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Combining Ability and Gene Action Studies for Yield and its Component Traits Over Different Environments in Cotton (*G. hirsutum* L.)

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ABSTRACT: To evaluate combing ability in cotton, twenty-eight hybrids were produced by half-diallel crossings between eight different parents. The results of combining ability studies' analysis of variance showed that the expression of seed cotton yield/plant (g) and its contributing traits was influenced by both additive and non-additive gene actions. The ratio of gca/sca for the pooled locations shows that all the traits, with the exception of day to 50% flowering and day to first picking at Surat and Bharuch, and plant height (cm) at Surat, were determined by non-additive gene action. This suggests that selection and hybridization would be an effective way to achieve desired improvements in seed cotton yield/plant and related traits, such as bolls/plant, boll weight, etc. The results of the GCA effect indicated that GN Cot 26 (5.54) and GBHV 200 (3.11) at Navsari, GN Cot 26 (4.70) and GSHV 242 (3.18) at Surat, and GBHV 200 (4.14) at Bharuch were the best combiners for seed cotton yield/plant among the eight parents. When combined over locations, GN Cot 26 (3.81) and GBHV 200 (2.43) performed well as general combiners.

Keywords: Combing ability, GCA, SCA, Half diallel, Seed Cotton Yield.

INTRODUCTION

Cotton, the king of fibers, noted for its desirable properties, is also known as "White Gold" due to its broad usage in agriculture, the industrial economy, and its high commercial value, which provides income to millions of farmers worldwide. The technological and agricultural term in English is Cotton, which describes cultivated species of *Gossypium*, comes from the Arabic word *qutum* or *kutum* (Brown and Ware 1958). Cotton, genus *Gossypium*, belongs to the Malvaceae family and comprises of approximately 50 identified dicotyledonous species, four of which are cultivated for their spinnable fiber and the remaining 46 of which are wild species. Among the four cultivated species, *G. arboreum* and *G. herbaceum*, are diploids (2n=26), while *G. hirsutum* and *G. barbadense* are tetraploids (2n=52), respectively.

In cotton, parents should be chosen for a good hybridization program based on their combining ability impacts in addition to their diversity. Selecting desirable parents for the purpose of exploiting hybridity and transgressive expressions requires knowledge of combining ability. Combining ability studies also give idea about the nature and magnitude of gene action involved in the inheritance of seed cotton yield and its related traits. The knowledge of nature of gene action governing the expression of various traits could be helpful in predicting the effectiveness of selection. Formulating an efficient and sound breeding program will be made easier by the effective division of genetic variance into its component parts, namely additive, dominance, and epistasis (Singh and Chaudhary 2004).

Finding the ideal pairing of two or more parental genotypes to maximize variance within related breeding populations is necessary in order to identify superior transgressive segregants in the segregating populations of any hybridization program (Singh and Chaudhary 2004).Sprague and Tatum defined GCA as the average performance of a genotype in a series of hybrid combinations. They defined SCA as those cases in which certain hybrid combinations perform better or poorer than would be expected on the basis of the average performance of the parental inbred lines. Higher GCA showing better average combining ability in crosses while if their capacity to combine in particular cross, they are regarded as good SCA. Therefore, in order to identify a better combination of parents, combining analysis must be performed.

MATERIALS AND METHODS

The experimental materials use for present investigation including 28 hybrids developed by 8×8 half diallel design, 8 parents and one check. The current experiment involved crossing at the Agronomy Farm on the Navsari campus in Rabi 2020-21. The hybrids and their parents were assessed in *Kharif* 2021-22 at three different Navsari Agricultural University locations: College Farm, N. M. College of Agriculture, Navsari (L1), Main Cotton Research Station, Surat (L2), and Regional Cotton Research Station, Bharuch (L3). For crossing, eight parents-GN Cot 22, G Cot 10, G Cot 16, GN Cot 26, GBHV 200, GSHV 242, GISV 361, and GBHV 253-were utilized. The G.Cot.Hy-8 was utilized as a check and comparison.

The complete set of 37 genotypes comprising of 28 F_1, 8 parents including check were evaluated in a Randomized Block Design (RBD) with three replications over three different locations during *Kharif* 2021-22. Each entry was sown in a single row having 12 plants keeping row-to-row and plant-to-plant distance of 120 cm and 45 cm, respectively. The recommended package of practices and plant protection measures were followed to raise the healthy crop. Five randomly chosen plants from each entry in each replication across the locations had the following observations made on them: days to 50% flowering, days to first picking, plant height (cm), monopodia/plant, sympodia/plant, bolls/plant, boll weight (g), seed cotton yield/plant (g), lint yield (%), and gining outturn (%).

RESULTS AND DISCUSSION

The analysis of variance for combining ability, using diallel mating design in respect of eight parents and twenty-eight hybrids for all the ten traits in individual location and pooled over locations (pooled basis) is presented in Table 1-4**.** All traits examined during the experimental program at all three individual locations as well as when pooled over locations showed significant analysis of variance for GCA, with the exception of days to 50% flowering and sympodia/plant at Navsari (L1) and ginning outturn at Surat (L2). According to their GCA effects, parents can be categorized as good, average, or poor due to differences in their combining abilities. Significant result for GCA was also observed earlier by Karademir and Gencer (2010); Bilwal *et al*. (2018); Hafez *et al.* (2022).

With the exception of days to first picking at Bharuch (L3), SCA mean squares was likewise significant for all the attributes examined during the experimental program at each of the three individual locations as well as when pooled over locations. Additionally, significant findings for the SCA mean squares were previously noted by Hafez *et al.* (2022); Bilwal *et al.* (2018); Karademir and Gencer (2010). Consequences for combining abilities for environments at pooled ANOVA showed that environments (locations) had an impact on all of the attributes. The interactions between GCA and environments, as well as SCA and environments, were significant for all traits in the pooled ANOVA, and their size indicated the importance of both SCA and GCA variance. In a similar vein, the results agreed with Bilwal *et al.* (2018).

All the traits that were found to be significant for GCA and SCA at all three locations as well as pooled over locations (as seen above), explains that both additive and non-additive gene action were functioning. Similar findings were earlier reported by Karademir and Gencer (2010); Bilwal *et al*. (2018); Hafez *et al*. (2022). Therefore, in order to ascertain the predominant effect, the ratio σ^2 gca/ σ^2 SCA was computed for each trait. If the value of σ^2 gca/ σ^2 SCA is greater than unity, it suggests that additive gene action is important, and if it is less than unity, it indicates that non-additive gene action predominates in the control of trait.

The findings showed that non-additive gene activity was primarily responsible for regulating the traits at all three locations and for the pooled over locations, with the exception of plant height at Surat (L2) and Bharuch (L3), as well as day to 50% flowering and day to first picking at Surat (L2). This implied that in order to achieve the desired improvements in these traits, hybridization and selection would work well together. The comparable conclusion for yield and its contributing features was also established by Karademir and Gencer (2010); Bilwal *et al.* (2018); Hafez *et al.* (2022).

Estimation of general and specific combining ability effect. The estimation and interpretation of GCA effects and SCA effects and the results of GCA effects (g_i) and the SCA effects (s_{ij}) are presented trait-wise in Table 5-9.

Day to 50% flowering. A parent having significant and negative GCA effect while hybrid having significant and negative SCA effect for day to 50% flowering were considered as good general and good specific combiner respectively. Among the eight parents, at Surat, GN Cot 26 (-2.19) and GISV 361 (-2.06); at Bharuch, GBHV 253 (-2.00) and GISV 361 (-1.10) identified as best combiners for this trait. None of the parent manifested significant and desirable GCA effect at Navsari location. Pooled over locations, GISV 361 (-0.97) manifested as good general combiner while GN Cot 22 (1.79) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -4.98 (GBHV 200 X GSHV 242) to 3.76 (G Cot 10 X GSHV 242) at Navsari; from -2.79 (GBHV 200 X GSHV 242) to 1.91(G Cot 10 X GBHV 200) at Surat; while it was from -4.20 (GN Cot 22 X GN Cot 26) to 2.73 (GBHV 200 X GBHV 253) at Bharuch centre. Six, one and two hybrids had significant and desirable (negative) SCA effect for this trait at Navsari, Surat and Bharuch location respectively. Top three hybrids with significant and desirable (negative) SCAeffect at Navsari centre were GBHV 200 X GSHV 242 (-4.98) followed by GBHV 200 X GBHV 253 (-4.48) and G Cot 16 X GISV 361 (-4.28). At Surat location, GBHV 200 X GSHV 242 (-2.79), GN Cot 26 X GBHV 200 (-1.99) and G Cot 10 X GISV 361 (-1.66), GBHV 200 X GBHV 253 (-1.66) were the best three hybrids while at Bharuch, GN Cot

22 X GN Cot 26 (-4.20) followed by GN Cot 22 X GBHV 253 (-4.06) were top most hybrids with significant and desirable (negative) SCA effect.

Pooled over all the three locations *i.e*., over Navsari (L_1), Surat (L_2) and Bharuch (L_3) centres; SCA effect ranged from -2.80 (GBHV 200 X GSHV 242) to 2.63 (G Cot 16 X GBHV 253). Among 28 F_1s developed and evaluated, two and one hybrids registered significant and desirable (negative) as well as significant and undesirable (positive) SCA effect respectively. Top best hybrid with significant and desirable (negative) SCA effect were GBHV 200 X GSHV 242 (-2.80) followed by GN Cot 22 X GBHV 253 (-2.39).

Eswari *et al*. (2016); Monicashree *et al*. (2017); Vaghela *et al.* (2019) had reported significant negative and positive GCA as well as SCA effect for days to 50% flowering.

Days to first picking. A parent having significant and negative GCA effect while hybrid having significant and negative SCA effect for day to first picking were considered as good general and good specific combiners respectively. Among the 8 parents, at Surat, G Cot 16 (-1.63) and GISV 361 (-1.20); at Bharuch, GBHV 253 (-3.47) and GSHV 242 (-1.90) identified as best combiners for this trait. Pooled over locations, GSHV 242 (-1.11) manifested as good general combiner while GN Cot 22 (1.66) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -3.44 (GBHV 200 X GSHV 242) to 4.63 (GN Cot 22 X G Cot 16) at Navsari; from -3.72 (G Cot 16 X GBHV 200) to 2.55 (GSHV 242 X GBHV 253) at Surat; while it was from -5.59 (G Cot 10 X GN Cot 26) to 4.98 (GBHV 200 X GISV 361) at Bharuch centre. One, two and one hybrids had significant and desirable (negative) SCA effect for this trait at Navsari, Surat and Bharuch location respectively. Top best hybrid with significant and desirable (negative) SCA effect at Navsari centre was GBHV 200 X GSHV 242 (-3.44). At Surat location, G Cot 16 X GBHV 200 (-3.72) followed by G Cot 10 X GISV 361 (-3.62) were the best hybrids while at Bharuch, G Cot 10 X GN Cot 26 (-5.59) was significant and desirable (negative) SCA effect.

Pooled over location *i.e*., Navsari (L_1), Surat (L_2) and Bharuch (L_3) centres; SCA effect ranged from -2.16 (GSHV 242 X GISV 361) to 1.99 (GBHV 200 X GISV 361). Among 28 F_1s developed and evaluated, four and two hybrids registered significant and desirable (negative) as well as significant and undesirable (positive) SCA effect. Top three hybrids with significant and desirable (negative) SCAeffect, across all the three locations, were GSHV 242 X GISV 361 (-2.16), G Cot 10 X GN Cot 26 (-1.67) and G Cot 10 X GBHV 253 (-1.61).

Rauf *et al.* (2004); Basbag *et al.* (2007); Song Mei-zhen *et al.* (2012) had reported significant negative and positive GCA as well as SCA effect for days to first picking.

Plant height (cm). A parent having significant and positive GCA effect while hybrid having significant and positive SCA effect for plant height were considered as good general and good specific combiners respectively. Among the eight parents, at Navsari GN Cot 22 (5.82) and GBHV 200 (4.28); at Surat, GSHV 242 (11.46) and GN Cot 26 (6.79) identified as best combiners for this trait. Pooled over locations, GSHV 242 (3.02) manifested as good general combiner while GISV 361 (-3.64) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -19.76 (GN Cot 26 X GBHV 253) to 15.11 (G Cot 16 X GN Cot 26) at Navsari; from -17.37 (G Cot 10 X G Cot 16) to 21.53 (G Cot 16 X GBHV 200) at Surat; while it was from -34.49 (G Cot 16 X GBHV 253) to 28.94 (GISV 361 X GBHV 253) at Bharuch location. One, one and three hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch location respectively. Top best hybrids with significant and desirable (positive) SCA effect at Navsari centre was G Cot 16 X GN Cot 26 (15.11). At Surat location, G Cot 16 X GBHV 200 (21.53), G Cot 10 X GSHV 242 (15.30) and GBHV 200 X GISV 361(14.40) were the best three hybrids while at Bharuch, GISV 361 X GBHV 253 (28.94) followed by GN Cot 22 X GBHV 253 (18.61) and G Cot 10 X GBHV 200 (14.11) were the top most hybrids with significant and desirable (positive) SCAeffects.

Pooled over location *i.e*., over Navsari (L_1), Surat (L_2) and Bharuch (L_3); SCA effect ranged from -12.38 (G Cot 10 X GBHV 253) to 12.88 (G GISV 361 X GBHV 253). Among 28 F_1s developed and evaluated, none of the hybrid significant and desirable (positive) as well as significant and undesirable (negative) SCA effect.

Monicashree *et al*. (2017); Vekariya *et al.* (2017); Khokhar *et al.* (2018); Roy *et al.* (2018); Thiyagu *et al.* (2019); Kirthika *et al.* (2020); Richika *et al.* (2021); Abo Sen *et al.* (2022) had reported significant positive and negative GCA as well as SCA effect for plant height.

Monopodia/plant. A parent having significant and positive GCA effect while hybrid having significant and positive SCA effect for monopodia/plant is considered as good general and good specific combiners respectively. Among the eight parents, at Navsari, GBHV 200 (0.13) and G Cot 10 (0.10); at Surat, GN Cot 22 (0.10) while at Bharuch, G Cot 10 (0.13), G Cot 16 (0.13) and GN Cot 26 (0.12) identified as best combiner for this trait. Pooled over locations, GBHV 200 (0.07) manifested as good general combiner while G Cot 16 (-0.06) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -0.40 (GN Cot 22 X G Cot 16) to 0.31 (G Cot 10 X G Cot 16) at Navsari; from -0.81 (GSHV 242 X GISV 361) to 0.36 (GSHV 242 X GBHV 253) at Surat; while it was from -0.51 (G Cot 26 X GISV 361) to 0.37 (GBHV 200 X GISV 361) at Bharuch centre. Three, four and two hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch location respectively. Best hybrids with significant and desirable (positive) SCA effect at at Navsari centre were G Cot 10 X G Cot 16, GSHV 242 X GBHV 253 (0.31) and G Cot 16 X GBHV 200 (0.28). At Surat location, GSHV 242 X GBHV 253 (0.36) followed by G Cot 16 X GISV

361 (0.30) and GN Cot 22 X GISV 361, G Cot 10 X GISV 361 (0.28) were the best three hybrids while at Bharuch, GBHV 200 X GISV 361 (0.37) and G Cot 10 X GN Cot 26 (0.30) were the best hybrids with significant and desirable (positive) SCA effect.

Pooled over location *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3); SCA effect ranged from -0.31 (GISV 361 X GBHV 253) to 0.31 (GSHV 242 X GBHV 253). Among 28 F_1s developed and evaluated, one and two hybrids were significant and desirable (positive) as well as significant and undesirable (negative) SCA effect. Best hybrid with significant and desirable (positive) SCA effect was GSHV 242 X GBHV 253 (0.31).

Eswari *et al*. (2016); Monicashree *et al*. (2017); Vekariya *et al.* (2017); Khokhar *et al.* (2018); Roy *et al.* (2018); Kirthika *et al.* (2020); Richika *et al.* (2021) had reported significant positive and negative GCA as well as SCA effect for monopodia/plant.

Sympodia/plant. A parent having significant and positive GCA effect while hybrid having significant and positive SCA effect for sympodia/plant were considered as good general and good specific combiners respectively. Among the eight parents, at Surat GISV 361 (1.01) while at Bharuch, G Cot 16 (1.78) identified as best combiners for this trait. Pooled over locations, G Cot 16 (0.83) manifested as good general combiner while GISV 361 (-0.50) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -4.40 (G Cot 16 X GBHV 253) to 3.21 (GBHV 200 X GBHV 253) at Navsari; from -4.90 (GN Cot 22 X GSHV 242) to 3.50 (GBHV 200 X GSHV 242) at Surat; while it was from -5.04 (GSHV 242 X GBHV 253) to 4.22 (GBHV 200 X GSHV 242) at Bharuch centre. Five, five and two hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch centre respectively. Top three hybrids having significant and desirable (positive) SCA effect at Navsari centre were GBHV 200 X GBHV 253 (3.21) followed by G Cot 16 X GSHV 242 (2.64) and GSHV 242 X GBHV 253 (2.45). At Surat location, GBHV 200 X GSHV 242 (3.50), GSHV 242 X GISV 361 (3.46) and G Cot 10 X GN Cot 26 (3.33) were the best three hybrids while at Bharuch, GBHV 200 X GSHV 242 (4.22) and GN Cot 26 X GSHV 242 (3.47) (L_3) were best hybrids with significant and desirable (positive) SCA effect.

Pooled over location *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3); SCA effect ranged from -2.56 (GN Cot 22 X GSHV 242) to 1.83 (GBHV 200 X GSHV 242). Among 28 F_1s developed and evaluated, three hybrids were significant and undesirable (negative) SCA effect. None of the hybrid was significant and desirable (positive) SCA effect.

Eswari *et al*. (2016); Monicashree *et al*. (2017); Bilwal *et al.* (2018); Khokhar *et al.* (2018); Roy *et al.* (2018); Vaghela *et al.* (2019); Kirthika *et al.* (2020); Manonmani *et al.* (2020); Mudhavan *et al.* (2021) had reported significant and positive and negative GCA as well as SCA effect for sympodia/plant.

Bolls/plant. A parent having significant and positive GCA effect while hybrid having significant and positive SCA effect for bolls/plant is considered as good general and good specific combiners respectively. Among the eight parents, at Navsari, G Cot 16 (0.79) and GBHV 200 (0.57); at Surat, GBHV 253 (2.28) while at Bharuch, GSHV 242 (1.13) and G Cot 16 (1.12) identified as best combiners for this trait. Pooled over locations, G Cot 16 (0.69) manifested as good general combiner while GISV 361(-1.12) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -5.77 (GN Cot 22 X G Cot 10) to 4.23 (GN Cot 26 X GBHV 200) at Navsari; from -8.40 (GN Cot 26 X GBHV 253) to 8.04 (GSHV 242 X GBHV 253) at Surat; while it was from -6.06 (G Cot 10 X GBHV 253) to 5.26 (G Cot 10 X GSHV 242) at Bharuch centre. Four, three and four hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch centre respectively. Top three hybrids with significant and desirable (positive) SCA effect at Navsari centre were GN Cot 26 X GBHV 200 (4.23) followed by GN Cot 26 X GISV 361 (3.97) and GSHV 242 X GBHV 253 (3.79). At Surat location, GSHV 242 X GBHV 253 (8.04), GN Cot 22 X G Cot 10 (5.68) and GN Cot 26 X GBHV 200 (5.05) (L_2) were the best three hybrids while at Bharuch, G Cot 10 X GSHV 242 (5.26), GSHV 242 X GBHV 253 (4.24) and GN Cot 26 X GBHV 253 (4.07) were top most hybrids with significant and desirable (positive) SCA effect.

Pooled over location *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3); SCA effect ranged from -4.50 (GBHV 200 X GSHV 242) to 5.36 (GSHV 242 X GBHV 253). Among 28 F_1s developed and evaluated, six hybrids registered significant and desirable (positive) as well as significant and undesirable (negative) SCA effect. Top best hybrids with significant and desirable (positive) SCA effect across all the three location, were GSHV 242 X GBHV 253 (5.36) and GN Cot 26 X GISV 361 (3.22).

Kannan and Saravanan (2015); Eswari *et al*. (2016); Monicashree *et al*. (2017); Vekariya *et al.* (2017); Bilwal *et al.* (2018); Khokhar *et al.* (2018); Roy *et al.* (2018); Thiyagu *et al.* (2019); Vaghela *et al.* (2019); Kirthika *et al.* (2020); Manonmani *et al.* (2020); Hamed and Said (2021); Manan *et al.* (2021); Mudhavan *et al.* (2021); Richika *et al.* (2021)had reported significant positive and negative GCA as well as SCA effect for Bolls/plant.

Boll weight (g). A parent having significant and positive GCA effect while hybrid having significant and positive SCA effect for boll weight is considered as good general and good specific combiners respectively. Among the eight parents, at Navsari, GN Cot 26 (0.23), GISV 361 (0.16) and GSHV 242 (0.14); at Surat, GSHV 242 (0.20) and GBHV 200 (0.17) while at Bharuch, GISV 361 (0.31) and GBHV 200 (0.21) identified as best combiners for this trait. Pooled over locations, GISV 361 (0.17) manifested as good general combiner while G Cot 16 (-0.18) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -0.52 (GN Cot 26 X GISV 361) to 0.81 (GISV 361 X GBHV 253) at Navsari; from -0.97 (G Cot 16 X GISV 361) to 0.86 (GN Cot 22 X GISV 361) at Surat; while it was from -0.54 (GN Cot

26 X GSHV 242) to 0.97 (G Cot 16 X GN Cot 26) at Bharuch centre. Seven, five and three hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch centre respectively. Top three hybrids with significant and desirable (positive) SCA effect at Navsari centre were GISV 361 X GBHV 253 (0.81) followed by G Cot 16 X GBHV 200 (0.55) and G Cot 10 X GBHV 253 (0.48). At Surat locations, GN Cot 22 X GISV 361 (0.86), GN Cot 26 X GBHV 253 (0.81) and GBHV 200 X GSHV 242 (0.67) were the best three hybrids while at Bharuch, G Cot 16 X GN Cot 26 (0.97), GN Cot 26 X GBHV 200 (0.79) and G Cot 10 X GBHV 253 (0.43) were top most hybrids with significant and desirable (positive) SCA effect.

Pooled over location *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3) centres; SCA effect ranged from -0.49 (G Cot 16 X GISV 361) to 0.37 (GN Cot 22 X GISV 361). Among 28 F_1s developed and evaluated, four hybrids registered significant and desirable (positive) as well as significant and undesirable (negative) SCA effect. Top three hybrids with significant and desirable (positive) SCAeffect, across all the three centres (*i.e.* pooled over three centres) were 0.37 (GN Cot 22 X GISV 361) followed by 0.34 (G Cot 10 X GBHV 253) and 0.31 (G Cot 16 X GN Cot 26).

Kannan and Saravanan (2015); Eswari *et al*. (2016); Monicashree *et al*. (2017); Vekariya *et al.* (2017); Bilwal *et al.* (2018); Khokhar *et al.* (2018); Roy *et al.* (2018); Thiyagu *et al.* (2019); Vaghela *et al.* (2019); Kirthika *et al*. (2020); Manonmani *et al.* (2020); Hamed and Said (2021); Manan *et al.* (2021);Mudhavan *et al.* (2021); Richika *et al.* (2021); Hafez *et al*. (2022) had reported significant positive and negative GCA as well as SCA effect for Boll weight.

Seed Cotton Yield/Plant (g). A parent having significant and positive GCA effect while hybrid having significant and positive SCA effect for seed cotton yield/plant were considered as good general and good specific combiners respectively. Among the eight parents, at Navsari, GN Cot 26 (5.54) and GBHV 200 (3.11); at Surat, GN Cot 26 (4.70) and GSHV 242 (3.18) while at Bharuch, GBHV 200 (4.14) identified as best combiners for this trait. Pooled over locations, GN Cot 26 (3.81) and GBHV 200 (2.43) manifested as good general combiners while GN Cot 22 (-4.35) was the worst combiner among the 8 parents for this trait.

SCA effect ranged from -11.46 (GN Cot 22 X G Cot 10) to 11.83 (GSHV 242 X GBHV 253) at Navsari; from -15.73 (G Cot 10 X GBHV 200) to 23.26 (GBHV 200 X GISV 361) at Surat; while it was from -21.34 (GBHV 200 X GSHV 242) to 18.93 (GSHV 242 X GBHV 253) at Bharuch centre. Three, five and five hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch centre respectively. Top three hybrids with significant and desirable (positive) SCA effect at Navsari centre were GSHV 242 X GBHV 253 (11.83) followed by GBHV 200 X GISV 361 (8.60) and G Cot 16 X GN Cot 26 (7.61). At Surat location, GBHV 200 X GISV 361 (23.26), GSHV 242 X GBHV 253 (21.28) and GN Cot 26 X GISV 361 (13.30) were the best three hybrids while at Bharuch, GSHV 242 X GBHV 253 (18.93) followed by G Cot 16 X GN Cot 26 (18.04) and GBHV 200 X GISV 361 (12.12) were top most hybrids with significant and desirable (positive) SCA effect.

Pooled over *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3) centres; SCA effect ranged from -13.71 (GBHV 200 X GSHV 242) to 17.35 (GSHV 242 X GBHV 253). Among 28 F_1s developed and evaluated, four hybrids registered significant and desirable (positive) as well as significant and undesirable (negative) SCA effect. Top three hybrids with significant and desirable (positive) SCA effect, across all the three centres (*i.e.* pooled over three centres) were GSHV 242 X GBHV 253 (17.35), GBHV 200 X GISV 361 (14.66) and G Cot 16 X GN Cot 26 (11.64).

Kannan and Saravanan (2015); Eswari *et al*. (2016); Monicashree *et al*. (2017); Vekariya *et al.* (2017); Bilwal *et al.* (2018); Khokhar *et al.* (2018); Roy *et al.* (2018); Thiyagu *et al.* (2019); Vaghela *et al.* (2019); Kirthika *et al.* (2020); Manonmani *et al.* (2020); Hamed and Said (2021); Manan *et al.* (2021); Mudhavan *et al.* (2021); Richika *et al.* (2021); Hafez *et al*. (2022) had reported significant positive and negative GCA as well as SCA effect for seed cotton yield/plant.

Lint yield (%). A parent having significant and positive GCA effect and hybrid having significant and positive SCA effect for lint yield is considered as good general and good specific combiners respectively. Among the eight parents, at Navsari, GSHV 242 (1.87) and GBHV 253 (0.98); at Surat, GN Cot 26 (2.90) while at Bharuch GN Cot 26 (3.36) and G Cot 16 (1.71) identified as best combiners for this trait. Pooled over locations, GN Cot 26 (1.92) manifested as good general combiner while GISV 361 (-1.11) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -5.22 (GSHV 242 X GISV 361) to 6.99 (GISV 361 X GBHV 253) at Navsari; from -10.32 (G Cot 10 X GISV 361) to 6.48 (G Cot 16 X GBHV 253) at Surat; while it was from -10.27 (G Cot 10 X GN Cot 26) to 6.64 (GN Cot 26 X GSHV 242) at Bharuch centre. Four, one and six hybrids had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch centre respectively. Top three hybrids with significant and desirable (positive) SCAeffect at Navsari, GISV 361 X GBHV 253 (6.99) followed by GN Cot 26 X GSHV 242 (5.57) and GSHV 242 X GBHV 253 (4.07). At Surat location, G Cot 16 X GBHV 253 (6.48) was the top performing hybrid while at Bharuch, GN Cot 26 X GSHV 242 (6.64), G Cot 16 X GBHV 253 (5.99) and GN Cot 26 X GBHV 200 (5.97) were top most hybrids with significant and desirable (positive) SCA effect.

Pooled over location *i.e.*, over Navsari (L_1), Surat (L_2) and Bharuch (L_3); SCA effect ranged from -5.19 (GSHV 242 X GISV 361) to 3.67 (GN Cot 26 X GSHV 242). Among 28 F_1s developed and evaluated, neither of hybrid registered significant and desirable (positive) as well as significant and undesirable (negative) SCA effect for this trait.

Bilwal *et al.* (2018); Khokhar *et al.* (2018); Manonmani *et al.* (2020); Hamed and Said (2021); Manan *et al.* (2021); Hafez *et al*. (2022); Abo Sen *et al.* (2022) had reported significant positive and negative GCA as well as SCA effect for lint yield.

Ginning Outturn (%). A parent having significant and positive GCA effect and hybrid having significant and positive SCA effect for ginning outturn is considered as good general and good specific combiners respectively. Among the eight parents, at Navsari, GN Cot 22 (1.85); at Surat, G Cot 10 (1.60) while at Bharuch, GN Cot 26 (2.71) identified as best combiners for this trait. Pooled over locations, GN Cot 22 (0.98) manifested as good general combiner while GBHV 200 (-1.33) was the worst combiner among 8 parents for this trait.

SCA effect ranged from -4.63 (GSHV 242 X GISV 361) to 8.09 (GN Cot 26 X GSHV 242) at Navsari; from -6.76 (G Cot 10 X GISV 361) to 5.11 (G Cot 10 X GBHV 200) at Surat; while it was from -8.70 (GN Cot 26 X GISV 361) to 13.84 (GN Cot 26 X GSHV 242) at Bharuch centre. Five, one and five crosses had significant and desirable (positive) SCA effect for this trait at Navsari, Surat and Bharuch centre respectively. Top three hybrids with significant and desirable (positive) SCA effect at Navsari, GN Cot 26 X GSHV 242 (8.09) followed by GISV 361 X GBHV 253 (5.95) and GN Cot 22 X G Cot 10 (5.50). At Surat location,G Cot 10 X GBHV 200 (5.11) was the best hybrid while at Bharuch, GN Cot 26 X GSHV 242 (13.84), G Cot 16 X GBHV 253 (5.69) and G Cot 16 X GISV 361 (5.43) were top most hybrids with significant and desirable (positive) SCA effect.

Pooled over location *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3); SCA effect ranged from -5.63 (G Cot 16 X GN Cot 26) to 7.91 (GN Cot 26 X GSHV 242). Among 28 F_1s developed and evaluated, five hybrids registered significant and desirable (positive) as well as significant and undesirable (negative) SCA effect. GN Cot 26 X GSHV 242 (7.91) is the only hybrid with significant and desirable (positive) SCAeffect pooled over all the three centres.

Kannan and Saravanan (2015); Eswari *et al*. (2016); Vekariya *et al*. (2017); Bilwal *et al*. (2018); Roy *et al*. (2018); Thiyagu *et al*. (2019); Vaghela *et al*. (2019);Mudhavan *et al*. (2021); Richika *et al*. (2021)had reported significant positive and negative GCA as well as SCA effect for ginning outturn.

Table 1: Analysis of variance for combining ability for days to 50% flowering, days to first picking and plant height (cm) at individual location and pooled over environments.

Sources	Df	Days to 50% flowering				Days to first picking				Plant height (cm)			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
GCA	7	11.38	24.73**	30.64**	21.40**	9.26**	15.81**	60.69**	25.63**	143.75**	639.13**	104.54**	272.40**
SCA	28	193.18**	2.11*	5.37*	8.31**	5.28**	2.81*	10.01	15.15**	78.11**	97.81**	242.50**	302.93**
Environments (E)	2	-	-	-	32.82**	-	-	-	50.41**	-	-	-	9435.16**
GCA X Environments	14	-	-	-	10.53**	-	-	-	10.28**	-	-	-	686.92**
SCA X Environments	56	-	-	-	5.48**	-	-	-	7.15**	-	-	-	222.64**
Error	210	1.17	1.26	2.76	1.78	2.42	1.49	6.52	3.46	25.60	85.29	35.60	60.38
Estimates													
σ^2gca		0.05	2.35	2.79	0.65	0.68	1.43	5.41	0.74	11.81	55.38	6.89	7.07
σ^2SCA		5.73	0.85	2.60	0.17	2.86	1.31	3.49	3.90	52.51	12.51	206.89	80.85
σ^2gca/ σ^2SCA		0.01	2.77	1.07	0.30	0.24	1.09	1.55	0.19	0.22	4.43	0.03	0.09

* and ** indicates significance at 5 % and 1 % level of probability, respectively.
For individual location, df for error is 70.

Table 2: Analysis of variance for combining ability for monopodia/plant, sympodia/plant and bolls/plant at individual location and pooled over environments.

Sources	Df	Monopodia/plant				Sympodia/plant				Bolls/plant			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
GCA	7	0.08**	0.07**	0.17**	0.06**	1.69	4.61*	10.12**	11.15**	4.28**	19.57**	6.48*	9.26**
SCA	28	0.05**	0.07**	0.08**	0.06**	4.87**	6.93**	5.92**	6.62**	15.28**	16.06**	12.45**	16.72**
Environments (E)	2	-	-	-	0.15**	-	-	-	30.51**	-	-	-	620.35**
GCA X Environments	14	-	-	-	0.10**	-	-	-	8.15**	-	-	-	11.88**
SCA X Environments	56	-	-	-	0.08**	-	-	-	5.06**	-	-	-	15.33**
Error	210	0.02	0.02	0.02	0.02	0.82	1.67	2.77	1.80	0.91	4.42	2.29	2.55
Estimates													
σ^2gca		0.01	0.01	0.01	0.13	0.09	0.29	0.73	0.31	0.34	1.51	0.42	0.22
σ^2SCA		0.04	0.01	0.05	1.43	4.05	5.26	3.15	1.61	14.37	11.64	10.16	4.72
σ^2gca/ σ^2SCA		0.16	0.01	0.26	0.09	0.02	0.06	0.23	0.19	0.02	0.13	0.04	0.05

* and ** indicates significance at 5 % and 1 % level of probability, respectively.
For individual location, df for error is 70.

Table 3: Analysis of variance for combining ability for boll weight (g), seed cotton yield/plant (g) and lint yield (%) at individual location and pooled over environments.

Sources	Df	Boll weight				Seed cotton yield/plant				Lint yield			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
GCA	7	0.30**	0.17**	0.42**	0.47**	145.31**	91.21**	56.48**	177.73**	13.92**	27.56*	33.70**	40.02**
SCA	28	0.15**	0.16**	0.16**	0.15**	48.89**	119.71**	113.79**	88.12**	10.92**	17.94*	23.46**	19.89**
Environments (E)	2	-	-	-	0.44**	-	-	-	4575.06**	-	-	-	810.46**
GCA X Environments	14	-	-	-	0.15**	-	-	-	65.70**	-	-	-	20.06**
SCA X Environments	56	-	-	-	0.16**	-	-	-	100.62**	-	-	-	21.85**
Error	210	0.01	0.02	0.05	0.03	17.10	11.68	18.32	15.51	2.02	9.61	5.92	5.83
Estimates													
σ^2gca		0.03	0.01	0.04	1.48	12.82	7.95	3.82	5.41	1.19	1.80	2.78	1.14
σ^2SCA		0.14	0.14	0.11	3.97	31.78	108.03	95.47	24.20	8.90	8.33	17.54	4.69
σ^2gca/ σ^2SCA		0.21	0.11	0.34	0.37	0.40	0.07	0.04	0.22	0.13	0.22	0.16	0.24

* and ** indicates significance at 5 % and 1 % level of probability, respectively.
For individual location, df for error is 70.

Table 4: Analysis of variance for combining ability for ginning outturn (%) at individual location and pooled over environments.

Sources	Df	Ginning outturn			
		Navsari	Surat	Bharuch	Pooled
GCA	7	15.85**	10.15	32.50**	52.12**
SCA	28	11.83**	12.72*	30.00**	16.09**
Environments (E)	2	-	-	-	332.17**
GCA X Environments	14	-	-	-	21.79**
SCA X Environments	56	-	-	-	20.11**
Error	210	2.81	6.37	6.14	5.03
Estimates					
σ^2gca		1.30	0.38	2.64	1.57
σ^2SCA		9.02	6.35	23.87	3.68
σ^2gca/ σ^2SCA		0.14	0.06	0.11	0.42

* and ** indicates significance at 5 % and 1 % level of probability, respectively.
For individual location, df for error is 70.

Table 5: GCA and SCA effect for day to 50% flowering and days to first picking.

Sr. No.	Genotypes	Day to 50% flowering				Days to first picking			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
	Parents								
1.	GN Cot 22	0.65*	0.94**	3.77**	1.79*	0.18	0.03	4.77**	1.66*
2.	G Cot 10	-0.15	0.91**	0.60	0.45	-0.79	1.33**	1.57*	0.70
3.	G Cot 16	-0.59	-0.73*	-0.73	-0.68	-0.13	-1.63**	-0.57	-0.77
4.	GN Cot 26	-0.15	-2.192**	0.47	-0.62	0.78	-0.03	0.80	0.51
5.	GBHV 200	-0.42	2.37**	-0.03	0.64	-0.36	2.20**	-0.60	0.41
6.	GSHV 242	0.12	0.61	-0.97	-0.08	-0.86	-0.57	-1.90*	-1.11*
7.	GISV 361	0.25	-2.06**	-1.10*	-0.97*	-0.76	-1.20**	-0.60	-0.83
8.	GBHV 253	0.28	0.14	-2.00**	-0.53	1.94**	-0.13	-3.47**	-0.55
	S.E.gi ±	**0.32**	**0.33**	**0.49**	**0.43**	**0.46**	**0.36**	**0.75**	**0.57**
	Hybrids								
1.	GN Cot 22 X G Cot 10	-1.78	-0.32	2.34	0.08	-1.71	1.15	2.44	0.62
2.	GN Cot 22 X G Cot 16	0.66	1.31	0.67	0.88	4.63**	-0.88	0.24	1.33*
3.	GN Cot 22 X GN Cot 26	1.56	-1.56	-4.20**	-1.40	0.73	-0.48	1.54	0.60
4.	GN Cot 22 X GBHV 200	1.82	0.54	-0.70	0.56	-0.14	0.95	-4.06	-1.08
5.	GN Cot 22 X GSHV 242	1.62	1.31	0.57	1.17	2.03	-0.95	-4.09	-1.00
6.	GN Cot 22 X GISV 361	0.82	-1.02	-1.63	-0.61	-2.41	2.02	-0.39	-0.26
7.	GN Cot 22 X GBHV 253	-2.21*	-0.89	-4.06**	-2.39*	1.56	-0.72	-4.19	-1.12
8.	G Cot 10 X G Cot 16	1.12	-0.66	2.50	0.99	1.93	0.82	-0.89	0.62
9.	G Cot 10 X GN Cot 26	-1.31	-1.52	-2.63	-1.73	-0.97	1.55	-5.59*	-1.67*
10.	G Cot 10 X GBHV 200	0.29	1.91	-2.20	-0.01	-0.17	1.99	-3.19	-0.46
11.	G Cot 10 X GSHV 242	3.76**	1.01	0.07	1.61	-1.01	0.42	-1.89	-0.83
12.	G Cot 10 X GISV 361	1.62	-1.66	1.54	0.50	4.56**	-3.62**	-0.52	0.14
13.	G Cot 10 X GBHV 253	-1.74	-0.19	-0.23	-0.72	-2.47	-0.02	-2.32	-1.61*
14.	G Cot 16 X GN Cot 26	2.12*	0.44	-1.70	0.29	-1.97	1.52	-0.79	-0.42
15.	G Cot 16 X GBHV 200	-2.94**	0.54	-1.20	-1.20	0.83	-3.72**	-1.39	-1.43*
16.	G Cot 16 X GSHV 242	0.19	-0.02	0.07	0.08	-0.34	0.05	2.24	0.65
17.	G Cot 16 X GISV 361	-4.28**	-0.36	1.54	-1.03	-1.77	0.02	0.28	-0.49

18.	G Cot 16 X GBHV 253	4.02**	1.44	2.44	2.63*	0.19	1.95	-3.52	-0.46
19.	GN Cot 26 X GBHV 200	2.29*	-1.99	2.27	0.86	-1.74	2.02	-0.09	0.06
20.	GN Cot 26 X GSHV 242	-0.24	0.78	-2.13	-0.53	-1.24	-0.88	-1.12	-1.08
21.	GN Cot 26 X GISV 361	-1.71	1.44	-0.66	-0.31	-1.01	0.42	-2.09	-0.89
22.	GN Cot 26 X GBHV 253	-1.41	-0.76	2.57	0.13	0.63	0.02	3.11	1.25
23.	GBHV 200 X GSHV 242	-4.98**	-2.79**	-0.63	-2.80*	-3.44*	1.22	0.28	-0.65
24.	GBHV 200 X GISV 361	0.22	-1.46	-1.16	-0.80	-0.87	1.85	4.98*	1.99*
25.	GBHV 200 X GBHV 253	-4.48**	-1.66	2.73	-1.13	-0.57	-1.22	-1.82	-1.20
26.	GSHV 242 X GISV 361	-3.64**	-0.02	-2.56	-2.08	-2.71	-1.05	-2.72	-2.16**
27.	GSHV 242 X GBHV 253	2.32*	-1.56	-0.66	0.03	-0.74	2.55*	1.48	1.10
28.	GISV 361 X GBHV 253	0.52	1.78	-1.53	0.26	0.49	-0.82	-0.82	-0.38
	S.E.sij ±	**0.98**	**1.01**	**1.51**	**1.33**	**1.41**	**1.10**	**2.31**	**1.75**

* and ** indicates significance at 5% and 1% level of probability, respectively

Table 6: GCA and SCA effect for plant height (cm) and monopodia/plant.

Sr. No.	Genotypes	Plant height				Monopodia/plant			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
	Parents								
1.	GN Cot 22	5.82**	-14.24**	2.24	-2.06	-0.02	0.10*	0.04	0.04
2.	G Cot 10	2.98	-5.87*	2.44	-0.51	0.10*	-0.10*	0.13**	0.05
3.	G Cot 16	-3.52*	-1.21	1.34	-1.13	0.04	0.01	0.13**	-0.06
4.	GN Cot 26	-2.32	6.79*	2.70	2.40	-0.14**	-0.12*	0.12**	-0.04
5.	GBHV 200	4.28**	1.89	2.27	2.82	0.13**	0.07	0.01	0.07
6.	GSHV 242	-0.85	11.46**	-1.56	3.02	-0.01	-0.08	-0.07	-0.05
7.	GISV 361	-3.75*	-3.07	-4.09*	-3.64	-0.07	0.03	-0.19**	-0.08
8.	GBHV 253	-2.65	4.26	-5.36**	-1.25	-0.03	0.07	-0.17**	-0.04
	S.E.gi ±	**1.50**	**2.73**	**1.76**	**2.31**	**0.04**	**0.04**	**0.04**	**0.04**
	Hybrids								
1.	GN Cot 22 X G Cot 10	-1.86	0.33	-2.86	-1.46	-0.03	-0.02	0.05	0.01
2.	GN Cot 22 X G Cot 16	-1.69	1.66	7.91	2.63	-0.40**	-0.03	0.18	-0.08
3.	GN Cot 22 X GN Cot 26	-3.22	6.33	-25.13	-7.34	-0.12	-0.14	0.03	-0.08
4.	GN Cot 22 X GBHV 200	-1.49	1.90	-8.03	-2.54	0.08	-0.23	0.12	-0.09
5.	GN Cot 22 X GSHV 242	-0.36	14.00	-21.20**	-2.52	-0.16	-0.14	-0.15	-0.15
6.	GN Cot 22 X GISV 361	2.55	3.20	-16.66*	-3.64	-0.29*	0.28*	-0.27*	-0.09
7.	GN Cot 22 X GBHV 253	-1.22	5.20	18.61*	7.53	0.24	-0.09	0.08	0.08
8.	G Cot 10 X G Cot 16	-2.52	-17.37*	-7.63	-9.17	0.31*	-0.20	-0.12	-0.02
9.	G Cot 10 X GN Cot 26	2.61	7.30	2.01	3.97	0.18	0.03	0.30*	0.17
10.	G Cot 10 X GBHV 200	-7.66	-0.80	14.11*	1.88	-0.12	0.14	-0.01	0.00
11.	G Cot 10 X GSHV 242	5.81	15.30	-2.39	6.24	0.11	0.02	-0.28*	-0.05
12.	G Cot 10 X GISV 361	4.71	-6.50	-5.86	-2.55	-0.38**	0.28*	-0.26	-0.12
13.	G Cot 10 X GBHV 253	-11.72**	-4.84	-20.59**	-12.38	-0.02	0.01	-0.15	-0.05
14.	G Cot 16 X GN Cot 26	15.11**	3.63	-7.89	3.62	0.08	-0.45**	-0.07	-0.15
15.	G Cot 16 X GBHV 200	-0.49	21.53**	7.87	9.64	0.28*	-0.21	-0.25	-0.06
16.	G Cot 16 X GSHV 242	-5.69	-1.70	-0.63	-2.67	-0.29*	0.18	-0.05	-0.05
17.	G Cot 16 X GISV 361	-15.79**	-4.17	-7.43	-9.13	-0.19	0.30*	0.01	0.04
18.	G Cot 16 X GBHV 253	-0.22	11.83	-34.49**	-7.63	-0.13	-0.10	-0.28*	-0.17
19.	GN Cot 26 X GBHV 200	6.64	2.20	4.84	4.56	0.09	-0.08	0.23	0.08
20.	GN Cot 26 X GSHV 242	3.44	-4.70	12.34	3.69	0.08	0.07	-0.50**	-0.11
21.	GN Cot 26 X GISV 361	7.34	-4.84	9.21	3.90	-0.08	0.07	-0.51**	-0.17
22.	GN Cot 26 X GBHV 253	-19.76**	-0.50	-2.86	-7.71	-0.05	0.06	-0.13	-0.04
23.	GBHV 200 X GSHV 242	-1.82	-3.14	5.44	0.16	-0.15	0.25	-0.08	0.01
24.	GBHV 200 X GISV 361	4.74	14.40	-17.03*	0.71	0.16	0.01	0.37**	0.18
25.	GBHV 200 X GBHV 253	5.31	-8.27	-6.43	-3.13	-0.32*	0.17	-0.18	-0.11
26.	GSHV 242 X GISV 361	-18.79**	-6.84	10.14	-5.16	0.05	-0.81**	-0.06	-0.27*
27.	GSHV 242 X GBHV 253	-0.56	-10.17	-4.26	-5.00	0.31*	0.36**	0.25	0.31*
28.	GISV 361 X GBHV 253	-0.99	10.70	28.94**	12.88	-0.18	-0.52**	-0.23	-0.31*
	S.E.sij ±	**4.59**	**8.38**	**5.41**	**7.11**	**0.13**	**0.13**	**0.13**	**0.14**

* and ** indicates significance at 5% and 1% level of probability, respectively

Table 7: GCA and SCA effect for sympodia/plant and bolls/plant.

Sr.No.	Genotypes	Sympodia/plant				Bolls/plant			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
	Parents								
1.	GN Cot 22	0.09	0.47	0.09	0.21	0.10	1.01	-0.49	0.21
2.	G Cot 10	0.10	-0.56	0.64	0.06	0.17	-0.89	0.21	-0.17
3.	G Cot 16	0.33	0.39	1.78**	0.83*	0.79**	0.18	1.12*	0.69
4.	GN Cot 26	0.12	-0.84*	-0.25	-0.32	-0.14	1.12	-0.24	0.25
5.	GBHV 200	-0.42	-0.36	-0.30	-0.36	0.57*	-0.56	0.10	0.04
6.	GSHV 242	0.05	-0.64	-0.53	-0.38	0.39	-1.87**	1.13*	-0.12
7.	GISV 361	-0.78**	1.01*	-1.73**	-0.50	-1.13**	-1.26*	-0.95*	-1.12*
8.	GBHV 253	0.52	0.54	0.30	0.45	-0.75**	2.28**	-0.87	0.22
	S.E.gi ±	**0.27**	**0.38**	**0.49**	**0.40**	**0.28**	**0.62**	**0.45**	**0.58**
	Hybrids								
1.	GN Cot 22 X G Cot 10	0.03	-3.81**	2.20	-0.53	-5.77**	5.68**	2.75*	0.89
2.	GN Cot 22 X G Cot 16	-0.83	-1.39	-0.07	-0.77	0.45	-1.96	1.08	-0.14
3.	GN Cot 22 X GN Cot 26	0.11	1.37	0.66	0.71	-3.01**	0.16	-3.70**	-2.18
4.	GN Cot 22 X GBHV 200	-2.53**	2.59*	-3.03*	-0.99	-0.46	-1.94	-2.93*	-1.78
5.	GN Cot 22 X GSHV 242	-3.15**	-4.90**	0.37	-2.56*	1.16	-3.49	-1.55	-1.29
6.	GN Cot 22 X GISV 361	-0.67	0.32	-1.60	-0.65	-0.87	-4.26*	2.18	-0.98
7.	GN Cot 22 X GBHV 253	0.44	1.56	-0.89	0.37	-2.88**	0.88	0.20	-0.60
8.	G Cot 10 X G Cot 16	-3.27**	0.26	-1.59	-1.53	-1.29	-0.52	0.68	-0.38
9.	G Cot 10 X GN Cot 26	0.24	3.33**	-1.89	0.56	-0.62	-0.18	-1.93	-0.91
10.	G Cot 10 X GBHV 200	-1.27	-3.02**	-1.74	-2.01	-2.90**	1.52	-0.09	-0.49
11.	G Cot 10 X GSHV 242	-2.66**	-3.04**	-1.25	-2.31*	-1.11	-1.54	5.26**	0.87
12.	G Cot 10 X GISV 361	2.16**	-0.12	0.58	0.87	1.36	-0.79	0.97	0.52
13.	G Cot 10 X GBHV 253	1.33	1.31	1.06	1.23	-3.02**	-2.73	-6.06**	-3.94**
14.	G Cot 16 X GN Cot 26	2.24**	-0.29	-0.47	0.50	1.33	3.42	-0.80	1.32
15.	G Cot 16 X GBHV 200	1.54	-2.27	-2.26	-1.00	-5.52**	2.33	-3.35*	-2.18
16.	G Cot 16 X GSHV 242	2.64**	3.15**	-0.62	1.72	-5.25**	-0.72	-3.81**	-3.26*
17.	G Cot 16 X GISV 361	-1.44	-1.17	-2.36	-1.65	1.17	-1.55	-2.36	-0.91
18.	G Cot 16 X GBHV 253	-4.40**	2.13	-1.15	-1.14	-1.33	-5.92**	-1.70	-2.98*
19.	GN Cot 26 X GBHV 200	1.01	1.23	2.44	1.56	4.30**	5.05**	-4.46**	1.63
20.	GN Cot 26 X GSHV 242	0.25	-0.09	3.47*	1.21	-3.27**	0.24	-1.89	-1.64
21.	GN Cot 26 X GISV 361	-2.86**	-1.77	-1.50	-2.04*	3.97**	3.33	2.35	3.22*
22.	GN Cot 26 X GBHV 253	1.04	-2.60*	0.64	-0.31	-3.29**	-8.40**	4.07**	-2.54
23.	GBHV 200 X GSHV 242	-2.22**	3.50**	4.22**	1.83	-1.38	-8.19**	-3.92**	-4.50**
24.	GBHV 200 X GISV 361	0.37	0.32	-0.48	0.07	2.78**	-1.85	3.32*	1.42
25.	GBHV 200 X GBHV 253	3.21**	-5.85**	1.36	-0.43	-0.71	-2.68	-0.82	-1.41
26.	GSHV 242 X GISV 361	0.04	3.46**	-2.45	0.35	-4.15**	-0.63	2.62	-0.72
27.	GSHV 242 X GBHV 253	2.45**	-0.84	-5.04**	-1.15	3.79**	8.04**	4.24**	5.36**
28.	GISV 361 X GBHV 253	-0.20	0.12	-0.95	-0.34	-4.60**	3.38	1.71	0.16
	S.E.sij ±	**0.82**	**1.17**	**1.51**	**1.21**	**0.86**	**1.91**	**1.37**	**1.77**

* and ** indicates significance at 5% and 1% level of probability, respectively

Table 8: GCA and SCA effect for boll weight (g) and seed cotton yield/plant (g).

Sr. No.	Genotypes	Boll weight				Seed cotton yield/plant			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
	Parents								
1.	GN Cot 22	-0.28**	-0.01	-0.22**	-0.17*	-6.87**	-1.88	-4.30**	-4.35*
2.	G Cot 10	-0.12**	-0.06	-0.01	-0.06	-2.24	-2.91**	-0.31	-1.82
3.	G Cot 16	-0.13**	-0.17**	-0.25**	-0.18*	-0.16	-0.35	0.25	-0.09
4.	GN Cot 26	0.23**	0.04	0.08	0.12	5.54**	4.70**	1.20	3.81*
5.	GBHV 200	-0.02	0.17**	0.21**	0.12	3.11*	0.03	4.14**	2.43*
6.	GSHV 242	0.14**	0.20**	-0.19**	0.01	0.94	3.18**	-0.14	1.32
7.	GISV 361	0.16**	-0.05	0.31**	0.17*	1.87	-4.19**	0.56	-0.59
8.	GBHV 253	0.03	-0.12**	0.08	-0.05	-2.18	1.42	-1.40	-0.72
	S.E.gi ±	**0.03**	**0.04**	**0.07**	**0.07**	**1.22**	**1.01**	**1.27**	**1.56**
	Hybrids								
1.	GN Cot 22 X G Cot 10	0.42	-0.29*	-0.16	0.09	-11.46**	-5.69	5.34	-3.93
2.	GN Cot 22 X G Cot 16	0.05	0.32**	-0.36	0.03	-1.61	0.03	-6.16	-2.58
3.	GN Cot 22 X GN Cot 26	0.09	-0.46**	0.31	-0.02	-4.25	-4.76	-3.25	-4.09
4.	GN Cot 22 X GBHV 200	-0.09	-0.19	-0.43*	-0.23	-6.23	-10.88**	4.44	-4.23
5.	GN Cot 22 X GSHV 242	-0.36**	0.16	0.06	-0.05	-4.29	-1.88	-0.92	-2.36
6.	GN Cot 22 X GISV 361	-0.05	0.86**	0.40	0.37*	-5.12	3.99	-3.24	-1.46
7.	GN Cot 22 X GBHV 253	0.04	-0.26*	-0.31	-0.17	3.69	0.96	-1.95	0.90
8.	G Cot 10 X G Cot 16	0.01	0.06	-0.32	-0.09	-3.37	-8.82**	-2.14	-4.78
9.	G Cot 10 X GN Cot 26	0.46**	-0.11	0.08	0.14	5.87	2.47	-2.90	1.81

10.	G Cot 10 X GBHV 200	0.17*	-0.18	-0.32	0.11	0.17	-15.73**	2.68	-4.29
11.	G Cot 10 X GSHV 242	-0.26**	-0.26*	-0.26	-0.22	-2.40	2.40	4.68	1.56
12.	G Cot 10 X GISV 361	-0.15	-0.14	-0.09	-0.16	6.54	-7.06*	-1.08	-0.53
13.	G Cot 10 X GBHV 253	0.48**	0.12	0.43*	0.34*	-0.47	4.71	-17.48**	-4.41
14.	G Cot 16 X GN Cot 26	-0.02	-0.01	0.97**	0.31*	7.61*	9.26**	18.04**	11.64**
15.	G Cot 16 X GBHV 200	0.55**	-0.03	-0.02	0.16	-6.50	-5.66	-12.76**	-8.31*
16.	G Cot 16 X GSHV 242	0.19*	-0.04	-0.22	0.02	-6.31	-1.35	-14.28**	-7.31*
17.	G Cot 16 X GISV 361	-0.28**	-0.97**	-0.14	-0.49*	-6.53	-10.22**	-4.25	-5.00
18.	G Cot 16 X GBHV 253	-0.10	0.22	-0.18	-0.02	-4.01	5.98	-0.50	0.49
19.	GN Cot 26 X GBHV 200	-0.44**	-0.38**	0.79**	-0.01	5.64	10.21**	11.15**	9.00*
20.	GN Cot 26 X GSHV 242	-0.06	-0.13	-0.54*	0.20	-10.64**	-10.62**	-19.67**	-13.64**
21.	GN Cot 26 X GISV 361	-0.52**	0.14	-0.01	-0.16	1.00	13.30**	6.85	7.05
22.	GN Cot 26 X GBHV 253	0.33**	0.81**	-0.51	0.22	-4.50	-11.90**	-2.69	-6.36
23.	GBHV 200 X GSHV 242	-0.22**	0.67**	-0.06	0.17	-5.27	-14.54**	-21.34**	-13.71**
24.	GBHV 200 X GISV 361	-0.02	0.56**	0.21	0.07	8.60*	23.26**	12.12**	14.66**
25.	GBHV 200 X GBHV 253	0.08	-0.18	0.11	0.06	-1.86	-9.88**	-1.03	-4.26
26.	GSHV 242 X GISV 361	-0.35**	-0.24*	-0.15	0.07	0.07	1.66	8.63*	3.45
27.	GSHV 242 X GBHV 253	-0.12	-0.06	0.28	0.04	11.83**	21.28**	18.93**	17.35**
28.	GISV 361 X GBHV 253	0.81**	-0.05	-0.38	0.10	-0.99	-12.25**	-3.73	-5.66
	S.E.sij ±	**0.09**	**0.12**	**0.21**	**0.07**	**3.75**	**3.10**	**3.88**	**3.37**

* and ** indicates significance at 5% and 1% level of probability, respectively

Table 9: GCA and SCA effect for seed cotton yield per plant (gm) and ginning outturn (%).

Sr. No.	Genotypes	Lint yield				Ginning outturn			
		Navsari	Surat	Bharuch	Pooled	Navsari	Surat	Bharuch	Pooled
	Parents								
1.	GN Cot 22	0.03	-0.19	-0.43	-0.20	1.85**	0.25	0.85	0.98
2.	G Cot 10	-0.27	1.24	-1.98**	-0.34	0.44	1.60*	-1.94*	0.03
3.	G Cot 16	-0.42	-0.33	1.71*	0.32	-0.31	-0.13	1.43	0.33
4.	GN Cot 26	0.49	2.90**	3.36**	1.92	-1.71**	0.91	2.71**	0.64
5.	GBHV 200	0.45	-1.31	-1.62*	-0.83	-0.34	-0.89	-2.76**	-1.33*
6.	GSHV 242	1.87**	1.18	-1.53*	0.50	0.81	0.10	-0.98	-0.02
7.	GISV 361	-2.15**	-1.69	0.51	-1.11	-1.68**	-0.15	0.36	-0.49
8.	GBHV 253	0.98*	-1.81	-0.02	-0.28	0.94	-1.68*	0.32	-0.14
	S.E.gi ±	**0.42**	**0.92**	**0.72**	**0.69**	**0.50**	**0.75**	**0.73**	**0.64**
	Hybrids								
1.	GN Cot 22 X G Cot 10	1.81	0.38	-4.11	-0.64	5.50**	1.91	-5.14*	0.76
2.	GN Cot 22 X G Cot 16	0.44	0.17	-5.31*	-1.57	0.67	-0.07	-2.97	-0.79
3.	GN Cot 22 X GN Cot 26	-1.54	-0.64	0.25	-2.86	-0.68	0.79	1.51	0.54
4.	GN Cot 22 X GBHV 200	-3.22*	-2.07	-3.29	1.28	-1.55	0.98	-4.21	-1.60
5.	GN Cot 22 X GSHV 242	0.52	-1.29	4.62*	2.73	2.55	-0.44	3.98	2.03
6.	GN Cot 22 X GISV 361	1.62	4.63	1.95	-1.81	2.12	2.29	2.67	2.36
7.	GN Cot 22 X GBHV 253	-2.77*	-3.38	0.70	2.41	-3.15*	-2.75	1.28	-1.54
8.	G Cot 10 X G Cot 16	0.52	2.05	4.67*	-4.09	1.22	3.93	4.78*	3.31
9.	G Cot 10 X GN Cot 26	-0.96	-1.04	-10.27**	-2.23	-2.37	-1.49	-8.27**	-4.04*
10.	G Cot 10 X GBHV 200	-4.95**	1.10	-2.84	0.30	-4.59**	5.11*	-2.81	-0.76
11.	G Cot 10 X GSHV 242	-0.41	0.32	1.01	-1.84	0.62	-0.57	-0.81	-0.26
12.	G Cot 10 X GISV 361	1.06	-10.32**	3.74	-2.52	-1.41	-6.76**	3.50	-1.56
13.	G Cot 10 X GBHV 253	-2.25	2.08	-7.41**	0.32	-1.60	0.67	-1.57	-0.83
14.	G Cot 16 X GN Cot 26	-3.65**	-4.93	-1.52	-3.37	-4.53**	-5.41*	-6.93**	-5.63**
15.	G Cot 16 X GBHV 200	-0.52	-0.88	0.52	-0.29	1.06	0.26	4.49*	1.94
16.	G Cot 16 X GSHV 242	-3.90**	1.67	-2.96	-1.73	-1.37	1.56	1.43	0.54
17.	G Cot 16 X GISV 361	-1.16	-0.25	4.42*	1.01	-0.09	2.14	5.43*	2.49
18.	G Cot 16 X GBHV 253	-2.35	6.48*	5.99**	3.37	-0.63	3.16	5.69**	2.74
19.	GN Cot 26 X GBHV 200	-0.12	1.99	5.97**	2.62	-1.33	-0.94	1.18	-0.36
20.	GN Cot 26 X GSHV 242	5.57**	-1.20	6.64**	3.67	8.09**	1.80	13.84**	7.91**
21.	GN Cot 26 X GISV 361	1.10	3.10	-7.31**	-1.04	0.08	-0.95	-8.70**	-3.19
22.	GN Cot 26 X GBHV 253	-4.21**	-5.94*	0.73	-3.14	-2.33	-1.82	1.30	-0.95
23.	GBHV 200 X GSHV 242	2.39	-3.05	-4.12	-1.59	4.22**	0.87	2.37	2.49
24.	GBHV 200 X GISV 361	-1.49	-0.72	-3.24	-1.82	-3.60*	-5.45*	-5.88**	-4.98*
25.	GBHV 200 X GBHV 253	2.73*	-1.61	-3.99	-0.96	3.29*	0.83	-3.14	0.32
26.	GSHV 242 X GISV 361	-5.22**	-8.24**	-2.11	-5.19	-4.63**	-6.52**	-4.82*	-5.33**
27.	GSHV 242 X GBHV 253	4.07**	-0.49	-0.88	0.90	1.15	-4.41	-6.13**	-3.13
28.	GISV 361 X GBHV 253	6.99**	-2.73	2.86	2.37	5.95**	0.68	3.81	3.48
	S.E.sij ±	**1.29**	**2.44**	**2.21**	**2.13**	**1.52**	**2.29**	**2.25**	**1.95**

* and ** indicates significance at 5% and 1% level of probability, respectively

CONCLUSIONS

Studies on combining ability help to identify the best parents and provide genetic information on the inheritance pattern of traits. Among the eight parents, at Navsari, GN Cot 26 (5.54) and GBHV 200 (3.11); at Surat, GN Cot 26 (4.70) and GSHV 242 (3.18) while at Bharuch, GBHV 200 (4.14) identified as best combiners for this trait. Pooled over locations, GN Cot 26 (3.81) and GBHV 200 (2.43) manifested as good general combiners while GN Cot 22 (-4.35) was the worst combiner among the 8 parents for this trait. An analysis for the specific combining ability effect revealed that top three hybrids with significant and desirable(positive) SCA effect at Navsari centre were GSHV 242 X GBHV 253 (11.83) followed by GBHV 200 X GISV 361 (8.60) and G Cot 16 X GN Cot 26 (7.61). At Surat location, GBHV 200 X GISV 361 (23.26), GSHV 242 X GBHV 253 (21.28) and GN Cot 26 X GISV 361 (13.30) were the best three hybrids while at Bharuch, GSHV 242 X GBHV 253 (18.93) followed by G Cot 16 X GN Cot 26 (18.04) and GBHV 200 X GISV 361 (12.12) were top most hybrids with significant and desirable (positive) SCA effect.

Pooled over *i.e.*, Navsari (L_1), Surat (L_2) and Bharuch (L_3) centres; top three hybrids with significant and desirable (positive) SCA effect, across all the three centres (*i.e.* pooled over three centres) were GSHV 242 X GBHV 253 (17.35), GBHV 200 X GISV 361 (14.66) and G Cot 16 X GN Cot 26 (11.64).

FUTURE SCOPE

Breeders should be familiar with the genetic makeup of the relevant plant species in order to create an effective breeding strategy. GCA effect revealed that the parents, GN Cot 26 and GBHV 200 were identify as good general combiners at all three locations. Hence, these parents may be used in the crop improvement programmes aimed at improving seed cotton yield and yield contributing traits. SCA effect revealed that the crosses GBHV 200 X GISV 361 and GSHV 242 X GBHV 253 were best at most of the location. The analysis of variance revealed that non-additive gene action was playing principal role in controlling the traits at all the three locations as well as for pooled over locations excepted for day to 50% flowering and day to first picking at Surat (L_2) and Bharuch (L_3); plant height at Surat (L_2). In this scenario, hybridization followed by recurrent selection seems to be most suitable breeding method for cotton.

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