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# COMBINING ABILITY ANALYSIS FOR YIELD AND PHYSIOLOGICAL DROUGHT RELATED TRAITS IN TOMATO (*SOLANUM LYCOPERSICUM* L.) UNDER MOISTURES STRESS

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## ABSTRACT

Eighteen parents were crossed in line X tester fashion comprising 15 lines and 3 testers to estimate combining ability in tomato for fruit yield, yield components and drought tolerant traits. F1 and parents were evaluated under stress (10 days and 15 days irrigation interval) and irrigated conditions. For fruit yield per plant, the top five crosses EC310301 X EC164654 (251.33), EC 251578 X EC 164654 (304.82), IC249512 X IC249503 (381.70), EC162516 X IC249503 (468.85) and EC164845 X IC249505 (571.92) having high and positively significant *sca* effects under irrigated normal condition. Whereas, in stressed condition IC249512 X IC249503 (258.06), IC249512 X EC164654 (260.16), EC310301 X EC164654 (314.06), EC162516 X IC249505 (388.34) and EC164845 X IC249505 (469.54) having high and positively significant *sca* effects. Based on results, the genotypes EC251578, IC249512, EC162516, EC249503 and EC164654 recorded high positive *gca* effects. IC249512, EC164845, EC249505 and EC164654 are ideal choice for yield under stressed condition. IC249512 was good performer for most of the traits in both irrigated and stressed conditions. Three parents EC162516, EC249505 and EC168096 are identified as good general combiners with high yield potential in drought environment. So, these lines are reliable for further drought tolerance breeding.

## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the widely grown vegetable crops cultivated for its fleshy fruits in the world. Tomato is protective supplementary food and considered as important commercial and dietary vegetable crop. As it is short duration crop and gives high yield, it is important from economic point of view and hence area under its cultivation is increasing day by day. In India tomato ranks second among vegetables in area and production, which is grown over an area of 9,33,250 ha with annual production of 193,77,440 MT and productivity of 20.8MT/ha (Indian Horticulture Database 2012-13).

To meet the ever increasing demand for this vegetable crop, there is a need for development of hybrids and varieties with improvement in yield, quality and resistance to different biotic and abiotic stresses. Plants are exposed to a range of environmental stresses and have to adapt physiologically to them as the local environment changes. Insufficient availability of water *i.e.*, drought, is presumably the most common stress experienced by plants. Drought is one of the main factors for the yield loss in plants. Drought is the major inevitable and recurring feature of semi-arid tropics. Drought tolerance is the ability of plants to survive water deficit stress and to maintain plant growth under water deficit conditions (Nahar and Gretzmacher, 2011). Moreover in recent years, due to dramatic change in climatic conditions from the effect of global warming, drought stands as first problem for the crop production. Breeders and biotechnologist are much focused on development of drought resistant or tolerant crops. Drought resistant crop plants would provide a great benefit to the global market. Especially arid and semi-arid areas of the planet would benefit the most from such an invention (Roberto Gaxiola, 2006).

During the course of the last century, tomato varietal improvement programme has been based on various standard breeding methods. Tomato improvement occurred due to increasing exploitation of exotic resources and introgression of new valuable genes into the tomato gene-pool (Shende *et al.,* 2012). Tomato breeders prefer hybrid breeding to varietal breeding, not only because it is comparatively easier to incorporate desirable characteristics in F1 hybrid but also the right of the bred hybrid is protected in terms of parental lines. Identification and selection of flexible parental lines are required to be used in any hybridisation programme to produce genetically modified and potentially rewarding germplasm by assembling fixable gene effects more or less in a homozygous line. Information pertaining to different types of gene action, relative magnitude of genetic variance, and combining ability estimates are important and vital parameters to mould the genetic makeup of tomato crop. This important information could prove an essential strategy to tomato breeders in the screening of better parental combinations for further enhancement.

There are several techniques for the evaluation of varieties or strains in terms of their combining ability especially line x tester analysis is one of them. This technique was developed by Kempthorne in 1957. Keeping in view with the above problem, the present investigation is taken up with the following objectives: To study the general and specific combining ability of parents and crosses for yield and yield contributing characters and to study the relative performance of parents and $F_1$'s for various characters under stress and irrigated conditions.

## MATERIALS AND METHODS

Tomato is generally grown under irrigated conditions, and its cultivation as a rainfed crop has gained importance particularly in semi-arid region. It is therefore very important to obtain information on the drought resistance mechanisms and incorporate drought tolerant traits in breeding programme for crop improvement. Hence, this experiment was undertaken during 2011-2013 at Vegetable Research Station, Dr.Y.S.R.H.U, Rajendranagar, Hyderabad. Field imposed irrigation treatments with an interval of 10 days and 15 days irrigation interval (DII)

The 45 $F_1$'s obtained were evaluated along with parents and commercial checks for yield, yield contributing various characters under stress and irrigated conditions. Plants uprooted carefully with the help of crow bar without causing damage to the root portion. Roots were washed thoroughly with water and the root and shoot portions were separated. These root and shoot parts were allowed to dry in an oven at 80°C till constant dry weights were obtained and root to shoot dry weight ratio was calculated

Stomatal diffusive resistance (SDR) was recorded at 60 days after transplanting between 11.00 hr and 12.00 hrs using LI 6400 XT portable photosynthesis system and expressed in seconds per centimeter. To measure the RWC, the leaves were sampled at fixed time of the day. Fully opened physiologically functional leaf from top was selected. Fresh weight of the samples was recorded by detaching the petiole. The leaf samples were kept in water for overnight to attain turgidity. The turgid weight of sample was recorded. After oven drying at 72ºC for 48 hours, dry weight of sample was recorded (Bars and Weatherly, 1962). The relative leaf water content (RWC) was estimated and expressed in per cent by using the equation given below

Leaf area was measured by taking five leaves from each sample plant were taken and the leaf area was measured with the CI-202 portable laser leaf area meter and mean value was expressed in square centimetres. Specific leaf weight (SLW), differs significantly among the genotypes under moisture stress. Specific leaf weight were estimated in sq.cm and was measured with leaf area meter, then the leaf samples were dried in hot air oven at 80°C for 48 hours and the weight was recorded in milligrams. Specific leaf weight was calculated by using the formula

$$\text{Specific leaf weight (mg/sq.cm)} = \frac{\text{Dry weight of the leaf in milligrams}}{\text{Area of the leaf in sq.cm.}}$$

**Table 1: Analysis of variance for combining ability for 22 traits under control, 10 days and 15 days moisture stress treatments**

| S. no | Source | df | Fruit yield (g) Control | 10 days | 15 days | Shoot dry weight (g) Control | 10 days | 15 days | Root dry weight (g) Control | 10 days | 15 days | RDW/ SDW Control | 10 days | 15 days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Replication | 2 | 9118.6 | 10635.00 | 59126 | 0.30 | 0.03 | 0.66 | 1.35 | 3.35 | 1.86 | 0.002 | 0.003 | 0.001 |
| 2. | Parents | 17 | 28127.4 | 84120.47 | 85344 | 1537.00** | 1511.00** | 1495.45** | 145.12** | 185.88** | 196.86** | 0.040** | 0.048** | 0.056** |
| 3. | Parents (Line) | 14 | 21025.9 | 84714.67 | 57064 | 1777.43** | 1739.05** | 1719.84** | 149.28** | 198.84** | 211.90** | 0.042** | 0.052** | 0.061** |
| 4. | Parents (Testers) | 2 | 28970.7 | 81154.00 | 48714 | 32.34* | 15.05** | 10.36** | 4.93* | 7.61** | 10.26** | 0.004 | 0.010** | 0.013** |
| 5. | Line VS Tester | 1 | 125872.0** | 81748.00 | 554524** | 1180.38** | 1310.09** | 1324.24** | 367.34** | 361.02** | 359.61** | 0.088** | 0.067** | 0.072** |
| 6. | F1's | 44 | 257149.1** | 243398.80** | 168766** | 1495.06** | 1511.84** | 1493.30** | 183.61** | 185.88** | 190.87** | 0.120** | 0.143** | 0.170** |
| 7. | Parents VS Hybrids | 1 | 27712.0 | 50592.00 | 106960** | 40.39** | 0.16 | 12.27** | 7.79** | 13.73** | 28.00** | 0.001 | 0.037** | 0.076** |
| 8. | Error | 124 | 27752.6 | 68152.25 | 84569 | 10.50 | 0.03 | 0.05 | 1.56 | 0.20 | 0.04 | 0.002 | 0.000 | 0.000 |

**Table 1: Cont.....**

| S. No. | Source | df | SDR (sec/cm) Control | 10 days | 15 days | Relative Water content Control | 10 days | 15 days | Leaf area (sq.cm) Control | 10 days | 15 days | Specific leaf weight (mg/sq.cm) Control | 10 days | 15 days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Replication | 2 | 0.3 | 0.57 | 0.01 | 4.0 | 3.36 | 3.76 | 0.2 | 0.24 | 0.29 | 5504.7 | 27164.00 | 19596.00 |
| 2. | Parents | 17 | 68.7** | 67.83** | 69.51** | 381.0** | 360.80** | 340.76** | 2110.5** | 2084.33** | 2096.37** | 16915.6 | 32506.98 | 41286.59 |
| 3. | Parents (Line) | 14 | 21.8** | 22.35** | 22.17** | 422.6** | 397.24** | 370.29** | 2267.8** | 2234.06** | 2247.38** | 20121.1 | 36019.24 | 31533.14 |
| 4. | Parents (Testers) | 2 | 7.6** | 9.22** | 17.10** | 273.2** | 279.79** | 294.81** | 40.6** | 37.66* | 40.00** | 2221.2 | 10466.00 | 59034.33* |
| 5. | Line VS Tester | 1 | 847.7** | 821.74** | 837.12** | 14.8** | 12.68 | 19.24** | 4048.5** | 4081.32** | 4095.01** | 1427.0 | 27420.00 | 142330.00** |
| 6. | F1's | 44 | 25.7** | 24.79** | 24.64** | 225.6** | 232.51** | 225.71** | 2047.1** | 2091.42** | 2148.86** | 27061.0** | 30875.27 | 84868.84** |
| 7. | Parents VS Hybrids | 1 | 69.5** | 91.96** | 121.87** | 194.6** | 140.63** | 132.28** | 12.6 | 220.94** | 1084.69** | 2808.0 | 184336.00** | 347920.00** |
| 8. | Error | 124 | 0.005 | 0.03 | 0.17 | 1.0 | 1.66 | 1.96 | 0.8 | 0.14 | 0.17 | 11891.2 | 22000.50 | 25417.70 |

**Table 2: Estimates of *gca* effects for lines and testers for fruit yield (g), shoot dry weight (g), root dry weight (g) and RDW/SDW traits in tomato under irrigation (control) and drought stress (10 and 15 days irrigation interval) conditions**

| Source | Fruit yield (g) Control | 10 days | 15 days | Shoot dry weight (g) Control | 10 days | 15 days | Root dry weight (g) Control | 10 days | 15 days | RDW/SDW Control | 10 days | 15 days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC251578 | 339.74** | 295.59** | 47.31 | -12.34** | -12.27** | -12.45** | -9.82** | -9.75** | -10.02** | -0.19** | -0.21** | -0.23** |
| NS537 | -154.57** | -39.98 | -98.33 | 36.54** | 36.61** | 36.41** | 8.67** | 8.59** | 8.48** | -0.05** | -0.05** | -0.05** |
| EC162516 | 254.18** | -77.62 | -67.33 | 23.03** | 22.79** | 22.49** | 10.31** | 10.13** | 10.01** | 0.03** | 0.03* | 0.03** |
| EC164845 | 53.00 | 176.72* | 164.79* | -5.54** | -5.25** | -5.23** | -3.35** | -3.43** | -3.42** | -0.06** | -0.07** | -0.07** |
| IC249512 | 324.77** | 358.97** | 329.37** | -19.70** | -19.55** | -19.69** | -6.62** | -6.69** | -6.82** | -0.04** | -0.05** | -0.06** |
| EC165952 | -99.06 | -13.33 | 1.60 | -11.20** | -11.23** | -11.11** | 1.92** | 1.96** | 1.86** | 0.12** | 0.13** | 0.13** |
| EC164665 | -220.14** | -132.28 | -143.98 | -24.42** | -24.64** | -24.35** | 1.25** | 1.21** | 1.07** | 0.40** | 0.44** | 0.46** |
| IC249511 | 20.83 | -269.05** | -81.82 | 6.44** | 6.52** | 6.61** | 9.41** | 10.45** | 10.50** | 0.13** | 0.15** | 0.16** |
| EC168096 | -58.07 | -20.19 | 20.44 | -13.49** | -14.30** | -14.16** | -4.94** | -4.98** | -5.26** | -0.04** | -0.04** | -0.05** |
| EC164677 | -20.68 | 18.57 | -46.16 | -21.67** | -21.36** | -20.81** | -8.72** | -8.36** | -8.52** | -0.10** | -0.09** | -0.12** |
| EC162600 | -53.54 | 51.10 | 2.73 | 46.09** | 46.52** | 45.86** | 0.58 | 0.47** | 0.35** | -0.17** | -0.17** | -0.17** |
| EC310301 | -323.66** | -386.89** | -257.88** | -25.16** | -25.12** | -25.15** | -8.39** | -8.54** | -8.39** | -0.04** | -0.06** | -0.07** |
| EC635525 | -0.14 | 106.09 | 11.59 | 15.77** | 15.96** | 15.87** | 3.38** | 3.23** | 3.61** | -0.04** | -0.04** | -0.03** |
| IC249513 | -67.96 | -88.87 | 61.63 | 7.77** | 7.54** | 7.55** | 2.89** | 2.81** | 3.01** | -0.01 | -0.01 | -0.01 |
| EC241148 | 5.29 | 21.18 | 56.02 | -2.13** | -2.23** | -1.83** | 3.45** | 2.89** | 3.53** | 0.07** | 0.05** | 0.07** |
| SEi | 43.31 | 73.92 | 75.79 | 0.05 | 0.05 | 0.06 | 0.23 | 0.08 | 0.05 | 0.004 | 0.00 | 0.003 |
| EC164654 | 10.77** | 44.63 | 7.61 | 1.07** | 0.58 | 0.38** | 0.91** | 1.05** | 1.08** | 0.00 | 0.01 | 0.01 |
| IC249503 | 32.21** | 13.92 | -56.98 | -3.03** | -3.42** | -3.78** | -0.77** | -0.81** | -0.84** | 0.02 | 0.03** | 0.03** |
| IC249505 | -42.98** | -58.56* | 49.37 | 1.96** | 2.84** | 3.39** | -0.14 | -0.24** | -0.24** | -0.03 | -0.04** | -0.04** |
| SE | 16.37 | 27.94 | 28.65 | 0.02 | 0.02 | 0.02 | 0.09 | 0.03 | 0.03 | 0.002 | 0.00 | 0.001 |

Combining ability was estimated based on the method of Kempthorne (1957). The estimates of general and specific combining ability effects (gca and *sca*) and their variances were obtained by using covariance of half sibs and full sibs.

## RESULTS

The analysis of variance (ANOVA) for combining ability revealed the existence of significant variation for eight characters, representing a wide range of variability among the genotypes. Highly significant variation due to *gca* as well as *sca* indicated the importance of additive as well as non-additive types of gene action of inheritance for all the traits except the number of fruits per plant were presented in Table 1. The ANOVA revealed that the parents as well as crosses exhibited significant differences for all the traits studied except for fruit yield and specific leaf weight, (10 and 15 DII), whereas parents *vs* crosses exhibited significant differences for 8 traits (control), in 10 days irrigation interval except for yield and SDW. The effects of lines were found to be significant for all the traits studied except for specific leaf weight, fruit yield per plant, specific leaf weight (10 DII) fruit yield per plant, specific leaf weight(15 days irrigation interval). Whereas the effects of testers were non significant for average yield per plant, RDW/SDW and specific leaf weight (control), number of fruits per plant, fruit yield per plant, specific leaf weight (10 DII), fruit yield per plant (15 DII) .

The interaction effects (Lines X Testers) were found to be significant for all the traits except for specific leaf weight (control). Further, the mean sum of squares attributed to the male and female parents of hybrids provide a measure of their *gca* and the interaction between the male and female parents provide a measure of *sca*. In general, the hybrids were early in maturity and high yielding compared to the parents, which is desirable and exploited for development of high yielding hybrids.

### General combining ability

The summery of the *gca* effects of the parents (Table 2 and 3) revealed that, the line EC251578, IC249512, EC162516 and the tester EC249503 and EC164654 exhibited highly significant and positive *gca* effects and are adjudged as good general combiners for fruit yield per plant. Under 10 DII among the lines, IC249512, EC251578 and EC164845 recorded significant positive *gca* effects. Under 15 DII among the lines, IC249512 and EC164845 recorded significant positive *gca*. Among the testers positive significant *gca* effect was revealed by EC164654.

GCA effects differed according to the stress and non stress conditions the lines, NS537and EC162516, IC249512, EC635525 and IC249513 recorded significant positive *gca* effects for shoot dry weight. Among the testers positive significant *gca* effect was displayed by EC164654, while under 10 DII, EC162600, NS 537, and EC162516 recorded significant positive *gca* effects while among the testers positive significant *gca* effect was exhibited by IC249505 for shoot dry weight. The line which exhibited highest significant positive gca effect under 15 DII was EC162600, NS 537 and EC162516 while, among the testers positive significant *gca* effect was exhibited by IC249505. This implied that among the testers,

**Table 3: Estimates of *gca* effects for lines and testers for stomatal diffusive resistance (sec/cm), relative water content, leaf area (sq.cm) and specific leaf weight (mg/sq.cm) traits in tomato under irrigation (control) and drought stress (10 and 15 days irrigation interval) conditions**

| Source | Stomatal diffusive resistance (sec/cm) | | | Relative water content (%) | | | Leaf area (sq.cm) | | | Specific leaf weight (mg/sq.cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 10 days | 15 days | Control | 10 days | 15 days | Control | 10 days | 15 days | Control | 10 days | 15 days |
| EC251578 | -3.69** | -3.66** | -3.39** | -7.71** | -8.84** | -7.82** | -14.58** | -13.77** | -15.17** | -2.58 | -9.41 | 30.98 |
| NS537 | -2.02** | -2.03** | -1.91** | -9.11** | -9.71** | -9.83** | -15.61** | -15.15** | -14.86** | 96.42** | 43.84 | 60.95 |
| EC162516 | 0.36** | 0.36** | 0.19 | 1.65** | 2.47** | 1.95** | 43.76** | 44.09** | 44.37** | -73.16* | -94.04* | -114.46* |
| EC164845 | -2.57** | -2.62** | -2.70** | -0.33 | 0.52 | -0.61 | -16.82** | -17.00** | -16.70** | -32.19 | -22.06 | -59.44 |
| IC249512 | -3.35** | -3.29** | -2.76** | -9.87** | -9.22** | -9.59** | -8.25** | -7.93** | -7.98** | 9.10 | 7.13 | 20.56 |
| EC165952 | 0.25** | 0.26** | 0.16 | -2.03** | -1.94** | -2.20** | -20.06** | -19.61** | -18.83** | -1.08 | 17.61 | 11.80 |
| EC164665 | 2.18** | 2.25** | 2.27** | 6.89** | 6.12** | 6.23** | -22.21** | -22.69** | -22.09** | -91.82** | -66.50 | -74.39 |
| IC249511 | -1.87** | -1.82** | -1.99** | -3.30** | -3.36** | -3.45** | -23.67** | -24.07** | -24.44** | 15.03 | -77.84 | -87.41 |
| EC168096 | 3.94** | 3.84** | 3.89** | -7.75** | -7.72** | -7.51** | 38.83** | 38.25** | 38.54** | -9.95 | -7.47 | 20.32 |
| EC164677 | -1.85** | -1.75** | -1.81** | -0.24 | -1.24** | -0.61 | 51.48** | 52.98** | 53.15** | 40.39 | 104.99* | 104.66* |
| EC162600 | 2.10** | 1.89** | 1.96** | 8.41** | 8.75** | 9.16** | -3.36** | -3.73** | -3.46** | 73.71* | 6.41 | -11.58 |
| EC310301 | -0.72** | -0.79** | -0.82** | 9.98** | 10.76** | 9.52** | -1.87** | -2.45** | -3.15** | 15.02 | -4.38 | -34.06 |
| EC635525 | 0.32** | 0.46** | 0.23** | 8.81** | 9.17** | 9.12** | 10.66** | 10.61** | 10.23** | -75.99** | -64.06 | 31.38 |
| IC249513 | 4.96** | 4.92** | 4.82** | 3.25** | 2.58** | 3.63** | 1.30 | 0.20 | -0.11 | -10.25 | 108.91* | -10.26 |
| EC241148 | 1.95** | 1.98** | 1.86** | 1.35** | 1.66** | 2.02** | -19.60** | -19.73** | -19.51** | 47.35 | 56.86 | 110.96* |
| SEi | 0.06 | 0.04 | 0.09 | 0.28 | 0.39 | 0.41 | 0.29 | 0.11 | 0.12 | 24.91 | 37.41 | 45.73 |
| EC164654 | -0.47** | -0.20** | 0.05 | -0.70** | -0.64* | -1.01** | 2.65** | 1.17** | -0.37** | -37.15** | 4.19 | 61.19** |
| IC249503 | -0.10* | 0.18** | 0.49** | -5.33** | -5.28** | -4.97** | -2.99** | -4.31** | -5.78** | 21.06** | 46.38** | 115.02** |
| IC249505 | 0.58** | 0.02 | -0.54** | 6.02** | 5.92** | 5.97** | 0.34* | 3.14** | 6.15** | 16.09 | -50.57** | -176.21** |
| SE | 0.02 | 0.02 | 0.03 | 0.11 | 0.15 | 0.15 | 0.11 | 0.04 | 0.05 | 9.42 | 14.14 | 17.28 |

favourable genes for Shoot dry weight is present in IC249505.

Among the lines, NS537, EC162516, IC249511, EC241148, IC249513 and EC635525 exhibited significant positive *gca* effects. Whereas, among testers EC164654 recorded positive *gca* effect for root dry weight. Under 10 DII among the lines, IC249511, EC162516 and NS537 recorded significant positive *gca* effects while, among the testers positive significant *gca* effect was exhibited by EC164654 thus indicating their good general combining ability for root dry weight. Under 15 DII among the lines, IC249511, EC162516 and NS537 recorded significant positive *gca* effects. Among the testers positive significant *gca* effect was exhibited by EC164654, thus indicating their good general combining ability for root dry weight.

Each and every line exhibited significant positive and negative *gca* effect except IC249153. In this experiment, none of the testers are significant for RDW/SDW. Under 10 DII among the lines, EC164665, IC249511 and EC165952 recorded significant positive *gca* effects. Among the testers positive significant *gca* effect was exhibited by IC249503. Under 15 DII among the lines, EC164665, IC249511 and EC165952 recorded significant positive *gca* effects while, among the testers positive significant *gca* effect was exhibited by IC249503 for RDW/SDW.

All the lines and testers are highly significant in both positive and negative *gca* effect for stomatal diffusive resistance analysis. Under 10 DII among the lines, IC249513, EC168096 and EC164665 recorded significant positive *gca* effects while, among the testers positive significant *gca* effect was exhibited by IC249505 (0.18) for stomatal diffusive resistance. Under 15 DII among the lines, IC249513, EC168096 and EC164665 recorded significant positive *gca* effects while, among the testers positive significant *gca* effect was exhibited by IC249503 for stomatal diffusive resistance.

Under 10 DII among the lines, EC310301, EC635525 and EC162600 are judged as good general combiners for relative water content while, in testers positive significant *gca* effect was exhibited by IC249505 for relative water content. The lines, EC310301, EC162600 and EC635525 recorded significant positive *gca* effects. Among the testers positive significant *gca* effect was exhibited by IC249505 for relative water under 15 DII.

The highest significant positive gca effect was noticed in EC162516, EC168096, EC164677 and EC635525 for leaf area. Among the testers positive significant *gca* effects were exhibited by EC164654 and IC249505. Under 10 DII among the lines, EC164677, EC162516, EC168096 recorded significant positive *gca* effects whereas, in testers positive significant *gca* effect was exhibited by IC249505 for leaf area. Under 15 DII among the lines, EC164677, EC162516 and EC168096 recorded significant positive *gca* effects. Among the testers positive significant *gca* effect was exhibited by IC249505 thus indicating their good general combining ability for leaf area.

For the trait, specific leaf weight comparing the gca effects of lines, it was evident that the only two lines *viz.*, NS537 and EC162600 expressed positive and significant *gca* effects whereas, in tester, IC249503 exhibited significant and positive *gca* effect. Under 10 DII among the lines, IC249513, EC164677 and EC241148 recorded significant positive *gca* effects. Among the testers positive significant *gca* effect was exhibited by EC164654 for specific leaf weight. Under 15 DII among the lines, EC241148 and EC164677 recorded significant positive *gca* effects while, in testers positive significant *gca* effect was exhibited by IC249503 for specific leaf weight. From the studies on gca effects and their relative performance, it may be said that all the desirable characters were not present in any one single parent.

Based on combining ability results, the genotypes EC251578, IC249512, EC162516, EC249503 and EC164654 recorded high positive *gca* effects. IC249512, EC164845, EC249505 and EC164654 are ideal choice for yield under stressed condition. IC249512 was good performer for most of the traits in both irrigated and stressed conditions. Besides high yield, IC249512 is a very poor performer for stomatal diffusive resistance and shoot dry weight under irrigated conditions. Three parents EC162516, EC249505 and EC168096 are identified as good general combiners with high yield potential in drought environment. So, these lines are reliable for further drought tolerance breeding.

**Specific combining ability**

The SCA effects for hybrids pertaining to different traits are given in Table 4 and 5. In the present study, best cross combinations involved good x good, good x poor and even poor x poor SCA effects. The SCA effects signify the role of non-additive gene action in the expression of a trait and this is due to dominance variance and epistatic variances. It shows the highly specific combining abilities leading to the higher performance of some specific cross combinations and that is the reason why it is related to a particular cross. High SCA effects may arise not only in crosses involving high combiners but also in those involving low combiners.

SCA effects also differed according to the stress and non-stress environments. The higher positive *sca* effects were exhibited by EC164845 X IC249505. Under stringent irrigation conditions (10 DII) the *sca* effects IC249512 X IC249503 recorded highest *sca* effects. In case of 15 DII, the *sca* effects significant positive *sca* effects obtained in EC164845 X IC249505 for fruit yield per plant. For shoot dry weight the *sca* effects ranged from -19.97 (IC249511 X IC249503) to 12.98 (IC249511 X IC249505). The higher positive *sca* effects were exhibited by IC249511 X IC249505. Under stringent irrigation conditions (10 DII) the *sca* effects ranged from -19.92 (IC249511 X IC249503) to 12.96 (IC249511 X IC249505). Twenty one crosses expressed positive *sca* effects *viz*. IC249511 X IC249505 followed by EC164677 X IC249503 and IC249511 X EC164654. At 15 DII, the *sca* effects ranged from -19.96 (IC249511 X IC249503) to 12.96 (IC249511X IC249505).

The sca effects for root dry weight were positive significant in EC164665 X IC249503. The *sca* effects ranged from -8.53 (EC241148 X IC249503) to 15.34 (EC164665 X IC249503). Under stringent irrigation conditions (10 DII) the *sca* effects ranged from -8.84 (IC249511 X IC249503) to 15.43 (EC164665 X IC249503). At 15 DII, The significant positive *sca* effects obtained in EC164665 X IC249503 (15.63).

The higher positive *sca* effects for RDW/SDW were exhibited by EC164665 X IC249503 followed by EC241148 X EC164654 and IC249513 X IC249505. Under stringent irrigation conditions (10 DII) at 15 DII, the *sca* effects ranged from -0.51 (EC164665 X IC249505) to 0.83 (EC164665 X IC249503). Estimates of the SCA effects for Stomatal diffusive resistance are presented in Table 4. The higher positive *sca* effects were exhibited by EC168096 X IC249503 followed by EC635525 X IC249505 and NS537 X IC249505. Under stringent irrigation conditions (10 DII) the highest *sca* effects showed in EC168096 X IC249503 (5.14) followed by EC635525 X IC249505 and IC249513 X EC164654. At 15 DII, the *sca* effects ranged from -2.72 (EC168096 X IC249505) to 5.26 (EC168096 X IC249503). The significant negative *sca* effects obtained in 14 crosses, whereas thirteen crosses expressed positive *sca* effects *viz*. EC168096 X IC249503 followed by EC635525 X IC249505 and IC249513 X EC164654.

EC164665 X IC249503 shows significant positive *sca* for relative water content in irrigation as well as stress conditions. The estimates of sca effects were positive significant for the trait leaf area were exhibited by EC310301 X IC249503 under normal and stringent irrigation conditions (10 DII). For specific leaf weight the higher positive *sca* effects were exhibited by IC249511 X IC249503 over normal irrigation condition. Under stringent irrigation conditions (10 DII) only one cross expressed positive *sca* effects *viz*. EC164677 X IC249503. The highest significant positive *sca* effect was recorded by only in one cross at 15 days irrigation condition. The high SCA effects of these crosses may be due to complementary type of gene effects.

## DISCUSSION

The parents differed markedly in their ability to yield under moisture stress conditions. For fruit yield per plant, the top five crosses EC310301 X EC164654 (251.33), EC 251578 X EC 164654 (304.82), IC249512 X IC249503 (381.70), EC162516 X IC249503 (468.85) and EC164845 X IC249505 (571.92) having high and positively significant *sca* effects under irrigated normal condition in the order of merit mentioned. Whereas, in stressed condition IC249512 X IC249503 (258.06), IC249512 X EC164654 (260.16), EC310301 X EC164654 (314.06), EC162516 X IC249505 (388.34) and EC164845 X IC249505 (469.54) having high and positively significant *sca* effects.

The analysis of quantitative inheritance was also an equally important objective to gain knowledge regarding the nature and magnitude of gene action, which has prime bearing on choice of most appropriate and efficient breeding procedure. Information regarding nature of gene action will be highly helpful in the development of efficient breeding programme. General combining ability is attributed to additive × additive gene action and is fixable in nature. On the other hand, specific combining ability is attributed to non-additive gene action which may be due to dominance or epistasis or both and is non-fixable nature. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme. Combining ability analysis, therefore, was done to generate information on *gca* effects of parents

**Table 4: Estimates of *sca* effects for lines and testers for fruit yield (g), shoot dry weight (g), root dry weight (g) and RDW/SDW in tomato under irrigation (control) and drought stress (10 and 15 days) conditions**

| Source | Fruit yield per plant (g) | | | Shoot dry weight (g) | | | Root dry weight (g) | | | RDW/SDW | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 10 days | 15 days | Control | 10 days | 15 days | Control | 10 days | 15 days | Control | 10 days | 15 days |
| EC251578 X EC 164654 | 304.82** | 97.64 | 59.00 | 0.66** | 0.78** | 0.61** | -1.45** | -1.48** | -1.73** | -0.03* | -0.03* | -0.03* |
| EC251578 X IC249503 | 66.67 | 161.45 | -42.99 | 0.62** | 0.71** | 0.80** | 0.49 | 0.56** | 0.88** | -0.02 | -0.03* | -0.02* |
| EC251578 X IC249505 | -371.48** | -259.09* | -16.01 | -1.29** | -1.49** | -1.40** | 0.95** | 0.92** | 0.85** | 0.05** | 0.05** | 0.06** |
| NS537 X EC164654 | 49.25 | 149.57 | -45.36 | 2.03** | 2.12** | 1.91** | 2.53** | 2.14** | 2.08** | 0.02 | 0.02 | 0.02* |
| NS537 X IC249503 | -122.29* | -119.38 | 35.82 | -2.06** | -2.01** | -1.93** | 1.99** | 2.02** | 2.05** | 0.01 | 0.01 | 0.00 |
| NS537 X IC249505 | 73.04 | -30.19 | 9.54 | 0.04 | -0.11 | 0.03 | -4.53** | -4.16** | -4.13** | -0.03* | -0.02 | -0.02* |
| EC162516 X EC164654 | -393.04** | -312.35** | -276.43 | 0.25** | 0.81** | 0.90** | -4.26** | -4.52** | -4.46** | -0.06** | -0.07** | -0.07** |
| EC162516 X IC249503 | 468.85** | 18.30 | -111.90 | 2.36** | 1.72** | 1.96** | 4.43** | 4.48** | 4.49** | 0.03* | 0.04** | 0.03* |
| EC162516 X I C249505 | -75.81 | 294.05* | 388.34** | -2.61** | -2.54** | -2.86** | -0.18 | 0.04 | -0.03 | 0.03* | 0.03* | 0.04** |
| EC164845 X EC164654 | -225.24** | -200.09 | -208.66 | -0.17** | -0.31** | -0.38** | -0.54 | -0.79** | -0.68** | 0.00 | -0.01 | 0.00 |
| EC164845 X IC249503 | -346.68** | -236.28* | -260.88* | 1.13** | -0.28** | -0.15 | 0.13 | 0.30* | 0.04 | -0.03* | -0.02 | -0.03* |
| EC164845 X IC249505 | 571.92** | 436.37** | 469.54** | -0.97** | 0.58** | 0.53** | 0.41 | 0.49** | 0.64** | 0.03* | 0.02 | 0.03* |
| IC249512 X EC164654 | 124.67* | -49.07 | 260.16* | 1.44** | 1.10** | 0.86** | -1.22** | -1.21** | -1.43** | -0.04** | -0.04** | -0.04** |
| IC249512 X IC249503 | 381.70** | 598.26** | 258.06* | 4.13** | 5.06** | 5.29** | 0.41 | 0.38* | 0.43** | -0.05** | -0.06** | -0.07** |
| IC249512 X IC249505 | -506.37** | -549.19** | -518.22** | -5.57** | -6.17** | -6.15** | 0.81* | 0.84** | 1.01** | 0.09** | 0.10** | 0.11** |
| EC165952 X EC164654 | 93.66 | 89.72 | 188.04 | 2.38** | 2.72** | 2.62** | 4.11** | 3.85** | 3.90** | 0.09** | 0.09** | 0.10** |
| EC165952 X IC 249503 | -10.97 | 87.20 | 2.41 | -0.14** | -0.38** | -0.19 | -6.24** | -6.05** | -6.23** | -0.19** | -0.19** | -0.21** |
| EC165952 X IC249505 | -82.69 | -176.92 | -190.45 | -2.24** | -2.35** | -2.44** | 2.14** | 2.19** | 2.33** | 0.09** | 0.10** | 0.11** |
| EC164665 X EC164654 | -25.14 | 68.68 | -33.21 | -3.98** | -3.91** | -4.00** | -7.12** | -7.35** | -7.55** | -0.25** | -0.28** | -0.32** |
| EC164665 X IC249503 | 110.02 | 89.39 | 178.10 | 1.90** | 2.13** | 2.01** | 15.34** | 15.43** | 15.63** | 0.67** | 0.74** | 0.83** |
| EC164665 X IC249505 | -84.88 | -158.07 | -144.88 | 2.09** | 1.78** | 1.99** | -8.22** | -8.08** | -8.07** | -0.42** | -0.46** | -0.51** |
| IC249511 X EC164654 | 240.35** | -27.90 | 121.33 | 6.99** | 6.95** | 7.00** | 3.11** | 5.14** | 5.16** | -0.01 | 0.02 | 0.03* |
| IC249511 X IC249503 | -30.92 | -50.74 | -14.16 | -19.97** | -19.92** | -19.96** | -7.79** | -8.84** | -8.85** | 0.02 | 0.01 | 0.00 |
| IC249511X IC249505 | -209.43** | 78.64 | -107.17 | 12.98** | 12.96** | 12.96** | 4.69** | 3.70** | 3.69** | -0.01 | -0.03** | -0.03* |
| EC168096 X EC164654 | -14.16 | -136.75 | -114.20 | -2.04** | -3.29** | -3.30** | 0.73* | 0.94** | 1.02** | 0.05* | 0.08** | 0.09** |
| EC168096 X IC249503 | -35.64 | 127.06 | 116.94 | 3.93** | 4.70** | 4.89** | -2.13** | -2.03** | -2.23** | -0.12 | -0.13** | -0.15** |
| EC168096 X IC249505 | 49.81 | 9.69 | -2.74 | -1.89** | -1.41** | -1.59** | 1.40** | 1.09** | 1.21** | 0.06** | 0.05** | 0.06** |
| EC164677 X EC164654 | -134.73* | 130.82 | -147.65 | -6.02** | -5.98** | -4.62** | -1.22** | -0.63** | -0.93** | 0.03* | 0.06** | 0.03* |
| EC164677 X IC249503 | 27.27 | -101.76 | 83.58 | 7.98** | 8.01** | 7.65** | 0.50 | 0.07 | 0.47** | -0.07** | -0.10** | -0.08** |
| EC164677 X IC249505 | 107.46 | -29.06 | 64.07 | -1.96** | -2.04** | -3.03** | 0.72* | 0.56** | 0.46** | 0.04* | 0.04** | 0.05** |
| EC162600 X EC164654 | -101.81 | 25.40 | -79.80 | 5.26** | 5.01** | 5.68** | 0.47 | 0.17 | 0.41** | 0.00 | -0.01 | 0.00 |
| EC162600 X IC249503 | 79.83 | -10.58 | 51.43 | -0.56* | 0.09 | -1.18** | 0.05 | 0.19 | 0.11 | -0.02 | -0.03** | -0.03* |
| EC162600 X IC249505 | 21.97 | -14.82 | 28.38 | -4.70** | -5.10** | -4.50** | -0.52 | -0.36* | -0.52** | 0.02 | 0.04** | 0.04** |
| EC310301 X EC164654 | 251.33** | 229.90* | 314.06** | -2.36** | -2.39** | -2.21** | -0.22 | -0.82** | -0.98** | 0.04** | 0.02 | 0.01 |
| EC310301 X IC249503 | -486.57** | -546.23** | -463.00** | 0.83** | 0.67** | 0.88** | 0.90** | 1.14** | 1.24** | 0.01 | 0.02 | 0.03* |
| EC310301 X IC249505 | 235.24** | 316.33* | 148.95 | 1.53** | 1.73** | 1.33** | -0.69* | -0.32 | -0.26* | -0.05** | -0.04** | -0.04** |
| EC635525 X EC164654 | -121.89* | -96.20 | 11.32 | -3.65** | -3.30** | -4.37** | 1.57** | 1.73** | 1.27** | 0.04** | 0.04** | 0.04** |
| EC635525 X IC249503 | -76.65 | 1.08 | -90.79 | -0.33** | -0.38* | -0.42** | 2.70** | 2.47** | 3.15** | 0.02 | 0.01 | 0.02* |
| EC635525 X IC249505 | 198.54** | 95.12 | 79.48 | 3.98** | 3.68** | 4.79** | -4.28** | -4.21** | -4.42** | -0.07** | -0.06** | -0.07** |
| IC249513 X EC164654 | -204.03** | -74.73 | -65.43 | -1.44** | -1.10** | -1.03** | -3.03** | -3.15** | -2.32** | -0.04** | -0.05** | -0.03* |
| IC249513 X IC249503 | 41.00 | -3.86 | 109.31 | -0.34** | -0.85** | -0.97** | -2.26** | -1.88** | -2.30** | -0.06** | -0.05** | -0.07** |
| IC249513 X IC249505 | 163.03* | 78.59 | -43.88 | 1.78** | 1.95** | 2.00** | 5.30** | 5.03** | 4.62** | 0.10** | 0.10** | 0.10** |
| EC241148 X EC164654 | 155.95** | 105.35 | 16.85 | 0.65** | 0.77** | 0.35** | 6.54** | 5.97** | 6.25** | 0.15** | 0.14** | 0.16** |
| EC241148 X IC249503 | -65.62 | -13.90 | 148.10 | 0.54** | 0.73** | 1.32** | -8.53** | -8.22** | -8.87** | -0.21** | -0.22** | -0.25** |
| EC241148 X IC249505 | -90.33 | -91.46 | -164.95 | -1.18** | -1.50** | -1.67** | 1.99** | 2.26** | 2.62** | 0.07** | 0.08 | 0.09** |
| SE | 61.260 | 104.530 | 107.180 | 0.070 | 0.060 | 0.090 | 0.330 | 0.120 | 0.070 | 0.010 | 0.004 | 0.004 |

**Table 5: Estimates of *sca* effects for lines and testers for stomatal diffusive resistance (sec/cm), relative water content, leaf area (sq.cm) and specific leaf weight (mg/sq.cm) in tomato under irrigation (control) and drought stress (10 and 15 days) conditions**

| Source | Stomatal diffusive resistance (sec/cm) | | | Relative water content (%) | | | Leaf area (sq.cm) | | | Specific leaf weight (mg/sq.cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 10 days | 15 days | Control | 10 days | 15 days | Control | 10 days | 15 days | Control | 10 days | 15 days |
| EC251578 X EC 164654 | 0.20* | 0.20* | -0.09 | -3.93** | -5.63** | -5.35** | -1.95** | -1.42** | -4.51** | 23.71 | 11.30 | -18.48 |
| EC251578 X IC249503 | -0.33** | -0.30** | -0.44** | 1.09** | 1.70* | 2.56** | -1.37** | -0.98** | 0.76 | 4.26 | -10.73 | 55.34 |
| EC251578 X IC249505 | 0.13 | 0.11 | 0.53** | 2.85** | 3.93** | 2.79** | 3.31** | 2.41** | 3.75** | -27.97 | -0.56 | -36.86 |
| NS537 X EC164654 | -0.43** | -0.57** | -0.45** | 3.12** | 4.49** | 4.97** | 1.00* | -0.11 | 0.16 | 48.06 | 65.06 | 108.09 |
| NS537 X IC249503 | -0.94** | -0.69** | -0.92** | 5.68** | 3.62** | 3.24** | -6.38** | -4.71** | -4.62** | -141.07** | -150.43** | -159.37** |
| NS537 X IC249505 | 1.37** | 1.26** | 1.37** | -8.80** | -8.12** | -8.21** | 5.38** | 4.82** | 4.46** | 93.01* | 85.37 | 51.28 |
| EC162516 X EC164654 | 0.93** | 0.97** | 1.17** | -0.24 | -1.61* | -3.77** | 10.66** | 10.66** | 10.88** | -30.52 | -88.55 | -72.48 |
| EC162516 X IC249503 | 1.12** | 0.81** | 0.77** | -3.42** | -1.24 | 0.28 | 6.16** | 6.15** | 6.25** | 13.77 | 30.68 | -9.66 |
| EC162516 X IC249505 | -2.04** | -1.79** | -1.94** | 3.66** | 2.85** | 3.50** | -16.82** | -16.82** | -17.13** | 16.76 | 57.87 | 82.15 |
| EC164845 X EC164654 | 0.23* | 0.18* | 0.44** | 2.11** | 4.04** | -0.17 | -7.70** | -8.31** | -8.14** | -33.05 | -72.58 | -75.63 |
| EC164845 X IC249503 | -0.30** | -0.15 | -0.27* | -2.58** | -3.54** | -0.43 | -7.97** | -7.89** | -7.73** | 21.40 | 50.61 | 11.93 |
| EC164845 X IC249505 | 0.07 | -0.03 | -0.17 | 0.47 | -0.50 | 0.60 | 15.67** | 16.20** | 15.87** | 11.65 | 21.97 | 63.70 |
| IC249512 X EC164654 | 0.11 | -0.03 | -0.63** | 0.92* | 1.71* | 1.48* | 2.49** | 2.88** | 3.29** | -52.41 | -87.77 | -53.78 |
| IC249512 X IC249503 | 0.32** | 0.24** | 0.67** | 4.06** | 3.90** | 3.86** | 4.77** | 4.16** | 3.47** | 73.84 | 86.73 | 62.33 |
| IC249512 X IC249505 | -0.43** | -0.21** | -0.04 | -4.99** | -5.61** | -5.35** | -7.26** | -7.05** | -6.75** | -21.44 | 1.04 | -8.55 |
| EC165952 X EC164654 | 0.06 | 0.25** | 0.28* | 0.07 | 1.21* | 0.18 | 4.75** | 4.52** | 5.59** | 116.44** | 101.90 | 147.42 |
| EC165952 X IC 249503 | -0.36** | -0.29** | -0.24* | 2.86** | 1.83* | 2.71** | -5.70** | -5.25** | -5.59** | -110.07** | -97.53 | -152.85* |
| EC165952 X IC249505 | 0.31** | 0.04 | -0.04 | -2.93** | -3.05** | -2.88** | 0.95* | 0.73** | 0.00 | -6.37 | -4.36 | 5.43 |
| EC164665 X EC164654 | 0.01 | 0.03 | 0.06 | -4.14** | -5.49** | -4.23** | -2.29** | -3.43** | -2.52** | 112.02** | 77.63 | 94.27 |
| EC164665 X IC249503 | -0.20* | -0.07 | -0.18 | 5.71** | 6.29** | 5.01** | 2.29** | 2.94** | 2.77** | -62.61 | -23.22 | -51.81 |
| EC164665 X IC249505 | 0.18 | 0.03 | 0.12 | -1.57** | -0.80 | -0.78 | 0.00 | 0.49* | -0.25 | -49.40 | -54.41 | -42.46 |
| IC249511 X EC164654 | 0.66** | 0.62** | 0.60** | -1.77** | -1.33* | -1.49* | -3.32** | -4.24** | -5.42** | -47.10 | -4.91 | 4.05 |
| IC249511 X IC249503 | -0.87** | -1.02** | -0.92** | 0.46 | -0.04 | 0.10 | 3.85** | 4.29** | 5.00** | 191.43** | 36.03 | 13.47 |
| IC249511 X IC249505 | 0.20* | 0.40** | 0.32* | 1.31** | 1.37* | 1.39* | -0.53 | -0.05 | 0.42* | -144.33** | -31.12 | -17.51 |
| EC168096 X EC164654 | -2.47** | -2.57** | -2.55** | -1.23** | 0.10 | 1.41* | 5.77** | 6.49** | 6.77** | -16.79 | -24.38 | 14.36 |
| EC168096 X IC249503 | 5.10** | 5.14** | 5.26** | 1.17** | 0.11 | -1.27 | 3.15** | 1.94** | 1.97** | 27.08 | 16.92 | 1.83 |
| EC168096 X IC249505 | -2.62** | -2.57** | -2.72** | 0.07 | -0.21 | -0.14 | -8.93** | -8.43** | -8.74** | -10.29 | 7.46 | -16.20 |
| EC164677 X EC164654 | 0.04 | 0.02 | 0.14 | 1.46** | -0.10 | 0.22 | 9.10** | 11.91** | 12.01** | -103.37** | -140.26** | -201.24** |
| EC164677 X IC249503 | -0.22* | -0.36** | -0.29* | 2.22** | 2.84** | 3.25** | 2.43** | 1.34** | 1.42** | 153.91** | 235.23** | 291.61** |
| EC164677 X IC249505 | 0.18 | 0.34** | 0.16 | -3.68** | -2.74** | -3.47** | -11.53** | -13.25** | -13.43** | -50.54 | -94.97 | -90.37 |
| EC162600 X EC164654 | 0.45** | 0.47** | 0.64** | 1.93** | 3.29** | 2.92** | -7.07** | -6.59** | -6.38** | 37.72 | 17.61 | 1.67 |
| EC162600 X IC249503 | -0.85** | -0.88** | -1.07** | -1.55** | -2.63** | -1.99** | -1.31** | -1.00** | -0.90** | 57.29 | -10.31 | -16.43 |
| EC162600 X IC249505 | 0.40** | 0.40** | 0.44** | -0.38 | -0.66 | -0.93 | 8.38** | 7.59** | 7.28** | -95.01* | -7.30 | 14.76 |
| EC310301 X EC164654 | 0.21** | 0.29** | 0.15 | 1.43** | 1.23* | 1.54* | -16.92** | -16.87** | -16.77** | -38.72 | -18.98 | -59.76 |
| EC310301 X IC249503 | -0.31** | -0.32** | -0.29* | -4.62** | -3.70** | -5.29** | 19.56** | 19.67** | 18.91** | -16.96 | -14.50 | 1.54 |
| EC310301 X IC249505 | 0.10 | 0.03 | 0.14 | 3.19** | 2.47** | 3.74** | -2.64** | -2.80** | -2.14** | 55.67 | 33.47 | 58.22 |
| EC635525 X EC164654 | -1.78** | -1.70** | -1.82** | 2.33** | 0.89 | 2.84** | -8.54** | -8.72** | -9.90** | 51.09 | 76.95 | 197.67 |
| EC635525 X IC249503 | -2.22** | -2.37** | -2.29** | -3.63** | -1.82** | -3.70** | -0.11 | -0.47 | 0.43* | -85.97 | -70.10 | -90.49 |
| EC635525 X IC249505 | 3.99** | 4.07** | 4.11** | 1.30** | 0.93 | 0.86 | 8.65** | 9.19** | 9.48** | 34.88 | -6.85 | -107.18 |
| IC249513 X EC164654 | 1.36** | 1.36** | 1.51** | -0.89* | -1.31* | 0.49 | 16.06** | 14.53** | 15.32** | -27.02 | 72.56 | -33.93 |
| IC249513 X IC249503 | 0.03 | 0.11 | 0.13 | -3.89** | -4.21** | -5.08** | -23.29** | -23.07** | -24.20** | -54.07 | 7.33 | -8.51 |
| IC249513 X IC249505 | -1.39** | -1.46** | -1.65** | 4.78** | 5.51** | 4.59** | 7.23** | 8.54** | 8.87** | 81.08 | -79.89 | 42.44 |
| EC241148 X EC164654 | 0.43** | 0.47** | 0.55** | -1.14** | -1.50* | -1.03 | -2.05** | -1.31** | -0.37 | -40.08 | 14.44 | -52.22 |
| EC241148 X IC249503 | 0.01 | 0.15 | 0.10 | -3.57** | -3.11** | -3.27** | 3.94** | 2.87** | 2.07** | -72.22 | -86.72 | 51.06 |
| EC241148 X IC249505 | -0.44** | -0.62** | -0.64** | 4.71** | 4.61** | 4.30** | -1.88** | -1.56** | -1.70** | 112.30** | 72.28 | 1.16 |
| SE | 0.080 | 0.060 | 0.120 | 0.400 | 0.560 | 0.570 | 0.410 | 0.160 | 0.170 | 35.23 | 52.910 | 64.670 |

and *sca* effects of crosses which would help in selection of better parents and cross combinations for their further use in hybrid breeding programme. This will also provide the information regarding the type and magnitude of gene action, which will help in choice of the breeding method to be employed for the improvement of desired traits (Muhammad *et al.,* 2009).

Combining ability effects reveal the genetic worth of parents and hybrids. The *gca* effects are fixable, while *sca* effects are non-fixable. In the present investigation, combining ability analysis revealed that there were significant differences in the combining ability of parents and crosses for almost all the growth, earliness, yield related traits and quality parameters under consideration. The degree and direction of combining ability effects varied greatly for different traits and genotypes.

General combining ability helps in the selection of suitable parents (good general combiners) for hybridization. There were significant differences in the general combining ability of parents for all the growth, earliness, yield related traits and quality parameters under study. High *gca* effects are related to additive gene effects or additive × additive effects, which represent the fixable genetic components of variance, as also pointed out by Griffing (1956). The high estimates of *gca* effects as observed for different attributes of economic importance may be useful for sorting out outstanding parents with favorable alleles for different components of yield. It may, therefore, be suggested that the parents with high *gca* effects for a particular character may be used in hybridization programme for the improvement of that character. These findings are in consonance with the findings of Pandey *et al.* (2006), Katkar *et al.,* (2012). EC164665 X EC164654 combination gives poor X poor GCA effect due to non-additive gene interaction and non-fixable genetic component for total yield per plant. This indicated possibly to obtained desirable transgressive segregants and hybrid vigour from such crosses by adopting cycle selection or biparental breeding programme (Ravindra Kumar *et al.,* 2013).

## CONCLUSION

The superior general combiners viz., EC251578, IC249512, EC162516, EC249503 and EC164654 are recommended for use in breeding programmes to generate genetic variability in desirable direction for effective selection to improve the respective traits. Besides high yield, IC249512 is a very poor performer for stomatal diffusive resistance and shoot dry weight under irrigated conditions. High performance of these crosses may be attributed to additive × additive (high × high), additive × dominance (high × low) or dominance × dominance (low × low) epistatic interactions. Therefore, the best general combiner from the parental lines and the best specific combiners among the crosses may be selected for better parents and hybrids respectively for improvement of traits especially drought tolerant and fruit yield in tomato cultivation under moisture stress conditions.

## REFERENCES

**Griffing, B. 1956.** Concepts of general and specific combining ability in relation to diallel crossing system. *Australian J. Biological Science.* **9:** 463-493.

**Indian Horticulture Database 2011.** National Horticulture Board, Department of Agriculture and cooperation, Government of India.

**Katkar, G. D., Sridevi, O., Salimath, P. M. and Patil, S. P. 2012.** Combining ability analysis for yield, its contributing characters and fruit quality parameters of exotic Tomato (*Lycopersicon esculentum* Mill.) breeding lines. *Electronic J. Plant Breeding.* **3:** 908-915.

**Kempthorne, O. 1957.** An Introduction to genetic Statistic. *J. Wiley and Sons. Inc.* New York. pp. 208-223.

**Muhammad, Y. S., Muhammad, A., Tariq, H., Atif, R. K. and Asif, A. K. 2009.** Genetic analysis to identify suitable parents for hybrid seed production in tomato (*Lycopersicon esculentum* Mill.). *Pakistan J. Botany* **41:** 1107-1116.

**Nahar, K. and Ullah, S. M. 2011.** Effect of water stress on moisture content distribution in soil and morphological characters of two tomato (*Lycopersicon esculentum Mill*) cultivars. *J. Scientific Research.* **3:** 677-682.

**Pandey, S. K, Dixit, J., Pathak, V. N. and Singh, P. K. 2006.** Line x Tester analysis for yield and quality characters in tomato (*Solanum lycopersicon* Mill.). *Vegetable Science.* **33:** 13-17.

**Ravindra Kumar, K., Srivastava, K., Singh, N. P., Vasistha, N. K., Singh, R. K. and Singh, M.K. 2013.** Combining Ability Analysis for Yield and Quality Traits in Tomato (Solanum lycopersicum L.) *J. Agricultural Science.* **5:** 213-218.

**Roberto Gaxiola 2006.** Tomatoes Against Drought. *www. Checkbiotech . org*

**Shende Varun, D., Seth, T., Mukherjee, S. and Chattopadhyay, A. 2012.** Breeding tomato (*Solanum lycopersicum* L.) For higher productivity and better processing qualities. *Sabrao J. Breeding and Genetics.* **44:** 302-321.