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# EVALUATION OF COMBINING ABILITY EFFECTS IN COTTON USING DIALLEL CROSSES UNDER DIFFERENT ENVIRONMENTS

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**ABSTRACT**

Combining ability analysis in cotton using a diallel (half diallel) of ten parents revealed the significance of both additive and non-additive genetic variances in controlling various traits. Ten parental lines, 45 hybrids and one standard check were evaluated in a Randomized Block Design with three replications at Cotton Research Station, Junagadh Agricultural University, Junagadh during *Kharif* 2024-25 over three environments created by three dates of sowing. However, the ratio of $\sigma^2gca/\sigma^2sca$ greater than unity for plant height which indicated that the pre dominance additive gene action. On the other hand, traits such as number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant exhibited lower $\sigma^2gca/\sigma^2sca$ ratios (<1), indicating the predominance of non-additive gene action. Parents, GBHV-260, GJHV-603 and GJHV-592 were good general combiner, whereas crosses GJHV-522 x GJ. Cot-101, GJHV-522 x GJHV-603 and GTHV-20/348 x GJHV-592 were found to be best specific combiner for seed cotton yield per plant. The best three hybrids for seed cotton yield per plant on the basis of *per se* performance *viz.*, GBHV-260 x GJHV-603 (good x good), GJHV-522 x GJHV-603 (poor x good) and GSHV-269 x GJHV-592 (average x good) had significant desirable sca effects. This indicated that generally one or both parents with good gca effects are desirable for producing high yielding hybrids.
**Keywords:** diallel, general combining ability, specific combining ability

## Introduction

Cotton, the 'white gold' enjoys a pre-eminent status among all cash crops in the country. It is grown commercially in the temperate and tropical regions of more than 70 countries. Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role as a cash crop in commerce of many countries *viz*., USA, China, India, Pakistan, Uzbekistan, Australia and Africa. It resides a distinctive position in the global trade because it is a very important agricultural and industrial crop. In cotton, four cultivated species are present and India is the only country where all these four species are being cultivated. In India, *G. hirsutum* occupies the prime position in cultivation for its yield and fibre qualities. For breeding high quality varieties of cotton, the genetic information of yield attributing parameters is very essential.

Combining ability describes the breeding value of parental lines to produce hybrids. Sprague and Tatum (1942) used the terms general combining ability (GCA) to designate the average performance of a line in hybrid combinations and specific combining ability (SCA) as deviation in performance of a cross combination from that predicted on the basis of the general combining abilities of the parents involved in the cross. In order to choose appropriate parents for hybridization as well as specific crosses, it is essential to determine the combining ability of parents and specific combining ability (SCA) of cross combinations

In breeding high yielding varieties of crop plants for quantitative and qualitative traits, plant breeders often face the problem of selecting parents and crosses. Selection of parents on the basis of phenotypic performance alone is not a sound procedure, since phenotypically superior lines may yield poor combinations as well as influenced by environment. Knowledge on genetic architecture of parents, in terms of yield and quality related characters would help in identifying superior cross combinations in early generation itself. Selection of superior parents with good combining ability for most of the yield contributing and quality parameters is the prime objective of any crop improvement programmes. Hence, identification of parents based on their combining ability is an important step to proceed further for hybridization and selection of superior segregants or to identify good hybrids for commercial exploitation. In combining ability, the genetic variability of each trait can be partitioned into GCA and SCA (Sprague and Tatum 1942). GCA effects explains about the additive type of gene action, whereas, SCA effects estimates the non-additive (dominant or epistasis) gene action. Importance of non-additive gene action is observed for different yield contributing traits.

## Materials and Methods

The experimental materials comprised of ten parents (GJHV-522, GBHV-260, GTHV-20/348, GJHV-600, GSHV-269, GJHV-602, GJHV-603, GJHV-592, GJ. Cot-101 and Suraj) along with 45 hybrids and one standard check (G. Cot.Hy-22) were evaluated in a randomized block design with three replications. The experiment was conducted at Cotton Research Station, Junagadh Agricultural University, Junagadh during *Kharif* 2024-25 over three environments ($E_1$= onset monsoon, $E_2$= 20 days after 1$^{st}$ sowing, $E_3$= 20 days after 2$^{nd}$ sowing). Five competitive plants per genotype were selected randomly in each environment were selected randomly for data observations *viz.*, plant height, number of monopodia per plants, number of sympodia per plants, number of bolls per plant, boll weight and seed cotton yield per plant. The combining ability analysis was done following Griffing (1956).

## Result and Discussion

### Analysis of Variance and Components of Variance

The analysis of variance of combining ability for six characters in three environments as well as pooled over environments is depicted in Table 1 and 2. The analysis of variance for combining ability revealed that both general combining ability (GCA) and specific combining ability (SCA) mean squares were significant for most of the characters across all three environments ($E_1$, $E_2$ and $E_3$) except plant height in $E_1$, indicating the importance of both additive and non-additive gene effects in the inheritance of yield and its related traits in cotton. For traits such as number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant the magnitude of GCA variance was higher than SCA variance in most environments. The $\sigma^2$gca/$\sigma^2$sca ratio greater than unity except $E_3$ for plant height. This suggested the predominance of additive gene action for these traits, thereby indicating the effectiveness of selection in early generations for improving earliness in cotton. Similar trends were also observed for plant height in $E_1$ and $E_2$ where higher GCA variance indicated the role of additive genetic effects. In contrast, traits such as number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant exhibited lower $\sigma^2$gca/$\sigma^2$sca ratios (<1) across environments, indicating the predominance of non-additive gene action.

The pooled analysis of variance for combining ability revealed highly significant differences for both general combining ability (GCA) and specific combining ability (SCA) for all the characters studied, indicating the presence of substantial genetic variability among the parents and hybrids in cotton. Significant environmental effects were also observed for all the traits, suggesting that the environments considerably influenced the expression of these characters. Moreover, significant GCA × environment and SCA × environment interactions for several traits indicated differential performance of genotypes across environments. The estimates of GCA variance were higher than SCA variance for all the trait. The $\sigma^2$gca/$\sigma^2$sca ratios was greater than unity for plant height. This indicated the predominance of additive gene action in the inheritance these traits. Therefore, improvement of these characters through simple selection methods would be effective. Additive gene action has been finding worker for plant height (Sawarkar *et al*.,2015). On the other hand, traits such as number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant exhibited lower $\sigma^2$gca/$\sigma^2$sca ratios (<1), indicating the predominance of non-additive gene action.

As observed in the present study, the pre dominant role of non-additive gene action in the inheritance of seed cotton yield per plant was reported by Dave *et al*. (2015); Sawarkar *et al*. (2015); Usharani *et al*. (2016); Monicashree *et al*. (2017); Khokhar *et al*. (2018); Thiyagu *et al*. (2019), Bankar *et al*. (2020); Sudha Rani *et al*. (2020); Kanasagra *et al*. (2022) Muhammad *et al*. (2023) and Karthickeyan *et al.* (2025). Non-additive gene action has been observed in other crucial agronomic traits like number of monopodia and sympodia per plant (Sawarkar *et al*., 2015; Usharani *et al*.,2016; Monicashree *et al*., 2017; Khokhar *et al*., 2018; Thiyagu *et al*., 2019; Bankar *et al*., 2020; Sudha Rani *et al*., 2020; Kanasagra *et al*., 2022 and Madhu *et al*., 2023, Muhammad *et al*., 2023 and Karthickeyan *et al.*, 2025) and reproductive traits like number of bolls per plant (Dave *et al*. 2015; Sawarkar *et al*., 2015; Usharani *et al*., 2016; Khokhar *et al*., 2018; Thiyagu *et al*., 2019; Bankar *et al*., 2020; Sudha Rani *et al*., 2020; Chakholoma *et al*., 2022; Kanasagra *et al*., 2022; Muhammad *et al*., 2023 and Karthickeyan *et al.*, 2025) and boll weight (Madhu *et al*., 2023, and Karthickeyan *et al.*, 2025).

Mean squares due to environments, GCA was significant for all the characters in all environment. Likewise, mean squares due to GCA x E were significant for all the characters except plant height and number of bolls per plant. Moreover, mean squares due to SCA x E were significant for all the characters except plant height (Table 2).

**General combining ability effects**

The summary of general combining ability effects of parents for different characters based on pooled environments are presented Table 3. The parents were classified as good, average and poor combiners for different characters. The persual of general combining ability effects of parents revealed that parents, GBHV-260, GJHV-603 and GJHV-592 were good general combiner for seed cotton yield per plant having concentrated favourable genes indicated by significant and positive gca effects for these parents. Besides having good general combining ability effects for seed cotton yield per plant, Parent GBHV-260 was also good general combiner for plant height and number of bolls per plant; GJHV-603 was observed good general combiners for plant height, number of monopodia per plant and number of bolls per plant and parent GJHV-592 was observed good general combiner for number of bolls per plant. The high gca effects for seed cotton yield per plat also reported by Dave, *et al*. (2015); Sawarkar *et al*.,(2015); Ankit Kumar *et al.*, (2018); Ganansekaran and Padmavati (2017); Kumbhalkar *et al*., (2018); Monicashree *et al.* (2017); Rathava *et al*,.(2018); Gnanasekaran *et al.*, (2019); Thiyagu *et al.*, (2019); Vadodariya *et al.*, (2022); Mudhalvan *et al.*, (2021) and Muhammad *et al*, (2023).

**Specific combining ability effects**

The estimates of sca effects revealed that none of the top ten crosses was consistently superior for all the characters (Table-4). The hybrid GJHV-522 x GJ. Cot-101 had significant and high sca effect (40.24) for seed cotton yield per plant which involve poor x average combiner parents. This cross also expressed significant and desirable sca effects for plant height, number of sympodia per plant and number of bolls per plant. Based on *per se* performance, cross GBHV-260 x GJHV-603, GJHV-522 x GJHV-603 and GSHV-269 x GJHV-592 had significant positive and desirable sca effects and heterosis effects for seed cotton yield per plant (Table-5). Cross GBHV-260 x GJHV-603 involved good x good general combiner for seed cotton yield per plant. This cross also possessed significant and desirable effects for plant height and boll weight. The significant SCA effects for seed cotton yield per plant and different components traits were also recorded by many workers *viz*., Dave *et al* (2015); Usharani *et al*. (2016); Ankit Kumar *et al*. (2018); Monicashree *et al*. (2017); Kumbhalkar *et al.* (2018); Rathava *et al*. (2018); Gnanasekaran *et al*. (2019); Deshmukh *et al*. (2021); Chakholoma *et al*. (2022); Kansagra *et al*. (2022); Vadodariya *et .al* (2022); Vaid *et al.* (2022) and Muhammad *et al*. (2023).

In contrast to general combining ability and specific combining ability components of variation, which are non- fixable in nature. But the cross showing high SCA effects involving either both or one good general combining parents could be successfully exploited for varietal improvement and expected to show stable performance in transgressive segregants carrying fixable gene effects. The cross combinations involving good x poor or average x poor general combiner besides exhibiting favourable additive effects of good or average combining parents, manifested complementary interaction effect and thus resulted in higher SCA effects. In the present study, such combinations seed cotton yield per plant were GJHV-522 x GJ. Cot-101, GTHV-20/348 x GJHV-602 and GTHV-20/348 x Suraj. These crosses may be expected to throw transgressive yielding ability with stable performance. The hybrid GBHV-260 x GJHV-603 involving both the good general combiner parents offer still better possibilities of exploitation of additive x additive type of gene interaction as they are expected to yield stable segregants in the advance generations and need further exploitation in the breeding programme.

The pooled analysis (Table 5) revealed significant differences among parents and hybrids for all the characters studied, indicating the presence of substantial genetic variability. Significant positive SCA effects for plant height were observed in GBHV-260 × GJHV-603, GTHV-20/348 × GJHV-603 and GJHV-602 x GJHV-592. Yield contributing traits, including number of monopodia, sympodia, and bolls per plant were superior in crosses involving GJHV-522, particularly GJHV-522 × GJ. Cot-101 and GJHV-522 × GJHV-603. For boll weight, crosses GBHV-260 × GJHV-603, GJHV-592 × GJ. Cot-101 and GJHV-592 x Suraj performed good. Seed cotton yield per plant was highest in GJHV-522 × GJ. Cot-101 and GJHV-522 × GJHV-603 followed by GTHV-20/348 × GJHV-592.

The significant variation observed among genotypes indicates the presence of adequate genetic diversity, which is essential for effective selection and hybridization programmes. The predominance of significant SCA effects for most traits, especially seed cotton yield and its components, suggests the major role of non-additive gene action.

## Conclusion

The result indicated that *per se* performance of parents and hybrids was related with gca effects of parents and heterotic response of the hybrids, respectively. Therefore, the potentiality of a strain to be used as a parent in hybridization programme or a cross to be used as a commercial hybrid may be judged by comparing *per se* performance, high heterosis and significant desirable sca effect for various traits involved either good x good or good x average or poor x average or poor x poor combining parents. Thus, the crosses exhibiting high sca effect did not always involve the parents with high gca effects. The results, thus suggested that intrallellic interaction were also important for these characters. The best three hybrids for seed cotton yield per plant on the basis of *per se* performance *viz.*, GBHV-260 x GJHV-603 (good x good), GJHV-522 x GJHV-603 (poor x good) and GSHV-269 x GJHV-592 (average x good) had significant desirable sca effects. This indicated that generally one or both parents with good gca effcest are desirable for producing high yielding hybrids.

In present study, no one crosses combination exhibited consistently high sca effects for all the characters. The crosses displaying high sca effects did not always involve both the parents with high gca effects, suggesting that the interallelic interactions were important for the characters.

**Table 1 :** Analysis of variance and variance components of combining ability for individual environments for different characters in cotton

| Characters | D. F | GCA 9 | SCA 45 | Error 108 | $\sigma^2$gca | $\sigma^2$sca | $\sigma^2$gca/ $\sigma^2$sca |
|---|---|---|---|---|---|---|---|
| | Env. | | | | | | |
| Plant height (cm) | $E_1$ | 472.35** | 50.35 | 47.89 | 35.36 | 2.45 | 14.38 |
| | $E_2$ | 467.31** | 69.36* | 43.36 | 35.32 | 26.00 | 1.35 |
| | $E_3$ | 308.55** | 72.05* | 35.96 | 22.69 | 36.08 | 0.62 |
| Number of monopodia per plant | $E_1$ | 0.49** | 0.16** | 0.01 | 0.03 | 0.14 | 0.27 |
| | $E_2$ | 0.24** | 0.13** | 0.01 | 0.01 | 0.12 | 0.16 |
| | $E_3$ | 0.10** | 0.09** | 0.01 | 0.007 | 0.08 | 0.10 |
| Number of sympodia per plant | $E_1$ | 7.26** | 4.48** | 0.53 | 0.56 | 3.94 | 0.14 |
| | $E_2$ | 6.37** | 3.86** | 0.41 | 0.49 | 3.45 | 0.14 |
| | $E_3$ | 2.35** | 1.68** | 0.34 | 0.16 | 1.34 | 0.12 |
| Number of bolls per plant | $E_1$ | 116.15** | 46.49** | 8.46 | 8.97 | 38.03 | 0.23 |
| | $E_2$ | 78.65** | 46.16** | 7.54 | 38.70 | 38.70 | 0.15 |
| | $E_3$ | 77.57** | 39.71** | 4.62 | 35.09 | 35.09 | 0.17 |
| Boll weight (g) | $E_1$ | 0.20** | 0.07** | 0.01 | 0.01 | 0.06 | 0.28 |
| | $E_2$ | 0.14** | 0.07** | 0.01 | 0.01 | 0.05 | 0.11 |
| | $E_3$ | 0.29** | 0.15** | 0.01 | 0.02 | 0.14 | 0.08 |
| Seed cotton yield per plant (g) | $E_1$ | 1115.68** | 567.07** | 85.88 | 45.72 | 482.06 | 0.17 |
| | $E_2$ | 1234.75** | 515.71** | 72.37 | 96.86 | 433.34 | 0.21 |
| | $E_3$ | 551.58** | 293.16** | 44.29 | 42.27 | 248.86 | 0.16 |

**Table 2 :** Analysis of variance (mean squares) for combining ability and estimates of component of variance for different characters in pooled over environments in cotton

| Characters/d.f | GCA | SCA | ENV's (E) | GCA x E | SCA x E | Error | $\sigma^2$gca | $\sigma^2$sca | $\sigma^2$gca/$\sigma^2$sca |
|---|---|---|---|---|---|---|---|---|---|
| | 9 | 45 | 2 | 18 | 90 | 324 | - | - | - |
| Plant height (cm) | 1183.93** | 117.45** | 10333.28** | 31.98 | 37.15 | 42.40 | 31.70 | 25.01 | 1.26 |
| Number of monopodia per plant | 0.71** | 0.30** | 3.54** | 0.06** | 0.03** | 0.01 | 0.02 | 0.09 | 0.20 |
| Number of sympodia per plant | 9.46** | 6.05** | 494.52** | 3.25** | 1.98** | 0.43 | 0.25 | 1.87 | 0.13 |
| Number of bolls per plant | 251.23** | 92.62** | 1228.59** | 10.57 | 19.86** | 6.84 | 6.78 | 28.59 | 0.24 |
| Boll weight (g) | 0.49** | 0.17** | 1.20** | 0.07** | 0.05** | 0.01 | 0.01 | 0.05 | 0.25 |
| Seed cotton yield per plant (g) | 2590.87** | 1044.39** | 28563.56** | 155.56** | 165.76** | 67.22 | 70.10 | 325.72 | 0.21 |

* and ** significant at 5 and 1 per cent levels, respectively

**Table 3 :** Summary table showing the status of general combining ability effect of parents over environments for different characters in cotton

| Sr no. | Characters/ Parents | GJHV -522 | GBHV -260 | GTHV -20/348 | GJHV -600 | GSHV -269 | GJHV -602 | GJHV -603 | GJHV -592 | GJ. Cot-101 | Suraj |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Plant height (cm) | A | G | G | P | G | G | G | A | A | P |
| 2 | Number of monopodia per plant | P | A | P | A | G | G | G | A | A | A |
| 3 | Number of sympodia per plant | A | A | A | P | A | A | A | A | G | A |
| 4 | Number of bolls per plant | A | G | P | P | P | A | G | G | G | A |
| 5 | Boll weight (g) | P | A | A | G | G | G | A | A | P | A |
| 6 | Seed cotton yield per plant (g) | P | G | P | P | A | A | G | G | A | A |

Where G, A and P indicate good, average and poor general combining ability of parents, respectively.

**Table 4 :** Top ten crosses based on SCA effects for seed cotton yield per plant on pooled basis and its component characters showing desirable SCA effects across the environments

| Sr. No | Crosses | Seed cotton yield per plant | Components character showing desirable SCA effects |
|---|---|---|---|
| 1 | GJHV-522 x GJ. Cot-101 | 40.24** (P x A) | PH, NSP, NB, |
| 2 | GJHV-522 x GJHV-603 | 34.49** (P x G) | PH, NMP, NSP, NB |
| 3 | GTHV-20/348 x GJHV-592 | 28.37** (P x G) | NMP, NB, BW |
| 4 | GBHV-260 x GJHV-603 | 26.37** (G x G) | PH, BW |
| 5 | GJHV-522 x GTHV-20/348 | 26.18** (P x P) | NB |
| 6 | GSHV-269 x GJHV-592 | 23.88** (A x G) | PH, NB |
| 7 | GBHV-260 x GJ. Cot-101 | 19.35** (G x A) | ---- |
| 8 | GTHV-20/348 x GJHV-602 | 18.80** (P x A) | NB |
| 9 | GJHV-592 x Suraj | 16.63* (G x A) | NMP, BW |
| 10 | GTHV-20/348 x Suraj | 16.40* (P x A) | PH, NMP |

* and ** significant at 5 and 1 per cent levels, respectively

G, A and P indicate good, average and poor general combining ability of parents, respectively.

PH= Plant height, NMP= Number of monopodia per plant, NSP= number of sympodia per plant, BW= Boll weight, NB= Number of bolls per plant,

**Table 5 :** Summary of three best per se performance, best general combiners and best per se cross along with their SCA effects, as well as the best specific cross combinations along with their SCA effects for different characters in pooled environment in cotton

| Characters | Best *per se* Parents | Best general combiners | Best *per se* crosses | sca effects of best *per se* crosses | Best specific combinations based on sca effects | sca effects of best specific combinations |
|---|---|---|---|---|---|---|
| **Plant height (cm)** | GSHV-269 | GJHV-603 | GBHV-260 x GJHV-603 | 15.54** | GBHV-260 x GJHV -603 | 15.54** |
| | GJHV-603 | GSHV-269 | GTHV-20/348 x GJHV-603 | 13.24** | GTHV-20/348 x GJHV 603 | 13.24** |
| | GJHV 602 | GJHV-602 | GJHV-602 x GJHV-592 | 10.96** | GJHV 602 x GJHV 592 | 10.96** |
| **Number of monopodia per plant** | GJHV 602 | GJHV-602 | GJ.Cot-101 x Suraj | 0.71** | GJHV-522 x GJHV-603 | 0.81** |
| | GJHV-600 | GJHV-603 | GBHV-260 x GSHV-269 | 0.65** | GJ.Cot-101 x Suraj | 0.71** |
| | GSHV-269 | GSH- 269 | GJHV-522 x GJHV-603 | 0.81** | GBHV 260 x GSHV 269 | 0.65** |
| **Number of sympodia per plant** | GJHV-602 | GJ.Cot-101 | GJHV-522 x GJ.Cot.101 | 2.37** | GJHV -522 x GJ.Cot-101 | 2.37** |
| | GJ.Cot-101 | - | GJHV-603 x GJ.Cot-101 | 1.43 | GJHV-522 x GJHV-603 | 2.22* |
| | Suraj | - | GJHV-592 x GJ.Cot-101 | 0.85 | GBHV-260 x GJHV 603<br>GTHV-20/348 x GSHV-269 | 2.09**<br>2.09** |
| **Number of bolls per plant** | GJHV-603 | GJHV- 603 | GJHV-522 x GJ.Cot-101 | 15.72** | GJHV-522 x GJ.Cot-101 | 15.72** |
| | GJHV-592 | GJHV-592 | GJHV- 522 x GJHV-603 | 9.10** | GJHV 522 x GJHV 603 | 9.10** |
| | GBHV-260 | GJ.Cot-101 | GJHV-603 x GJ.Cot-101 | 3.02 | GJHV 522 x GJHV 602 | 6.97** |
| **Boll weight (g)** | GJHV-600 | GSHV -269 | GJHV-600 x GSHV-269 | 0.17 | GBHV-260 x GJHV 603 | 0.42** |
| | GSHV-269 | GJHV-600 | GSHV-269 x GJHV-602 | 0.16 | GJHV 592 x GJ.Cot-101 | 0.41** |
| | GJHV-602 | GJHV-602 | GJHV-592 x Suraj | 0.29* | GJHV-592 x Suraj | 0.29* |
| **Seed cotton yield per plant (g)** | GBHV-260 | GJHV- 603 | GBHV-260 x GJHV-603 | 26.37** | GJHV-522 x GJ.Cot-101 | 40.24** |
| | GJHV-603 | GJHV-592 | GJHV-522 X GJHV-603 | 34.49** | GJHV-522 x GJHV-603 | 34.49** |
| | GJHV-592 | GBHV-260 | GSHV-269 x GJHV-592 | 23.88** | GTHV 20/348 x GJHV-592 | 28.37** |

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