characters except number of bolls per plant and seed cotton yield which recorded highly significant differences, while mean boll weight and transpiration rate showed significant differences. Line x Tester interaction were highly significant differences for number of monopodia per plant, number of bolls per plant, mean boll weight, reproductive points on sympodia, seed index, lint index, photosynthetic rate, stomatal conductance and transpiration rate, while seed cotton yield had significant differences. The estimates of variance due to general combining ability (GCA), variance due to specific combining ability (SCA), the magnitude of SCA variances were greater than GCA variance for all 14 characters and the variance ratio was less than half in these traits, indicating that dominance variance was more than additive variance for these characters. For seed cotton yield, eight lines recorded significant *gca* effects, of which five lines exhibited positive significant *gca* effects. The highest *gca* effect was found by the line DB 533 x DB 534 F_4 IPS 8 (363.15). Among the testers, the tester DH 98-27 had positive significant *gca* effect (94.65) and the tester DH 18-31 showed positive *gca* effect (35.44), while 178-24 (-77.43) recorded negative significant *gca* effect. Two crosses manifested positive significant *sca* effects, of which the cross DH 98-27 X (DB 534 x DB 533 F_4 IPS 22) (680.34) recorded the highest positive *sca* effect. Based on weighted *gca* method ,the most potential combiners were found to be the lines DB 533 x DB 534 F_4 IPS 26, DB 533 x DB 534 F_4 IPS 17, DB 533 x DB 534 F_4 IPS 8 and DB 533 x DB 534 F_4 IPS 32 . Among the testers, the tester DH 18-31 based on weighted *gca* method is the most potential parent
Keywords Recombinational variability, F_4 barbadense lines, hirsutum testers, *gca*, *sca*

Introduction

Cotton, being the king of fibers in preparing human apparel has played a key role in civilization of mankind. Cotton is providing livelihood directly and indirectly to over 60 million people and accounting for about 16 per cent of India's export earnings. India has a pride place in the global cotton scenario due to several distinct features such as the largest cotton growing area, cultivation of all the four cultivated species, large area under tetraploid cotton, possibly the only country to grow hybrid cotton involving different species of cotton, native home of old world cultivated cotton and wide diversity in agro-climatic conditions under which cotton is grown. There is maximum diversity in the quality of cotton grown in India ranging from 5s counts to 120s counts.

There is a constant need to develop more potential hybrids and adopt noval approaches for improving hybrid performance. In cross pollinated crops like maize heterotic populations are developed and exploited through population improvement schemes meant for improving combining ability. Such programmes are integral part of hybrid breeding programme and these populations are shared among breeders and used further to obtain more potential hybrids. Studies have shown that even in cotton it is possible to adopt these concepts with suitable modifications in the procedure to suit the mating system of self pollinated crops (Patil and Patil, 2003 and Patil *et al* 2007).

In several studies conducted on improving combining ability in often cross pollinated crops like red gram (Patil, 1997), sorghum (Patil and Pandit, 1991 and Madhusudhana, 1993) and cotton (Patil and Patil, 2003, Mallikarjun, 2005, Somashekar, 2006 and Ramakrishna 2008), attempts were made to exploit the potentiality of the simple traditional method of practicing selection in segregating generations (obtained though hybridization) and utilizing the recombinational variability for improving combining ability as a trait. These studies have clearly indicated that combining ability of lines could be improved by following selection for combining ability (as a trait) in segregating generations.

Mallikarjun (2005), Patil and Patil (2003) and Somashekhar (2006) worked on developing intra hirsutum heterotic population for creating recombinational variability for combining ability. The studies have confirmed that it is possible to develop potential intra hirsutum hybrids through exploitation of recombinational variability for combining ability. There are no studies to evidence the possibility of exploiting recombinational variability for combining ability in developing potential inter specific hybrids. Realizing the need for developing potential inter specific (H×B) hybrids, a detailed study was initiated at University of Agricultural Sciences, Dharwad during 2007/08 to identify hirsutum and barbadense genotypes capable of giving potential inter specific hybrids.

Based on this study two barbadense and four hirsutum lines giving best hybrid (H×B) combinations between them were selected. To create recombinational variability, the two barbadense genotypes were crossed to get F_1 and it was advanced to F_4 generation. In the present phase of this continuing study, the F_4 lines of this population (barbadense x barbadense) is utilized for assessing recombinational variability for combining ability against selected hirsutum testers. Nature and magnitude of variability for combining ability was assessed against each hirsutum tester included in the heterotic box. In this study new population of F_4 lines was developed by crossing DB 533 and DB 534. The improvement seen in the barbadense lines was assessed in terms of productivity and fiber quality traits. The variability for combining ability of these F_4 lines was assessed in the study by crossing them with four hirsutum testers. These testers were decided upon based on evaluation of the hybrid involving parental barbadense lines with these hirsutum testers. The main objectives of this study:

Exploitation of heterotic groups by creation of recombinational variability in *G.barbadense* F_4 population for ability to combine with selected diverse *G. hirsutum* testers.

To determine combining ability effects (*gca* and *sca*), variances (GCA and SCA), combining ability patterns of these barbadense and hirsutum lines.

Conclusion

There are several advantages of evaluating combining ability of lines in early segregating generations. Identification of superior combining lines in early segregating generations would at least avoid undue multiplication and advancing of material of little genetic worth *i.e.,* with low combining ability. Jenkin's (1935) study revealed that combining ability of a line is heritable and thereby he indicated that potential parents of hybrids can be selected in an early generation of inbreeding. It is well known that plants in early segregating generation have a higher level of heterozygosity, while, the segregating lines in later generations *viz.,* F_5, F_6 and F_7 would be nearly homozygous. Hence, evaluating for combining ability in later generation perhaps would be automatically

more reliable. Despite this, it is felt that selection needs to be initiated as early as possible in a generation where the constitution would have reached a satisfactory level of uniformity (homozygosity). In fact, F_4 is a generation in which for the first time even in conventional pedigree method emphasis for the selection (for performance) is laid exclusively on the line mean. It means that F_4 onwards one need not distinguish individual plants performance in a line (Allard, 1960).

Material and Methods

Choice of the material

To create recombinational variability for combining ability (Figure 1), the elite barbadense lines DB 533 and DB 534 were crossed during 2007-2008. During two seasons 2008-2009 and 2009-2010 these barbadense crosses were advanced to F_2 and F_3 generations, respectively. The F_3 lines were evaluated for productivity and fiber quality parameters realizing the emphasis laid on developing ELS (Extra Long Stable) cotton hybrids out of 171 F_3 lines, only those F_3 lines with acceptable fiber strength were utilized in the study on recombinational variability of combining ability.

During 2010 -2011 those twenty eight F_4 lines of barbadense cross DB 533 × DB 534 depending on the higher value of fiber tenacity, were crossed with the selected four hirsutum testers *viz.,* DH 98-27 (T_1), ZCH 8 (T_2), 178-24 (T_3) and DH 18-31 (T_4) selected based on earlier study. Each barbadense F_4 line was involved in a set of crosses (112 crosses refer to as derived F_1 crosses) were subjected to Line x Tester analysis.

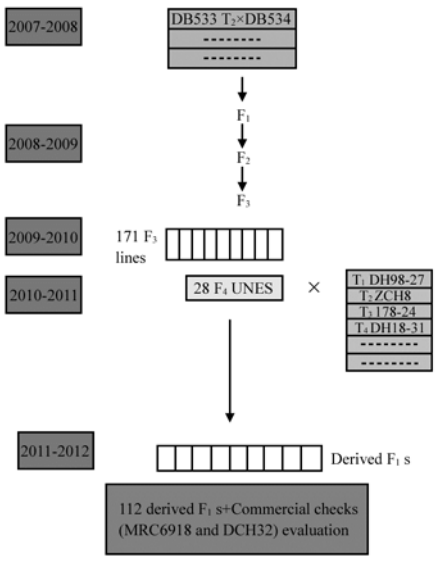

Figure 1 Schematic presentation of the procedure following in the study to improve combining ability

Crossing Programme

The crossing programme was taken up during 2010. The F_4 lines and four common testers were sown on staggered dates. To obtain derived F_1 crosses seeds, the flower buds of the proper size from testers (used as female) were hand emasculated in the evening between 3.00 to 6.00 pm. The emasculated flowers were covered by butter paper packets for avoiding out crossing as well as ensuring their easy identification at the time of crossing. The emasculated flowers were pollinated during the next day morning between 9.30 am and 11.30 am by brushing the pollen from one of the F_4 lines (used as male) on the stigmatic surface. The pedicel of each pollinated flower was tied with price label bearing date and lines number for identification of crossed bolls. In this manner derived F_1 crosses seeds were obtained. Simultaneously, the barbadense population of F_4 lines was selfed and material was advanced to F_5 generation during the same year.

Evaluation of derived F_1 crosses and F_5 barbadense lines

There was a need for improving performance of inter specific hybrids. This was possible through genetic improvement of barbadense varietal lines. So that both productivity and fiber quality of barbadense were improved. An improved barbadense varietal base is essential for improving performance of inter specific hybrids.

The entire experimental material was planted on a medium black soil at College of Agriculture, Dharwad under irrigated condition. All the 53 F_5 (included Suvin variety as check) lines, four hirsutum testers and derived F_1 crosses along with the straight crosses (Bench Mark Crosses (BMC)) and ruling commercial checks (MRC 6918 *Bt* check and DCH 32 non *Bt* check) were sown during *kharif* 2011 in a Randomized

Block Design with two replications and a spacing of 90 cm between rows and 60 cm between the plants within a row (Plate 1). Recommended fertilizer doses were applied and other cultural practices were carried out at regular interval. Plant protection measures were taken at appropriate time to control pests and diseases.

Plate 1. General view of the derived F_1 crosses at University of Agricultural Sciences, Dharwad

To facilitate Line × Tester analysis, the crosses obtained were randomized and were sown in one block along with checks, bench mark crosses and parents were sown in adjoining block.

Experimental Results and Discussion

This study was aimed at evaluating recombinational variability for combining ability in F_4 generation. To assess variability for combining ability, twenty eight F_4 (*Gossypium barbadense L.*) lines were crossed with four common diverse testers (*Gossypium hirsutum L.*) *viz.,* DH 98-27 (T_1), ZCH8 (T_2), 178-24 (T_3) and DH 18-31 (T_4) for use in assessing the variability for combining ability.

In this study an improvement in combining ability is defined (described) as improvement in performance of derived F_1s over respective other crosses involving the tester concerned. When we refer to "performance of derived F_1" we primarily look at on the performance of seed cotton yield as a measure of combining ability. Seed cotton yield is the most important character directly reflecting the economic worth of the crop. Hence, it is more meaningful to assess the combining ability of a line in terms of the seed cotton yield of the F_1s derived from it. The combining ability of each line with four testers was assessed for comparing the derived F_1s with the other crosses and commercial checks.

Combining ability analysis

Analysis of variance for combining ability

The analysis of variance for 14 characters studied for this set are presented in Table 1. Among the lines (males), the mean sum of squares (MSS) were not significant for all the characters except mean boll weight, reproductive points on sympodia and seed cotton yield which showed highly significant differences, while number of bolls per plant and ginning outturn exhibited significant differences. Testers (females) exhibited not significant difference for all the characters except number of bolls per plant and seed cotton yield which recorded highly significant differences, while mean boll weight and transpiration rate showed significant differences. Line x Tester interaction were highly significant differences for number of monopodia per plant, number of bolls per plant, mean boll weight, reproductive points on sympodia, seed index, lint index, photosynthetic rate, stomatal conductance and transpiration rate, while seed cotton yield had significant differences.

The estimates of variance due to general combining ability (GCA), variance due to specific combining ability (SCA), the magnitude of SCA variances were greater than GCA variance for all 14 characters and the variance ratio was less than half in these traits, indicating that dominance variance was more than additive variance for these characters (Table 2). Patel *et al*. (2005), Paulo Antnio de Aguiar *et al*. (2007), Kumboh *et al*. (2008), Wankhade *et al*. (2008), Naqib Ullah *et al*. (2009), Cetin Karademir *et al*. (2009), Basal *et al*. (2009) , Deosarkar *et al*. (2009b) and Mohammad Reza *et al*. (2010) recorded the same results.

Combining ability effects

The estimates of general combining ability effects of females and males presented in Table 3, their specific combining ability effects are presented in Table 4 for all the characters.

Seed cotton yield (kg/ha)

Eight lines recorded significant *gca* effects (Figure 2), of which five lines exhibited positive significant *gca*

Table 2 Variance due to general and specific combining ability in derived F_1 crosses for different quantitative characters

Characters	Variance Due to GCA	Variance Due to SCA	GCA/SCA
1- Seed cotton yield (kg/ha)	4745.8378	1429428.5000	0.0035
2- Plant height (cm)	2.4440	3348.4453	0.0007
3- No. of Monopodia	0.0018	2.1663	0.0010
4- No. of sympodia	0.0488	87.5278	0.0005
5- No. of bolls	1.6200	974.2978	0.0015
6- Mean boll Weight (g)	0.0008	2.8943	0.0003
7- Reproductive Points on Sympodia	0.0125	8.6920	0.0018
8- Length of Sympodia at 50% height (cm)	0.1350	595.2768	0.0000
9-Seed index (g)	0.0810	38.8530	0.0020
10-Ginning outturn (%)	0.1600	136.3290	0.0013
11- Lint index (g)	0.0300	15.5615	0.0018
12- Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$)	1.0598	838.8318	0.0013
13- Stomatal conductance ($\mu molm^{-2}s^{-1}$)	0.0020	1.1120	0.0018
14- Transpiration rate (mmol $H_2Om^{-2}s^{-1}$)	0.1745	42.3088	0.0035

effects. The highest *gca* effect was found by the line DB 533 x DB 534 F_4 IPS 8 (363.15). Among the testers, DH 98-27 had positive significant *gca* effect (94.65) and the tester DH 18-31 showed positive *gca* effect (35.44), while 178-24 (-77.43) recorded negative significant *gca* effect (Figure 2). Two crosses manifested positive significant *sca* effects, of which the cross DH 98-27 X (DB 534 x DB 533 F_4 IPS 22) (680.34) recorded the highest positive *sca* effect.

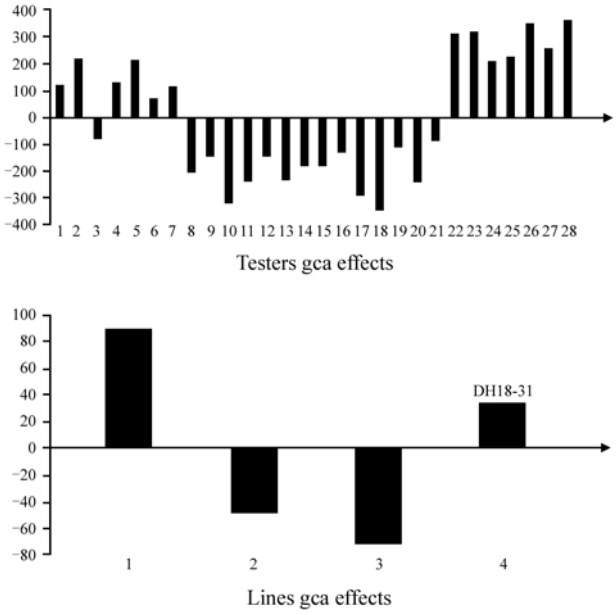

Figure 2 Estimates of general combining ability effects of parents involved in recombinational variability study for seed cotton yield

Plant height (cm)

The estimates of general combining ability effect indicated significant differences among the line parents, three lines had significant positive *gca* and two had significant negative *gca*. The highest value of *gca* effect was exhibited by DB 533 x DB 534 F_4 IPS 36 (14.29). All four testers exhibited non significant *gca* effects. Seven crosses differed significantly for *sca* effects, of these four had positive *sca* effects. The cross DH 98-27 X (DB 533 x DB 534 F_4 IPS 12) (26.27) had expressed the highest value of *sca* effect.

Number of monopodia per plant

Nine line parents expressed significant *gca* effects and the line DB 533 x DB 534 F_4 IPS 48 (0.40) was the best general combiner among the line parents. Among the testers, DH 18-31 showed significant positive *gca* effect (0.06) for number of monopodia per plant. Twenty seven crosses expressed significant *sca* effects. Among these, fourteen crosses had positive *sca* effects and the maximum *sca* effect was recorded by the cross DH 98-27 X (DB 533 x DB 534 F_4 IPS 23) (0.53).

Number of sympodia per plant

Out of 28 male (Line) parents used in the population based crosses, one line showed significant negative *gca* effect was shown by DB 533 x DB 534 F_4 IPS 15 (-2.36). Among the females (testers), there are no significant *gca* effects. Two crosses expressed

significant *sca* effects were shown by DH 98-27 X (DB 533 x DB 534 F_4 IPS 71) and 178-24 X (DB 533 x DB 534 F_4 IPS 48) -4.76 and -4.55, respectively.

Number of bolls per plant

Among the lines nine lines had significant *gca* effects, out of which five lines recorded positive significant *gca* effects and DB 533 X DB 534 F_4 IPS 24 (5.52) exhibited highest value of *gca* effect. Among the testers, DH 98-27 and DH 18-31 recorded positive significant *gca* effects 1.37 and 0.95, respectively. The tester 178-24 (-1.87) had negative significant *gca* effect. Two crosses differed significantly for *sca* effects, these two crosses had positive *sca* effects and shown by ZCH 8 X (DB 533 x DB 534 F_4 IPS 30) and 178-24 X (DB 533 x DB 534 F_4 IPS 17) 17.97 and 13.87, respectively.

Mean boll weight (g)

The estimates of *gca* effects of line parents in the population based crosses were found to be significant in two lines, out of which one was positive significant and other was negative significant differences were shown by DB 533 x DB 534 F_4 IPS 52 (0.38) and DB 533 x DB 534 F_4 IPS 30 (-0.47). Among the testers, ZCH 8 recorded positive significant *gca* effect (0.03), while 178-24 had negative significant *gca* effect (-0.05). One cross expressed positive significant *sca* effect shown by ZCH 8 X (DB 533 x DB 534 F_4 IPS 49) (0.88).

Reproductive points on sympodia

Out of 28 male (Line) parents used in the population based crosses, thirteen lines recorded significant *gca* effects. Among these, five lines showed significant positive *gca* effects and the cross DB 533 x DB 534 F_4 IPS 15 (0.93) had the highest value of *gca* effect. Among the testers, ZCH 8 (-0.17) exhibited negative significant *gca* effect. Twenty four crosses expressed significant *sca* effects. Among these, thirteen had positive *sca* effects and the maximum *sca* effect was recorded by the cross 178-24 X (DB 533 x DB 534 F_4 IPS 12) (1.56).

Sympodial length at 50 % plant height (cm)

The estimates of *gca* effects of lines revealed positive significant differences for two line parents. These lines are DB 533 x DB 534 F_4 IPS 30 (6.02) and DB 533 x DB 534 F_4 IPS 36 (5.00). Among the testers, there are no significant *gca* effects. The estimates of *sca* effects were significant for eight crosses. Of these, six crosses had positive *sca* effects and the highest *sca* effect was expressed by the cross DH 98-27 X (DB 533 x DB 534 F_4 IPS 38) (14.62).

Seed index (g)

Eight line parents exhibited significant *gca* effects, four lines had significant *gca* in positive direction and highest was recorded by the line DB 533 x DB 534 F_4 IPS 30 (1.30). Among the testers, 178-24 and DH 18-31 showed positive and negative significant *gca* effects 0.34 and -0.43, respectively. Twenty nine crosses revealed significant *sca* effects, of these fourteen crosses showed positive *sca* effects and the highest was displayed by the cross DH 98-27 X (DB 533 x DB 534 F_4 IPS 32) (5.80).

Ginning outturn (%)

Six line parents displayed significant *gca* effects, of which two lines exhibited significant positive *gca* effects. Highest *gca* effect was recorded by DB 533 x DB 534 F_4 IPS 16 (2.93). None of the testers depicted significant *gca* effect for this character. Six crosses expressed significant *sca* effects of these, two crosses showed positive *sca* effects. The cross ZCH 8 X (DB 533 x DB 534 F_4 IPS 26) (5.52) recorded highest positive *sca* effect.

Lint index (g)

Out of twenty eight lines, eight showed significant *gca* effects, of which three lines had positive *gca* effects. The highest *gca* effect was found by the line DB 533 x DB 534 F_4 IPS 17 (1.34). The tester ZCH 8 (-0.27) showed negative significant *gca* effect and the tester 178-24 (0.21) showed positive significant *gca* effect. Of the 112 crosses studied, seventeen crosses recorded significant *sca* effects for this character, of which nine showed significant *gca* effects in positive direction. The cross DH 98-27 X (DB 533 x DB 534 F_4 IPS 32) recorded highest positive *sca* effect (1.98).

Photosynthetic rate (µmol $CO_2m^{-2}s^{-1}$)

Out of 28 line parents, twenty one lines are having significant *gca* effects. The male parent DB 533 x DB

534 F_4 IPS 26 (7.36) showed highest positive significant *gca* effect. Among the testers, 178-24 and DH 18-31 had significant negative and positive *gca* effects -1.30 and 1.47, respectively. Fourty eight crosses showed significant *sca* effects, of these twenty six crosses had positive *sca* effects. The cross ZCH 8 X (DB 533 x DB 534 F_4 IPS 25) expressed the highest *sca* effect (13.09).

Stomatal conductance (μmol m^{-2} s^{-1})

Out of twenty eight male lines, sixteen showed significant *gca* effects, of which eight lines exhibited positive *gca* effects and the highest *gca* effect was found by the line DB 533 x DB 534 F_4 IPS 26 (0.31). The tester 178-24 registered significant negative *gca* effect (-0.07), while ZCH 8 and DH 18-31 revealed significant positive *gca* effects 0.03 and 0.05, respectively. Of the 112 crosses, fifty two crosses recorded significant *sca* effects, of which twenty seven showed positive *sca* effects and the cross ZCH 8 X (DB 533 x DB 534 F_4 IPS 52) (0.58) recorded highest positive *sca* effect.

Transpiration rate (mmol H_2O m^{-2} s^{-1})

The estimates of *gca* effects of lines and testers for transpiration rate trait, six line parents expressed significant *gca* effects. Out of which three lines showed positive significant *gca* effects and the highest *gca* effect was found by the line DB 533 x DB 534 F_4 IPS 55 (1.98). Among the testers, two are with significant *gca* effects, of which DH 18-31 indicated significant positive *gca* effect (0.55) and 178-24 indicated significant negative *gca* effect (-0.56). As regard to *sca* effects, twenty two crosses recorded significant *sca* effects, of which ten were significant positive *gca* and the hybrid DH 98-27 X (DB 533 x DB 534 F_4 IPS 1) registered significant and highest positive *sca* effect (3.58).

Pooled score for *gca* effects

Simple pooled *gca* score method

In this approach, significant *gca* effect in desirable direction is given positive weightage (+1) and negative weighatage (-1) is given for *gca* effect in undesirable direction (Arunachalam and Bandopadhyay, 1979). These values are added over different yield influencing characters to arrive at pooled score of *gca* effects. The inherent disadvantage with this system is that all the parents with significant *gca* effects in desirable direction get the same score (positive). Hence, it is not possible to quantify the magnitude of difference existing among the genotypes of this group which get a positive score. Therefore, it is necessary develop a system of working out pooled scores of *gca* by utilizing the actual *gca* values and ensuring quantification of every possible difference existing in *gca* effects between only two parents.

Per cent *gca* method

When the actual *gca* values are added across characters to arrive at pooled score, problem arises because of difference in unit of measurement of each character. Absolute values of *gca* effects may be big (plant height) or small (boll weight) depending on the character and if used, the importance of the character may not be projected correctly. If the raw values of *gca* effects are added across the characters, the character with higher *per se* effect influence the pooled scores most as against the character with low *per se gca* values. To overcome this disadvantage, the raw *gca* values have to be converted into per cent *gca* values.

Thus, by working out per cent *gca* values, the minute differences in *gca* values are also focussed and the possible problem arising out of the differences in unit of measurement, high and lower *per se gca* values associated with the type of character concerned are overcome.

Weighted per cent *gca* method

In this method further improvement is brought about in arriving at the pooled *gca* scores of the parents. In per cent *gca* method, the per cent *gca* values are straight away added across the characters which means each character including yield and yield components are all given equal weightage. The experience of the breeders would suggest sometimes that, in arriving the pooled score, it is desirable to attach differential weightages to each of the characters studied depending upon its economic importance, contribution to yield *etc.* These weightages can be multiplied with per cent *gca* values of corresponding characters and then added to arrive at the pooled *gca* score for each parent. In the present study weightages

for different yield related characters were worked out by consulting the senior breeder related to cotton *viz.,* Dr. S. S. Patil, Senior Scientist, Agricultural Research Station, Dharwad and Dr.B.C.Patil, principal scientist (Plant physiology), ARS, Dharwad Farm.

In F_4 lines, based on simple pooled *gca* score method (Table 5), the F_4 lines DB 533 x DB 534 F_4 IPS 26, DB 533 x DB 534 F_4 IPS 17, DB 533 x DB 534 F_4 IPS 48 and DB 533 x DB 534 F_4 IPS 8 (Decreasing order) are recognized as the most potential parents. Among the testers DH 18-31 based on simple pooled *gca* score method showed the most potential parent. Based on per cent *gca* method, the line parents DB 533 x DB 534 F_4 IPS 26, DB 533 x DB 534 F_4 IPS 8, DB 533 x DB 534 F_4 IPS 17 and DB 533 x DB 534 F_4 IPS 55 (Decreasing order) were the most potential combiners (Table 6). Among the testers, DH 18-31 based on per cent *gca* score method showed the most potential parent. Similarly, based on weighted *gca* method the most potential combiners were found to be the lines DB 533 x DB 534 F_4 IPS 26, DB 533 x DB 534 F_4 IPS 17, DB 533 x DB 534 F_4 IPS 8 and DB 533 x DB 534 F_4 IPS 32 . Among the testers, DH 18-31 based on weighted *gca* method is the most potential parent (Table 7). The overall combining ability status of F_4 barbadense lines was determined by working out pooled *gca* score. Three methods namely simple *gca* score, per cent *gca* and weighted *gca* method were used in arriving at the best general combiner lines. The overall ranking from these approaches differed and the weighted *gca* approach helped in preciese identification of potential combiners.

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Table 1 Analysis of variance for combining ability in derived F_1 crosses for different quantitative characters

Source	d.f.	Mean sum of squares												
		See (kg d cotton yield /ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (µmol $CO_2m^{-2}s^{-1}$)	Stomatal conductance ((µmol $m^{-2}s^{-1}$)	Transpiration rate (mmol $H_2Om^{-2}s^{-1}$)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Replications	1	1085229.86**	650.39	1.96**	303.32**	1484.54**	8.37**	5.41**	139.39	69.82**	2.79	77.99**	51.29**	0.034**	74.75**
Crosses	111	215277.08*	350.53*	0.20**	7.96	89.14**	0.28**	1.10**	60.89*	3.61**	15.61**	1.70**	90.50**	0.12**	4.24**
Line Effect	27	422120.75**	428.64	0.18	6.40	64.35*	0.28**	1.86**	72.82	2.66	22.45*	2.13	114.71	0.15	3.44
Tester Effect	3	354355.88**	182.50	0.14	3.65	120.97**	0.07*	0.92	10.10	6.04	11.93	2.25	79.13	0.16	13.04*
Line x Tester Effect	81	141178.12*	330.71	0.21**	8.64	96.23**	0.29**	0.86**	58.79	3.84**	13.46	1.54**	82.85**	0.11**	4.18**
Error	111	149093.70	238.15	0.06	8.58	81.66	0.28	0.24	43.06	0.89	9.69	0.66	5.39	0.00	0.61

Note: * Significant at P = 0.05 ** Significant at P = 0.01

Table 3 Estimates of general combining ability effects of parents involved in recombinational variability study for different quantitative characters

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (µmol CO_2 $m^{-2}s^{-1}$)	Stomatal conductance ((µmol $m^{-2}s^{-1}$)	Transpiration rate (mmol $H_2Om^{-2}s^{-1}$)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Males														
1	DB 533 x DB 534 F4 IPS 44	123.36	0.04	−0.080	−0.2	−3.82*	−0.09	0.04	3.65	−0.61*	1.58	−0.53	0.98	0.03	−1.1**
2	DB 533 x DB 534 F4 IPS 62	219.09	−5.66	0.050	0.43	3.35*	−0.21	−0.45**	−4.06	0.83**	−0.84	0.40	1.57	0.01	−0.56
3	DB 533 x DB 534 F4 IPS 105	−72.66	−4.33	0.19*	−0.86	−1.07	−0.18	0.12	−0.50	0.49	−1.09	−0.19	−7.5**	−0.3**	−0.23
4	DB 533 x DB 534 F4 IPS 26	131.44	5.00	0.19*	0.64	−1.69	−0.19	0.05	2.59	0.82**	1.97	0.46	7.36**	0.31**	0.38
5	DB 533 x DB 534 F4 IPS 71	212.97	−9.87	0.030	0.64	2.02	0.04	−0.58**	−3.14	−0.22	0.08	−0.03	−1.75*	0.02	−0.26
6	DB 533 x DB 534 F4 IPS 30	72.04	10.88*	−0.030	−0.74	−0.19	−0.47*	0.29	6.02**	1.3**	0.77	0.52	−0.79	−0.13**	−1.03*
7	DB 533 x DB 534 F4 IPS 25	118.02	−1.16	−0.21*	0.68	2.10	−0.08	−0.82**	−2.33	−0.52	0.52	0.32	3.92**	0.20**	0.16
8	DB 533 x DB 534 F4 IPS 49	−208.12	6.17	−0.17*	0.68	−1.98	0.14	0.73**	3.38	0.02	−2.53*	−0.56*	−3.46**	−0.09*	−0.46
9	DB 533 x DB 534 F4 IPS 23	−144.82	0.29	0.030	−0.07	2.52	0.21	0.19	0.65	−0.38	−2.41*	−0.52	−7.59**	−0.29**	−1.04*
10	DB 533 x DB 534 F4 IPS 36	−317.54*	14.29**	0.020	0.6	4.81**	0.04	0.62**	5.00*	0.18	−2.41*	−0.26	−3.53**	−0.04	0.32
11	DB 533 x DB 534 F4 IPS 15	−238.08	5.21	0.000	−2.36*	0.98	0.03	0.93**	2.94	−0.83**	−3.8**	−0.87**	−4.08**	−0.09*	−0.27
12	DB 533 x DB 534 F4 IPS 1	−142.35	10.63*	0.120	0.6	3.35*	0.31	−0.48**	−0.19	−0.84**	−0.18	−0.45	−2.91**	−0.03	0.3
13	DB 533 x DB 534 F4 IPS 33	−231.44	−0.87	0.130	0.05	0.39	0.12	0.83**	3.40	−0.15	−1.31	−0.61*	0.09	0.01	−0.33

Continued Table 3

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol CO_2 m^{-2} s^{-1})	Stomatal conductance ((μmol m^{-2} s^{-1})	Transpiration rate (mmol H_2Om^{-2} s^{-1})
14	DB 533 x DB 534 F4 IPS 24	−179.34	3.75	−0.23**	1.10	5.52**	−0.07	−0.27	−1.35	−0.03	−1.18	−0.53*	2.55**	0.10*	0.16
15	DB 533 x DB 534 F4 IPS 16	−179.86	−3.83	−0.140	0.01	0.94	−0.19	0.06	−2.54	0.13	2.93**	0.34	2.05*	−0.12**	0.02
16	DB 533 x DB 534 F4 IPS 52	−128.67	5.63	−0.040	1.72	−1.69	0.38*	−0.45**	−2.66	−0.41	1.65	0.38	1.62	0.09*	0.91*
17	DB 533 x DB 534 F4 IPS 12	−291.48*	−15.5**	0.040	−1.95	0.31	0.18	−0.71**	−4.29	−0.28	1.65	0.15	−3.49**	−0.19**	−0.66
18	DB 534 x DB 533 F4 IPS 22	−346.19**	1.50	0.040	−0.16	0.52	−0.06	−0.39*	−2.85	0.08	−0.53	−0.15	−3.57**	−0.01	0.01
19	DB 533 x DB 534 F4 IPS 14	−110.83	9.04	−0.070	0.72	−1.69	0.04	0.11	2.73	−0.86**	−0.65	−0.45	−2.77**	0.04	0.88*
20	DB 533 x DB 534 F4 IPS 34	−239.26	7.54	0.030	0.51	−1.57	−0.11	−0.11	0.21	0.39	−1.69	−0.58*	−3.26**	−0.07*	−0.18
21	DB 533 x DB 534 F4 IPS 55	−86.21	0.33	0.150	−0.11	2.77	0.19	−0.69**	0.86	−0.59	−0.20	0.01	0.49	0.18**	1.98**
22	DB 533 x DB 534 F4 IPS 17	311.05*	−11.29*	−0.100	−0.57	−2.94	0.06	−0.24	−3.46	0.17	2.75*	1.34**	5.21**	0.1**	0.23
23	DB 533 x DB 534 F4 IPS 32	320.04*	−6.50	−0.27**	−0.32	−3.40*	0.18	0.10	−2.60	1.17**	0.66	0.56*	2.78**	−0.01	−0.42
24	DB 533 x DB 534 F4 IPS 38	211.93	−3.08	0.020	0.43	−4.32**	−0.12	0.73**	2.43	0.4	−0.19	0.52	1.61	0.08*	−0.29
25	DB 533 x DB 534 F4 IPS 48	225.48	−6.41	0.4**	0.68	−1.07	−0.31	−0.13	−3.37	−0.19	0.97	0.75**	3.59**	0.00	0.59
26	DB 533 x DB 534 F4 IPS 13	349.48**	−5.79	0.18*	−1.24	−4.9**	0.11	−0.04	−1.60	0.41	0.71	−0.16	4.19**	0.00	0.18
27	DB 533 x DB 534 F4 IPS 6	258.82*	2.33	−0.21*	−0.82	3.64*	−0.02	0.30	2.90	−0.28	1.42	−0.11	3.07**	0.00	0.11
28	DB 533 x DB 534 F4 IPS 8	363.15**	−8.33	−0.090	−0.07	−2.9	0.04	0.25	−1.81	−0.21	1.36	0.25	3.61**	0.2**	0.59
	SE (gi)	129.59	5.18	0.08	1.08	3.10	0.18	0.17	2.21	0.30	1.06	0.27	0.86	0.04	0.41
	SEd (gi−gj)	183.27	7.32	0.12	1.53	4.39	0.25	0.24	3.12	0.43	1.51	0.38	1.22	0.05	0.58
	CD at 5%	378.40	15.12	0.24	2.87	8.86	0.52	0.48	6.43	0.93	3.05	0.79	2.28	0.07	0.76
	CD at 1%	498.10	19.91	0.31	3.78	11.66	0.68	0.64	8.47	1.22	4.02	1.04	3.00	0.09	1.01
	Females														
1	DH 98−27	94.65**	0.53	−0.05	0.13	1.37**	−0.01	0.09	0.59	0.14	−0.48	0.04	−0.53	−0.02	−0.19
2	ZCH 8	−52.66	1.48	−0.01	−0.14	−0.45	0.03*	−0.17**	−0.38	−0.05	0.15	−0.27**	0.36	0.03 *	0.20
3	178−24	−77.43**	−2.63	0.00	−0.28	−1.87**	−0.05**	0.10	−0.22	0.34**	0.57	0.21*	−1.3**	−0.07 **	−0.56**
4	DH 18−31	35.44	0.62	0.06*	0.29	0.95**	0.02	−0.02	0.02	−0.43**	−0.24	0.02	1.47**	0.05 **	0.55**
	SE (gi)	48.98	1.96	0.03	0.41	1.17	0.07	0.06	0.83	0.11	0.40	0.10	0.33	0.01	0.16
	SEd (gi−gj)	69.27	2.77	0.04	0.58	1.66	0.10	0.09	1.18	0.16	0.57	0.14	0.46	0.02	0.22
	CD at 5%	143.0233	5.72	0.09	1.08	3.35	0.20	0.18	2.43	0.35	1.15	0.30	0.86	0.03	0.29
	CD at 1%	188.2653	7.52	0.12	1.43	4.41	0.26	0.24	3.20	0.46	1.52	0.39	1.13	0.03	0.38

Note: * Significant at P = 0.05 ** Significant at P = 0.01

Table 4 Estimates of specific combining ability effects of derived F_1 crosses for different quantitative characters

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol CO_2 m^{-2} s^{-1})	Stomatal condu ctance ((μmol m^{-2} s^{-1})	Transpiration rate (mmol H_2Om^{-2} s^{-1})
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	[[DH 98−27 x (DB 533 x DB 534 F4 IPS 44)]	23.63	15.35	0.33	−1.80	3.30	−0.04	0.85*	11.1*	−1.25*	−0.32	−1.08*	−11.87**	−0.34**	−2.60**
2	[DH 98−27 x (DB 533 x DB 534 F4 IPS 62)]	−211.61	10.06	−0.57**	0.97	−3.88	−0.33	0.7*	−2.10	0.88	0.21	1.25*	4.96**	0.24**	−0.49
3	[DH 98−27 x (DB 533 x DB 534 F4 IPS 105)]	487.51	−19.50	−0.09	−1.22	0.37	0.15	−0.92**	−2.76	−0.95	−2.92	−1.01	3.26	0.11	1.37
4	[DH 98−27 x (DB 533 x DB 534 F4 IPS 26)]	−299.53	−5.91	0.33	2.05	0.21	0.23	−0.63	−6.25	1.32*	3.03	0.84	3.66*	−0.02	1.72*
5	[DH 98−27 x (DB 533 x DB 534 F4 IPS 71)]	−207.56	−6.94	−0.03	−4.76*	−7.04	−0.13	0.42	−1.27	−0.59	−1.03	0.13	−0.33	−0.14	0.69
6	[DH 98−27 x (DB 533 x DB 534 F4 IPS 30)]	−340.69	0.43	−0.22	3.51	−6.71	0.43	0.19	−4.64	−0.78	0.96	−0.99	−1.04	−0.04	−0.48
7	[DH 98−27 x (DB 533 x DB 534 F4 IPS 25)]	−62.01	−0.78	0.4*	2.15	4.87	−0.29	0.49	9.37*	1.60*	1.29	0.53	−1.53	0.06	−0.34
8	[DH 98−27 x (DB 533 x DB 534 F4 IPS 49)]	610.26*	7.30	−0.16	−0.91	8.88	−0.01	−1.11**	−3.46	−0.24	−1.21	0.32	2.9	0.12	0.13
9	[DH 98−27 x (DB 533 x DB 534 F4 IPS 23)]	45.12	4.56	0.53**	−0.63	6.05	0.00	−0.57	−1.34	0.09	2.65	1.46*	7.76**	0.16*	−0.17
10	[DH 98−27 x (DB 533 x DB 534 F4 IPS 36)]	−22.88	−0.07	0.00	2.80	−4.46	−0.25	−0.14	−0.78	0.00	0.16	−0.56	−9.22**	−0.26**	−2.08*
11	[DH 98−27 x (DB 533 x DB 534 F4 IPS 15)]	−20.33	−1.62	−0.55**	−0.89	−8.55	0.38	0.17	5.55	0.06	−1.57	0.15	−0.97	0.04	−1.32
12	[DH 98−27 x (DB 533 x DB 534 F4 IPS 1)]	−1.91	−2.87	0.02	−1.29	6.96	−0.13	0.54	−3.44	−0.15	−1.24	−1.05	2.44	0.06	3.58**
13	[DH 98−27 x (DB 533 x DB 534 F4 IPS 33)]	−372.07	14.73	0.31	2.70	1.67	−0.09	−0.38	−6.25	−0.15	0.07	−0.29	0.74	0.14	1.01
14	[DH 98−27 x (DB 533 x DB 534 F4 IPS 24)]	−335.87	0.10	0.38*	−1.03	−5.01	−0.28	1.02**	10.22*	−1.77**	0.18	−0.54	−0.76	−0.14	−2.15*
15	[DH 98−27 x (DB 533 x DB 534 F4 IPS 16)]	257.49	13.38	0.01	−2.22	8.58	0.20	0.66	0.39	−0.52	−2.00	−0.17	2.02	0.16*	2.43**
16	[DH 98−27 x (DB 533 x DB 534 F4 IPS 52)]	450.45	−28.20**	−0.7**	0.55	−5.24	0.18	−1.3**	−4.35	2.44**	1.75	0.99	−2	−0.16*	−1.29
17	[DH 98−27 x (DB 533 x DB 534 F4 IPS 12)]	−234.26	26.27*	−0.03	−2.13	−6.70	−0.18	0.41	2.23	0.47	2.30	0.45	4.71**	0.05	−0.55
18	[DH 98−27 x (DB 534 x DB 533 F4 IPS 22)]	680.34*	−12.53	0.38*	0.80	6.12	0.48	−0.60	−5.55	0.16	0.09	0.30	−16.66**	−0.42**	−0.52
19	[DH 98−27 x (DB 533 x DB 534 F4 IPS 14)]	−252.83	−14.58	0.41*	1.11	6.20	−0.09	−0.47	−2.22	0.33	−1.11	−0.89	10.38**	0.42**	1.71*
20	[DH 98−27 x (DB 533 x DB 534 F4 IPS 34)]	−193.25	0.84	−0.76**	0.21	−5.62	−0.21	0.66	5.55	−0.96	−1.27	0.14	1.56	−0.05	−0.64
21	[DH 98−27 x (DB 533 x DB 534 F4 IPS 55)]	119.24	−2.32	−0.19	−0.09	4.17	0.33	−0.32	−10.69*	−1.23*	2.94	0.66	6.70**	0.19*	0.00
22	[DH 98−27 x (DB 533 x DB 534 F4 IPS 17)]	453.96	19.73	0.00	−0.32	2.49	−0.16	0.01	0.45	−1.84**	−4.67*	−0.97	8.13**	0.28**	1.04
23	[DH 98−27 x (DB 533 x DB 534 F4 IPS 32)]	−306.23	−9.33	−0.06	0.32	−0.76	−0.03	−0.08	−4.38	5.80**	0.25	1.98**	−7.08**	−0.25**	−0.91
24	[DH 98−27 x (DB 533 x DB 534 F4 IPS 38)]	−266.97	−8.08	0.25	0.09	−5.91	−0.15	0.38	14.62**	−2.73**	1.48	−1.67**	−7.75**	−0.22**	−0.13
25	[DH 98−27 x (DB 533 x DB 534 F4 IPS 48)]	380.13	5.22	0.22	−1.67	8.05	0.15	−0.04	4.25	1.04	1.51	0.97	0.11	0.01	1.01
26	[DH 98−27 x (DB 533 x DB 534 F4 IPS 13)]	−16.11	−12.40	0.14	0.76	−5.80	−0.40	−0.61	−3.95	−2.49**	−1.39	−0.94	2.25	0.16*	0.82
27	[DH 98−27 x (DB 533 x DB 534 F4 IPS 6)]	−190.18	−1.46	−0.4*	−1.43	0.95	0.33	−0.20	−4.03	1.06	1.88	−0.34	4.49*	0.10*	0.31

Continued Table 4

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol CO_2 m^{-2} s^{-1})	Stomatal condu ctance ((μmol m^{-2} s^{-1})	Transpiration rate (mmol H_2Om^{-2} s^{-1})
28	[DH 98−27 x (DB 533 x DB 534 F4 IPS 8)]	−173.84	8.63	0.04	2.34	−3.20	−0.08	0.85*	3.73	0.39	−2.00	0.30	−6.85**	−0.26**	−2.14*
29	[ZCH 8 x (DB 533 x DB 534 F4 IPS 44)]	97.75	−3.11	−0.39*	1.49	9.80	0.62	0.58	4.21	−0.72	−4.23*	−1.11*	2.09	0.18*	0.47
30	[ZCH 8 x (DB 533 x DB 534 F4 IPS 62)]	−123.96	−4.90	0.25	−0.90	−6.05	0.13	−0.58	−7.41	−0.20	2.31	0.28	−3.53*	−0.13	0.19
31	[ZCH 8 x (DB 533 x DB 534 F4 IPS 105)]	227.66	8.55	−0.04	−1.76	−7.46	−0.34	−0.60	1.26	0.19	−3.60	−0.88	−4.21*	−0.11*	−0.81
32	[ZCH 8 x (DB 533 x DB 534 F4 IPS 26)]	−201.45	−0.54	0.18	1.17	3.71	−0.41	0.61	1.94	0.73	5.52*	1.71**	5.65**	0.07	0.15
33	[ZCH 8 x (DB 533 x DB 534 F4 IPS 71)]	−63.50	−16.07	−0.12	0.24	2.80	−0.24	−0.22	−7.65	−2.04**	2.82	−0.90	−10.84**	−0.21**	−0.82
34	[ZCH 8 x (DB 533 x DB 534 F4 IPS 30)]	−248.74	9.14	0.21	0.35	17.79**	−0.03	−0.54	6.99	−0.91	−4.48*	−1.2*	−9.57**	−0.27**	−1.34
35	[ZCH 8 x (DB 533 x DB 534 F4 IPS 25)]	−28.41	−5.25	0.03	−1.01	−10.30	−0.60	0.86*	−5.09	1.48*	1.76	1.97**	13.09**	0.32**	1.92*
36	[ZCH 8 x (DB 533 x DB 534 F4 IPS 49)]	340.65	12.17	−0.13	0.42	−10.29	0.88*	−0.10	5.75	1.47*	−0.10	0.13	7.33**	0.16*	0.24
37	[ZCH 8 x (DB 533 x DB 534 F4 IPS 23)]	57.63	14.76	0.10	0.41	3.17	0.22	0.18	13.50**	−0.77	1.03	−0.09	4.65**	0.28**	1.04
38	[ZCH 8 x (DB 533 x DB 534 F4 IPS 36)]	−69.77	9.48	−0.45**	0.35	2.33	−0.22	0.11	−1.28	0.65	−0.13	0.52	4.57**	0.32**	1.97*
39	[ZCH 8 x (DB 533 x DB 534 F4 IPS 15)]	15.10	−2.91	0.37*	0.49	−4.25	0.06	0.50	−2.44	0.42	1.48	0.93	4.68**	−0.08	−0.02
40	[ZCH 8 x (DB 533 x DB 534 F4 IPS 1)]	−2.95	−21.33*	−0.02	−1.25	−1.25	−0.06	−0.79*	−9.77*	−0.29	−2.37	−1.37*	−13.9**	−0.52**	−2.99**
41	[ZCH 8 x (DB 533 x DB 534 F4 IPS 33)]	−256.27	−7.65	−0.30	2.37	4.84	0.23	0.12	1.39	−0.86	−11.79**	−0.70	−16.68**	−0.28**	−1.82*
42	[ZCH 8 x (DB 533 x DB 534 F4 IPS 24)]	−195.07	−14.44	0.34*	−2.03	−2.84	−0.31	0.13	−5.89	0.88	3.71	−0.22	2.71	−0.20**	0.39
43	[ZCH 8 x (DB 533 x DB 534 F4 IPS 16)]	227.40	15.67	0.06	−0.72	−4.59	−0.03	0.36	6.62	−0.24	5.12*	1.26*	1.55	−0.11	−0.46
44	[ZCH 8 x (DB 533 x DB 534 F4 IPS 52)]	223.94	6.42	−0.10	0.38	2.59	0.10	−0.60	−2.12	0.22	2.96	−0.34	12.43**	0.58**	1.90*
45	[ZCH 8 x (DB 533 x DB 534 F4 IPS 12)]	−109.74	−9.74	−0.23	0.58	5.30	−0.29	0.08	−2.47	−1.04	0.85	0.11	−0.53	−0.25**	−1.18
46	[ZCH 8 x (DB 534 x DB 533 F4 IPS 22)]	346.89	−3.52	0.23	0.01	−9.05	0.07	−0.18	0.22	0.58	1.42	0.32	3.08	0.20**	0.38
47	[ZCH 8 x (DB 533 x DB 534 F4 IPS 14)]	−140.29	16.09	0.11	1.99	9.70	0.50	−0.30	3.00	−0.69	0.03	−0.13	−3.65*	−0.02	0.11
48	[ZCH 8 x (DB 533 x DB 534 F4 IPS 34)]	−96.86	−2.83	−0.11	−2.58	−5.95	−0.27	0.40	−0.74	1.16	−2.29	−0.30	1.1	0.07	0.70
49	[ZCH 8 x (DB 533 x DB 534 F4 IPS 55)]	154.92	8.27	−0.18	2.45	−2.08	−0.55	0.22	3.27	−0.53	2.19	0.22	−11.93**	−0.37**	−1.83*
50	[ZCH 8 x (DB 533 x DB 534 F4 IPS 17)]	325.54	−13.19	−0.19	−3.78	0.58	−0.30	−0.09	−0.76	−1.25*	0.64	−0.43	−1.34	−0.15*	−0.21
51	[ZCH 8 x (DB 533 x DB 534 F4 IPS 32)]	−282.53	0.09	0.00	3.03	4.16	0.28	−0.38	0.24	0.48	−2.55	−1.04	8.50**	0.50**	1.43
52	[ZCH 8 x (DB 533 x DB 534 F4 IPS 38)]	−197.94	4.84	0.37*	−1.70	−2.66	0.57	0.25	−2.75	1.3*	−0.28	1.25*	4.77**	0.02	0.62
53	[ZCH 8 x (DB 533 x DB 534 F4 IPS 48)]	204.94	−19.19	0.01	0.41	−3.70	−0.17	−0.67	−7.07	−0.39	0.11	−0.14	−0.44	−0.22**	−0.49
54	[ZCH 8 x (DB 533 x DB 534 F4 IPS 13)]	30.65	14.18	−0.06	2.18	7.12	0.54	0.75*	6.74	−0.98	−1.15	−0.36	5.50**	0.41**	1.63
55	[ZCH 8 x (DB 533 x DB 534 F4 IPS 6)]	−110.07	−6.20	0.50**	−1.68	−8.96	0.02	0.48	2.33	2.18**	−0.30	0.35	0.44	−0.15*	0.3

Continued Table 4

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol CO_2 m^{-2} s^{-1})	Stomatal condu ctance ((μmol m^{-2} s^{-1})	Transpiration rate (mmol H_2Om^{-2} s^{-1})
56	[ZCH 8 x (DB 533 x DB 534 F4 IPS 8)]	−125.52	11.21	−0.45**	−0.91	5.54	−0.40	−0.56	−2.00	−0.82	1.34	0.15	−5.5**	−0.04	−1.44
57	[178−24 x (DB 533 x DB 534 F4 IPS 44)]	175.77	−15.11	0.26	−0.84	5.71	−0.09	−0.26	−3.63	0.78	2.97	1.23*	5.86**	0.05	1.02
58	[178−24 x (DB 533 x DB 534 F4 IPS 62)]	−162.64	3.77	−0.12	−0.07	−4.80	−0.08	0.09	−1.16	−0.62	−0.37	−1.31*	2.32	0.05	0.87
59	[178−24 x (DB 533 x DB 534 F4 IPS 105)]	210.34	6.71	−0.28	0.24	−7.21	0.20	0.06	1.35	−0.01	−2.00	0.46	−3.72*	0.04	−1.27
60	[178−24 x (DB 533 x DB 534 F4 IPS 26)]	−223.47	4.63	0.14	0.67	6.30	−0.02	0.10	3.44	−0.15	−0.60	−0.39	−4.46*	−0.14	−0.62
61	[178−24 x (DB 533 x DB 534 F4 IPS 71)]	−52.56	−15.90	0.11	1.12	2.34	0.43	−1.14**	−3.92	0.10	−1.62	−0.20	0.56	0.08	1.72*
62	[178−24 x (DB 533 x DB 534 F4 IPS 30)]	−292.50	−13.86	−0.38*	−3.11	−8.51	−0.01	−0.06	−4.20	0.79	0.20	0.93	−2.36	−0.14	−2.37**
63	[178−24 x (DB 533 x DB 534 F4 IPS 25)]	63.81	22.75*	0.27	1.70	0.91	−0.38	1.33**	8.39	−1.49*	1.25	−0.39	1.37	−0.12	−0.32
64	[178−24 x (DB 533 x DB 534 F4 IPS 49)]	281.25	7.00	0.00	0.30	5.26	−0.05	−0.13	−0.27	0.60	0.18	−0.34	0.43	0.18*	0.98
65	[178−24 x (DB 533 x DB 534 F4 IPS 23)]	−26.25	−4.11	0.41*	−1.38	−0.32	−0.12	1.09**	2.37	−0.86	2.10	0.00	1.49	−0.08	−0.93
66	[178−24 x (DB 533 x DB 534 F4 IPS 36)]	−103.12	3.77	−0.22	1.22	−1.01	−0.01	−0.72*	−3.32	1.99**	−0.87	0.70	9.21**	0.19*	0.45
67	[178−24 x (DB 533 x DB 534 F4 IPS 15)]	64.07	−2.45	−0.31	−3.14	−6.59	0.47	−0.50	−2.90	−0.61	−1.07	−0.22	−11.53**	−0.28**	−1.26
68	[178−24 x (DB 533 x DB 534 F4 IPS 1)]	65.30	2.79	0.13	3.30	7.92	−0.35	0.13	3.86	−0.52	−0.16	−0.48	0.84	0.16*	1.74**
69	[178−24 x (DB 533 x DB 534 F4 IPS 33)]	−390.43	23.06*	−0.09	0.66	−6.87	−0.68	−0.07	−0.31	1.71*	0.65	0.16	2.22	0.24**	0.20
70	[178−24 x (DB 533 x DB 534 F4 IPS 24)]	−262.54	−2.73	−0.14	−1.24	−7.72	0.58	0.63	2.15	1.24*	−0.94	−0.17	5.78**	−0.08	0.61
71	[178−24 x (DB 533 x DB 534 F4 IPS 16)]	333.95	−6.62	0.35*	−1.43	8.70	−0.29	−0.40	−1.17	−1.14	−1.34	−1.12*	−10.91**	−0.45**	−2.26**
72	[178−24 x (DB 533 x DB 534 F4 IPS 52)]	319.02	−13.71	−0.13	2.01	5.88	0.39	−0.17	−0.67	−1.81**	1.63	1.13*	2.91	0.28**	1.45
73	[178−24 x (DB 533 x DB 534 F4 IPS 12)]	−191.28	12.35	−0.08	−0.71	−7.16	−0.03	1.56**	5.44	0.60	−1.92	0.26	4.61**	−0.25**	−1.89*
74	[178−24 x (DB 534 x DB 533 F4 IPS 22)]	302.35	−17.44	0.31	0.72	−0.01	−0.52	−0.30	0.16	−0.37	4.11	0.92	−0.95	0.19*	1.08
75	[178−24 x (DB 533 x DB 534 F4 IPS 14)]	−69.70	−1.66	−0.21	−1.80	3.24	0.01	−0.9**	−2.93	−1.02	1.36	0.02	−5.54**	−0.02	1.09
76	[178−24 x (DB 533 x DB 534 F4 IPS 34)]	−41.37	6.75	−0.02	1.80	3.92	0.54	−0.36	−2.66	0.79	−3.55	−1.2*	1.88	0.08	−0.27
77	[178−24 x (DB 533 x DB 534 F4 IPS 55)]	255.48	−14.49	−0.58**	−3.17	1.21	0.02	−0.67	−0.13	0.35	1.08	−0.35	−0.64	−0.17*	−0.32
78	[178−24 x (DB 533 x DB 534 F4 IPS 17)]	356.80	0.06	0.21	1.93	13.87*	0.48	−0.07	1.10	0.21	1.23	0.83	1.24	0.12	1.41
79	[178−24 x (DB 533 x DB 534 F4 IPS 32)]	−365.36	−0.83	−0.12	0.90	−7.38	−0.54	−0.26	−0.99	−1.93**	0.66	−0.68	−2.23	−0.25**	−3.33**
80	[178−24 x (DB 533 x DB 534 F4 IPS 38)]	−246.91	15.25	0.50**	0.34	−7.70	0.04	1.00**	0.02	1.37*	−2.97	0.20	1.63	0.30**	2.25**
81	[178−24 x (DB 533 x DB 534 F4 IPS 48)]	184.24	−22.61*	−0.03	−4.55*	0.05	0.22	−0.76*	−4.69	0.17	0.31	0.17	4.35*	0.13	0.83
82	[178−24 x (DB 533 x DB 534 F4 IPS 13)]	38.60	9.60	0.26	2.89	4.37	−0.37	−0.08	1.11	1.55*	0.77	0.68	−0.58	−0.06	0.32
83	[178−24 x (DB 533 x DB 534 F4 IPS 6)]	−94.84	−0.29	−0.59**	0.69	−3.21	0.31	0.23	−5.88	−1.25*	−0.53	−0.32	−1.29	0.05	−0.61

Continued Table 4

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol CO_2 m^{-2} s^{-1})	Stomatal condu ctance ((μmol m^{-2} s^{-1})	Transpiration rate (mmol H_2Om^{-2} s^{-1})
84	[178−24 x (DB 533 x DB 534 F4 IPS 8)]	−127.99	13.30	0.35*	0.96	−1.21	−0.16	0.60	9.46*	−0.47	−0.54	−0.52	−2.48	−0.11	−0.53
85	[DH 18−31 x (DB 533 x DB 534 F4 IPS 44)]	128.75	17.52	0.22	2.08	−0.75	−0.64	0.38	0.87	0.40	0.12	−0.78	−0.19	−0.03	0.12
86	[DH 18−31 x (DB 533 x DB 534 F4 IPS 62)]	−194.03	−10.28	−0.32	−1.99	−4.92	0.27	−0.35	−1.66	0.36	−1.61	0.80	−0.56	0.20**	0.12
87	[DH 18−31 x (DB 533 x DB 534 F4 IPS 105)]	175.30	1.17	0.17	−0.18	3.83	0.65	0.06	−0.57	−1.52*	2.67	−0.15	1.88	−0.03	0.83
88	[DH 18−31 x (DB 533 x DB 534 F4 IPS 26)]	−110.02	−8.41	−0.07	0.09	1.84	−0.27	−0.09	1.35	0.76	−1.18	0.13	−1.13	−0.14	−1.07
89	[DH 18−31 x (DB 533 x DB 534 F4 IPS 71)]	56.72	2.06	−0.11	4.00	−6.46	0.18	−0.55	−0.82	1.06	0.28	−0.69	2.67	0.1	0.90
90	[DH 18−31 x (DB 533 x DB 534 F4 IPS 30)]	−224.38	−9.90	0.01	−3.07	0.71	0.39	−0.12	0.56	0.26	−1.25	0.02	−8.16**	−0.12	−1.41
91	[DH 18−31 x (DB 533 x DB 534 F4 IPS 25)]	26.69	3.05	0.33*	0.24	7.95	0.02	0.27	1.93	0.93	−0.45	1.00	4.27*	0.04	0.53
92	[DH 18−31 x (DB 533 x DB 534 F4 IPS 49)]	140.97	4.80	−0.23	−1.16	−2.20	−0.60	0.40	−1.67	−2.25**	1.42	−0.33	1.22	−0.01	−0.02
93	[DH 18−31 x (DB 533 x DB 534 F4 IPS 23)]	16.86	−9.03	0.32	−0.92	−3.53	−0.07	−0.24	−4.60	0.45	0.06	0.51	2.25	0.36**	1.63
94	[DH 18−31 x (DB 533 x DB 534 F4 IPS 36)]	−111.58	24.02*	−0.45**	0.84	−1.22	0.29	−0.08	4.76	1.14	2.30	0.32	3.98*	−0.13	0.84
95	[DH 18−31 x (DB 533 x DB 534 F4 IPS 15)]	63.94	−3.87	0.15	3.32	10.54	−0.18	0.31	3.37	−1.06	−0.81	−0.84	−4.06*	0.02	−0.47
96	[DH 18−31 x (DB 533 x DB 534 F4 IPS 1)]	30.78	−11.12	−0.02	−3.24	−5.79	−0.05	0.02	−3.54	−0.53	−1.55	0.01	−2.17	−0.25**	−2.00**
97	[DH 18−31 x (DB 533 x DB 534 F4 IPS 33)]	−208.73	8.64	−0.28	0.83	−12.12	0.22	0.68*	3.29	0.85	−0.39	−0.43	−1.52	0.11	0.93
98	[DH 18−31 x (DB 533 x DB 534 F4 IPS 24)]	−204.84	3.68	0.01	−0.23	8.20	−0.17	0.69*	4.18	0.30	−0.31	−0.37	0.34	−0.07	−0.38
99	[DH 18−31 x (DB 533 x DB 534 F4 IPS 16)]	203.57	−10.54	0.17	−1.60	−2.72	−0.09	−1**	−6.24	−0.70	−0.09	0.16	−1.34	−0.05	−0.18
100	[DH 18−31 x (DB 533 x DB 534 F4 IPS 52)]	210.00	−1.78	0.10	1.00	6.63	0.04	−0.37	−1.23	−0.44	0.79	0.64	2.51	0.01	−0.38
101	[DH 18−31 x (DB 533 x DB 534 F4 IPS 12)]	−111.83	−14.65	0.25	−0.42	1.88	0.36	−0.15	−2.23	1.77**	−1.59	0.02	0.42	0.04	−0.09
102	[DH 18−31 x (DB 534 x DB 533 F4 IPS 22)]	245.30	6.56	0.22	0.35	6.54	0.32	−0.05	4.40	−0.42	−2.92	−0.39	−0.32	−0.02	0.42
103	[DH 18−31 x (DB 533 x DB 534 F4 IPS 14)]	−69.44	−3.50	−0.46**	0.82	−3.05	−0.35	−0.17	−1.42	−1.81**	2.23	−0.17	2.82	0.08	0.86
104	[DH 18−31 x (DB 533 x DB 534 F4 IPS 34)]	−64.04	11.59	−0.02	−0.75	−5.37	−0.32	0.37	−0.75	0.46	2.28	0.54	−2.91	−0.09	−1.19
105	[DH 18−31 x (DB 533 x DB 534 F4 IPS 55)]	185.14	4.89	−0.17	2.16	−2.16	0.38	0.19	4.85	0.58	−0.95	0.96	3.95*	0.01	0.54
106	[DH 18−31 x (DB 533 x DB 534 F4 IPS 17)]	289.59	2.10	0.00	−0.24	3.50	−0.56	0.51	0.41	−0.17	2.38	−0.29	−1.25	0.03	−0.26
107	[DH 18−31 x (DB 533 x DB 534 F4 IPS 32)]	−279.40	−4.45	−0.04	0.57	−2.76	−0.28	−0.84*	−5.34	0.32	0.31	−0.54	−1.56	0.07	0.59
108	[DH 18−31 x (DB 533 x DB 534 F4 IPS 38)]	−195.33	−2.54	0.21	−2.50	1.42	0.45	0.14	0.09	−0.73	−1.75	−0.13	−1.14	−0.11	−0.87
109	[DH 18−31 x (DB 533 x DB 534 F4 IPS 48)]	138.13	3.22	−0.28	1.58	−1.46	−0.08	−0.7*	0.31	−0.01	−0.19	−0.58	−0.16	0.22**	0.62
110	[DH 18−31 x (DB 533 x DB 534 F4 IPS 13)]	50.32	−1.40	0.16	−1.65	−1.63	0.03	−0.26	−0.72	0.81	−0.56	0.83	2.26	−0.16*	−0.85
111	[DH 18−31 x (DB 533 x DB 534 F4 IPS 6)]	−85.20	8.38	−0.19	1.49	7.79	−0.04	1.21**	4.53	0.12	0.06	0.11	0.87	−0.1	0.10
112	[DH 18−31 x (DB 533 x DB 534 F4 IPS 8)]	−103.25	−10.20	0.30	−1.41	−4.70	0.09	−0.25	−4.12	−0.92	0.70	−0.35	−2.97	0.04	0.13
	SEd	259.18	10.35	0.17	2.16	6.21	0.36	0.34	4.41	0.60	2.13	0.53	1.72	0.07	0.83
	CD at 5%	756.81	30.25	0.48	5.74	17.71	1.04	0.97	12.86	1.85	6.10	1.59	4.55	0.13	1.53
	CD at 1%	996.21	39.82	0.63	7.56	23.31	1.36	1.27	16.93	2.44	8.03	2.09	5.99	0.18	2.01

Note: * Significant at P = 0.05 ** Significant at P = 0.01

Table 5 Pooled scores of F_4 barbadense lines and hirsutum testers based on Simple pooled *gca* score

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol $CO_2 m^{-2} s^{-1}$)	Stomatal conductance ((μmol $m^{-2} s^{-1}$)	Transpiration rate (mmol $H_2O m^{-2} s^{-1}$)	Pooled gca
	Males	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	DB 533 x DB 534 F4 IPS 44	0	0	0	0	−1	0	0	0	−1	0	0	0	0	−1	−3
2	DB 533 x DB 534 F4 IPS 62	0	0	0	0	1	0	−1	0	1	0	0	0	0	0	1
3	DB 533 x DB 534 F4 IPS 105	0	0	1	0	0	0	0	0	0	0	0	−1	−1	0	−1
4	DB 533 x DB 534 F4 IPS 26	0	0	1	0	0	0	0	0	1	0	0	1	1	0	4
5	DB 533 x DB 534 F4 IPS 71	0	0	0	0	0	0	−1	0	0	0	0	−1	0	0	−2
6	DB 533 x DB 534 F4 IPS 30	0	1	0	0	0	−1	0	1	1	0	0	0	−1	−1	0
7	DB 533 x DB 534 F4 IPS 25	0	0	−1	0	0	0	−1	0	0	0	0	1	1	0	0
8	DB 533 x DB 534 F4 IPS 49	0	0	−1	0	0	0	1	0	0	−1	−1	−1	−1	0	−4
9	DB 533 x DB 534 F4 IPS 23	0	0	0	0	0	0	0	0	0	−1	0	−1	−1	−1	−4
10	DB 533 x DB 534 F4 IPS 36	−1	1	0	0	1	0	1	1	0	−1	0	−1	0	0	1
11	DB 533 x DB 534 F4 IPS 15	0	0	0	−1	0	0	1	0	−1	−1	−1	−1	−1	0	−5
12	DB 533 x DB 534 F4 IPS 1	0	1	0	0	1	0	−1	0	−1	0	0	−1	0	0	−1
13	DB 533 x DB 534 F4 IPS 33	0	0	0	0	0	0	1	0	0	0	−1	0	0	0	0
14	DB 533 x DB 534 F4 IPS 24	0	0	−1	0	1	0	0	0	0	0	−1	1	1	0	1
15	DB 533 x DB 534 F4 IPS 16	0	0	0	0	0	0	0	0	0	1	0	1	−1	0	1
16	DB 533 x DB 534 F4 IPS 52	0	0	0	0	0	1	−1	0	0	0	0	0	1	1	2
17	DB 533 x DB 534 F4 IPS 12	−1	−1	0	0	0	0	−1	0	0	0	0	−1	−1	0	−5
18	DB 534 x DB 533 F4 IPS 22	−1	0	0	0	0	0	−1	0	0	0	0	−1	0	0	−3
19	DB 533 x DB 534 F4 IPS 14	0	0	0	0	0	0	0	0	−1	0	0	−1	0	1	−1
20	DB 533 x DB 534 F4 IPS 34	0	0	0	0	0	0	0	0	0	0	−1	−1	−1	0	−3
21	DB 533 x DB 534 F4 IPS 55	0	0	0	0	0	0	−1	0	0	0	0	0	1	1	1
22	DB 533 x DB 534 F4 IPS 17	1	−1	0	0	0	0	0	0	0	1	1	1	1	0	4
23	DB 533 x DB 534 F4 IPS 32	1	0	−1	0	−1	0	0	0	1	0	1	1	0	0	2
24	DB 533 x DB 534 F4 IPS 38	0	0	0	0	−1	0	1	0	0	0	0	0	1	0	1
25	DB 533 x DB 534 F4 IPS 48	0	0	1	0	0	0	0	0	0	0	1	1	0	0	3
26	DB 533 x DB 534 F4 IPS 13	1	0	1	0	−1	0	0	0	0	0	0	1	0	0	2
27	DB 533 x DB 534 F4 IPS 6	1	0	−1	0	1	0	0	0	0	0	0	1	0	0	2
28	DB 533 x DB 534 F4 IPS 8	1	0	0	0	0	0	0	0	0	0	0	1	1	0	3
	Females															
1	DH 98−27	1	0	0	0	1	0	0	0	0	0	0	0	0	0	2
2	ZCH 8	0	0	0	0	0	1	−1	0	0	0	−1	0	1	0	0
3	178−24	−1	0	0	0	−1	−1	0	0	1	0	1	−1	−1	−1	−4
4	DH 18−31	0	0	1	0	1	0	0	0	−1	0	0	1	1	1	4

Table 6 Pooled scores of F_4 barbadense lines and hirsutum testers based on Per cent pooled *gca* score

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol $CO_2 m^{-2} s^{-1}$)	Stomatal conductance ((μmol $m^{-2} s^{-1}$)	Transpiration rate (mmol $H_2O m^{-2} s^{-1}$)	Pooled gca
	Males	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	DB 533 x DB 534 F4 IPS 44	6.30	0.04	−4.52	−0.94	−8.25	−2.90	1.14	10.62	−6.04	5.31	−11.28	4.02	4.84	−17.92	−19.58
2	DB 533 x DB 534 F4 IPS 62	11.19	−5.07	2.82	2.02	7.24	−6.77	−12.82	−11.82	8.22	−2.82	8.51	6.44	1.61	−9.12	−0.37
3	DB 533 x DB 534 F4 IPS 105	−3.71	−3.88	10.73	−4.03	−2.31	−5.81	3.42	−1.46	4.85	−3.66	−4.04	−30.78	−48.39	−3.75	−92.82
4	DB 533 x DB 534 F4 IPS 26	6.71	4.48	10.73	3.00	−3.65	−6.13	1.42	7.54	8.12	6.62	9.79	30.20	50.00	6.19	135.02
5	DB 533 x DB 534 F4 IPS 71	10.87	−8.83	1.69	3.00	4.36	1.29	−16.52	−9.14	−2.18	0.27	−0.64	−7.18	3.23	−4.23	−24.01
6	DB 533 x DB 534 F4 IPS 30	3.68	9.74	−1.69	−3.47	−0.41	−15.16	8.26	17.52	12.87	2.59	11.06	−3.24	−20.97	−16.78	4
7	DB 533 x DB 534 F4 IPS 25	6.03	−1.04	−11.86	3.19	4.54	−2.58	−23.36	−6.78	−5.15	1.75	6.81	16.09	32.26	2.61	22.51
8	DB 533 x DB 534 F4 IPS 49	−10.63	5.52	−9.60	3.19	−4.28	4.52	20.80	9.84	0.20	−8.50	−11.91	−14.20	−14.52	−7.49	−37.06
9	DB 533 x DB 534 F4 IPS 23	−7.39	0.26	1.69	−0.33	5.44	6.77	5.41	1.89	−3.76	−8.09	−11.06	−31.14	−46.77	−16.94	−104.02
10	DB 533 x DB 534 F4 IPS 36	−16.21	12.79	1.13	2.81	10.39	1.29	17.66	14.55	1.78	−8.09	−5.53	−14.49	−6.45	5.21	16.84
11	DB 533 x DB 534 F4 IPS 15	−12.16	4.66	0.00	−11.07	2.12	0.97	26.50	8.56	−8.22	−12.76	−18.51	−16.74	−14.52	−4.40	−55.57
12	DB 533 x DB 534 F4 IPS 1	−7.27	9.51	6.78	2.81	7.24	10.00	−13.68	−0.55	−8.32	−0.60	−9.57	−11.94	−4.84	4.89	−15.54
13	DB 533 x DB 534 F4 IPS 33	−11.82	−0.78	7.34	0.23	0.84	3.87	23.65	9.90	−1.49	−4.40	−12.98	0.37	1.61	−5.37	10.97
14	DB 533 x DB 534 F4 IPS 24	−9.16	3.36	−12.99	5.16	11.92	−2.26	−7.69	−3.93	−0.30	−3.96	−11.28	10.46	16.13	2.61	−1.93
15	DB 533 x DB 534 F4 IPS 16	−9.18	−3.43	−7.91	0.05	2.03	−6.13	1.71	−7.39	1.29	9.84	7.23	8.41	−19.35	0.33	−22.5
16	DB 533 x DB 534 F4 IPS 52	−6.57	5.04	−2.26	8.07	−3.65	12.26	−12.82	−7.74	−4.06	5.54	8.09	6.65	14.52	14.82	37.89
17	DB 533 x DB 534 F4 IPS 12	−14.88	−13.87	2.26	−9.15	0.67	5.81	−20.23	−12.49	−2.77	5.54	3.19	−14.32	−30.65	−10.75	−111.64
18	DB 534 x DB 533 F4 IPS 22	−17.68	1.34	2.26	−0.75	1.12	−1.94	−11.11	−8.29	0.79	−1.78	−3.19	−14.65	−1.61	0.16	−55.33
19	DB 533 x DB 534 F4 IPS 14	−5.66	8.09	−3.95	3.38	−3.65	1.29	3.13	7.95	−8.51	−2.18	−9.57	−11.37	6.45	14.33	−0.27
20	DB 533 x DB 534 F4 IPS 34	−12.22	6.75	1.69	2.39	−3.39	−3.55	−3.13	0.61	3.86	−5.67	−12.34	−13.38	−11.29	−2.93	−52.6
21	DB 533 x DB 534 F4 IPS 55	−4.40	0.30	8.47	−0.52	5.98	6.13	−19.66	2.50	−5.84	−0.67	0.21	2.01	29.03	32.25	55.79
22	DB 533 x DB 534 F4 IPS 17	15.88	−10.10	−5.65	−2.67	−6.35	1.94	−6.84	−10.07	1.68	9.23	28.51	21.38	16.13	3.75	56.82
23	DB 533 x DB 534 F4 IPS 32	16.34	−5.82	−15.25	−1.50	−7.34	5.81	2.85	−7.57	11.58	2.22	11.91	11.41	−1.61	−6.84	16.19
24	DB 533 x DB 534 F4 IPS 38	10.82	−2.76	1.13	2.02	−9.33	−3.87	20.80	7.07	3.96	−0.64	11.06	6.61	12.90	−4.72	55.05
25	DB 533 x DB 534 F4 IPS 48	11.51	−5.74	22.60	3.19	−2.31	−10.00	−3.70	−9.81	−1.88	3.26	15.96	14.73	0.00	9.61	47.42
26	DB 533 x DB 534 F4 IPS 13	17.84	−5.18	10.17	−5.82	−10.59	3.55	−1.14	−4.66	4.06	2.38	−3.40	17.19	0.00	2.93	27.33
27	DB 533 x DB 534 F4 IPS 6	13.22	2.09	−11.86	−3.85	7.86	−0.65	8.55	8.44	−2.77	4.77	−2.34	12.60	0.00	1.79	37.85
28	DB 533 x DB 534 F4 IPS 8	18.54	−7.46	−5.08	−0.33	−6.26	1.29	7.12	−5.27	−2.08	4.57	5.32	14.81	32.26	9.61	67.04
	Females															
1	DH 98−27	4.83	0.47	−2.82	0.61	2.96	−0.32	2.56	1.72	1.39	−1.61	0.85	−2.17	−3.23	−3.09	2.15
2	ZCH 8	−2.69	1.32	−0.56	−0.66	−0.97	0.97	−4.84	−1.11	−0.50	0.50	−5.74	1.48	4.84	3.26	−4.7
3	178−24	−3.95	−2.35	0.00	−1.31	−4.04	−1.61	2.85	−0.64	3.37	1.91	4.47	−5.33	−11.29	−9.12	−27.04
4	DH 18−31	1.81	0.55	3.39	1.36	2.05	0.65	−0.57	0.06	−4.26	−0.81	0.43	6.03	8.06	8.96	27.71
	F1 Mean	1958.45	111.73	1.77	21.32	46.29	3.10	3.51	34.36	10.10	29.78	4.70	24.37	0.62	6.14	

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Table 7 Pooled scores of F_4 barbadense lines and hirsutum testers based on weighted percent *gca* method

Sl.No	Parents	Seed cotton yield (kg/ha)	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	Mean boll weight (g)	Reproductive Points on sympodia	Length of sympodia at 50 % height (cm)	Seed index (g)	Ginning outturn (%)	Lint index (g)	Photosynthetic rate (μmol $CO_2 m^{-2} s^{-1}$)	Stomatal conductance (μmol $m^{-2} s^{-1}$)	Transpiration rate (mmol $H_2O m^{-2} s^{-1}$)	Pooled gca
	Males	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	DB 533 x DB 534 F4 IPS 44	63	0.08	−9.04	−2.82	−45.375	−20.3	2.28	26.55	−24.16	29.205	−73.32	16.08	14.52	−17.92	−41.22
2	DB 533 x DB 534 F4 IPS 62	111.9	−10.14	5.64	6.06	39.82	−47.39	−25.64	−29.55	32.88	−15.51	55.315	25.76	4.83	−9.12	144.855
3	DB 533 x DB 534 F4 IPS 105	−37.1	−7.76	21.46	−12.09	−12.705	−40.67	6.84	−3.65	19.4	−20.13	−26.26	−123.12	−145.17	−3.75	−384.705
4	DB 533 x DB 534 F4 IPS 26	67.1	8.96	21.46	9	−20.075	−42.91	2.84	18.85	32.48	36.41	63.635	120.8	150	6.19	474.74
5	DB 533 x DB 534 F4 IPS 71	108.7	−17.66	3.38	9	23.98	9.03	−33.04	−22.85	−8.72	1.485	−4.16	−28.72	9.69	−4.23	45.885
6	DB 533 x DB 534 F4 IPS 30	36.8	19.48	−3.38	−10.41	−2.255	−106.12	16.52	43.8	51.48	14.245	71.89	−12.96	−62.91	−16.78	39.4
7	DB 533 x DB 534 F4 IPS 25	60.3	−2.08	−23.72	9.57	24.97	−18.06	−46.72	−16.95	−20.6	9.625	44.265	64.36	96.78	2.61	184.35
8	DB 533 x DB 534 F4 IPS 49	−106.3	11.04	−19.2	9.57	−23.54	31.64	41.6	24.6	0.8	−46.75	−77.415	−56.8	−43.56	−7.49	−261.805
9	DB 533 x DB 534 F4 IPS 23	−73.9	0.52	3.38	−0.99	29.92	47.39	10.82	4.725	−15.04	−44.495	−71.89	−124.56	−140.31	−16.94	−391.37
10	DB 533 x DB 534 F4 IPS 36	−162.1	25.58	2.26	8.43	57.145	9.03	35.32	36.375	7.12	−44.495	−35.945	−57.96	−19.35	5.21	−133.38
11	DB 533 x DB 534 F4 IPS 15	−121.6	9.32	0	−33.21	11.66	6.79	53	21.4	−32.88	−70.18	−120.315	−66.96	−43.56	−4.4	−390.935
12	DB 533 x DB 534 F4 IPS 1	−72.7	19.02	13.56	8.43	39.82	70	−27.36	−1.375	−33.28	−3.3	−62.205	−47.76	−14.52	4.89	−106.78
13	DB 533 x DB 534 F4 IPS 33	−118.2	−1.56	14.68	0.69	4.62	27.09	47.3	24.75	−5.96	−24.2	−84.37	1.48	4.83	−5.37	−114.22
14	DB 533 x DB 534 F4 IPS 24	−91.6	6.72	−25.98	15.48	65.56	−15.82	−15.38	−9.825	−1.2	−21.78	−73.32	41.84	48.39	2.61	−74.305
15	DB 533 x DB 534 F4 IPS 16	−91.8	−6.86	−15.82	0.15	11.165	−42.91	3.42	−18.475	5.16	54.12	46.995	33.64	−58.05	0.33	−78.935
16	DB 533 x DB 534 F4 IPS 52	−65.7	10.08	−4.52	24.21	−20.075	85.82	−25.64	−19.35	−16.24	30.47	52.585	26.6	43.56	14.82	136.62
17	DB 533 x DB 534 F4 IPS 12	−148.8	−27.74	4.52	−27.45	3.685	40.67	−40.46	−31.225	−11.08	30.47	20.735	−57.28	−91.95	−10.75	−346.655
18	DB 534 x DB 533 F4 IPS 22	−176.8	2.68	4.52	−2.25	6.16	−13.58	−22.22	−20.725	3.16	−9.79	−20.735	−58.6	−4.83	0.16	−312.85
19	DB 533 x DB 534 F4 IPS 14	−56.6	16.18	−7.9	10.14	−20.075	9.03	6.26	19.875	−34.04	−11.99	−62.205	−45.48	19.35	14.33	−143.125
20	DB 533 x DB 534 F4 IPS 34	−122.2	13.5	3.38	7.17	−18.645	−24.85	−6.26	1.525	15.44	−31.185	−80.21	−53.52	−33.87	−2.93	−332.655
21	DB 533 x DB 534 F4 IPS 55	−44	0.6	16.94	−1.56	32.89	42.91	−39.32	6.25	−23.36	−3.685	1.365	8.04	87.09	32.25	116.41
22	DB 533 x DB 534 F4 IPS 17	158.8	−20.2	−11.3	−8.01	−34.925	13.58	−13.68	−25.175	6.72	50.765	185.315	85.52	48.39	3.75	439.55
23	DB 533 x DB 534 F4 IPS 32	163.4	−11.64	−30.5	−4.5	−40.37	40.67	5.7	−18.925	46.32	12.21	77.415	45.64	−4.83	−6.84	273.75
24	DB 533 x DB 534 F4 IPS 38	108.2	−5.52	2.26	6.06	−51.315	−27.09	41.6	17.675	15.84	−3.52	71.89	26.44	38.7	−4.72	236.5
25	DB 533 x DB 534 F4 IPS 48	115.1	−11.48	45.2	9.57	−12.705	−70	−7.4	−24.525	−7.52	17.93	103.74	58.92	0	9.61	226.44
26	DB 533 x DB 534 F4 IPS 13	178.4	−10.36	20.34	−17.46	−58.245	24.85	−2.28	−11.65	16.24	13.09	−22.1	68.76	0	2.93	202.515
27	DB 533 x DB 534 F4 IPS 6	132.2	4.18	−23.72	−11.55	43.23	−4.55	17.1	21.1	−11.08	26.235	−15.21	50.4	0	1.79	230.125
28	DB 533 x DB 534 F4 IPS 8	185.4	−14.92	−10.16	−0.99	−34.43	9.03	14.24	−13.175	−8.32	25.135	34.58	59.24	96.78	9.61	352.02
	Females	48.3	0.94	−5.64	1.83	16.28	−2.24	5.12	4.3	5.56	−8.855	5.525				
1	DH 98−27	−26.9	2.64	−1.12	−1.98	−5.335	6.79	−9.68	−2.775	−2	2.75	−37.31	−8.68	−9.69	−3.09	−96.38
2	ZCH 8	−39.5	−4.7	0	−3.93	−22.22	−11.27	5.7	−1.6	13.48	10.505	29.055	5.92	14.52	3.26	−0.78
3	178−24	18.1	1.1	6.78	4.08	11.275	4.55	−1.14	0.15	−17.04	−4.455	2.795	−21.32	−33.87	−9.12	−38.115
4	DH 18−31	48.3	0.94	−5.64	1.83	16.28	−2.24	5.12	4.3	5.56	−8.855	5.525	24.12	24.18	8.96	128.38
	Weightage	10.00	2.00	2.00	3.00	5.50	7.00	2.00	2.50	4.00	5.50	6.50	4.00	3.00	1.00	