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# DIALLEL ANALYSIS OF YIELD AND SOME YIELD COMPONENTS IN TOMATO (*SOLANUM LYCOPERSICUM* L.)

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**Abstract**

Diallel analysis revealed highly significant differences among tomato genotypes for days to maturity, plant height, number of fruits per plant, fruit weight, fruit length, fruit width and fruit yield per plant. Significant mean squares for general combining ability (GCA), specific combining ability (SCA) and reciprocal combining ability (RCA) indicated joint role of additive, non-additive and maternal effects for the expression of days to maturity, fruit length and fruit yield per plant. The predictability ratio of GCA/SCA variance was less than 1 for days to maturity, plant height, number of fruits per plant, fruit weight, fruit length and fruit yield per plant showing preponderance of non-additive gene effects while it was more than 1 for fruit weight indicating predominance of additive gene effect. Among parents, B26 and B27 were found good general combiner for yield and some of the yield related traits studied. The hybrids viz. B23 x B27, B25 x B26 and B24 x B27 had significant SCA effects for yield and were suggested for the exploitation of heterosis.

## Introduction

Tomato (*Solanum lycopersicum* L.) belongs to family *Solanaceae*. It is grown as summer vegetable in Pakistan. Tomato is a rich source of vitamin A, C and minerals like Ca, P and Fe (Dhaliwal *et al*., 2003). It also plays a pivotal role in improving nutrition resource's of poor population as compared to meat, milk, fruits and other high priced fruit items. Tomatoes are major contributors of antioxidants such as carotenoids (especially, lycopene and β-carotene), phenolics, ascorbic acid (vitamin C) and small amounts of vitamin E in daily diets (Rai *et al*., 2012).

During 2011, tomato was grown on an area of 52.3 thousand hectare in Pakistan which is about 20% of the total area under vegetable cultivation. The average productivity of tomato in the country has been stagnant between 9.5 to 10.5 tonne per hectare during the last decade (Anon., 2011a) compared to 33.6 tonne per hectare of modern agricultural areas (Anon., 2013) Current open pollinated (OP) varieties of tomato are unable to meet the domestic demand due to their low genetic potential, susceptibility to biotic and abiotic stresses, limited area under cultivation, water shortage and competition with major crops (Saleem *et al*., 2009; Saleem *et al*., 2011; Akhtar *et al*., 2010; Sajjad *et al*., 2011; Akhtar *et al*., 2012). Hybrid variety ($F_1$ population) gives 3 to 4 times more yield in contrast to that of OP variety (Tiwari & Choudhury, 1986). Unlike OP varieties, the superior characters of $F_1$ hybrids however, are lost during seed multiplication therefore; growers need to buy fresh hybrid seed every time they want to plant. Main reason for slow progress in tomato hybrid breeding in Pakistan is lack of good combiner parents to be crossed for exploitation of heterosis. Pakistan is facing higher imports of tomato seed due to limited quality seed producing agencies that can fulfill domestic seed requirements. During the last two years, the import of tomato seed has been increased from 38 metric tonnes to 57 metric tonnes which amounts 83 million to 185 million rupees, respectively (Anon., 2011b). It indicates a big shift of farmer's trend towards hybrid seeds.

Different biometrical techniques are now available to select parent lines suitable for hybrid seed production. Diallel analysis technique developed and illustrated by Hayman (1957) and Jinks (1956) provides guideline for the assessment of relative breeding potential of the parents and has been extensively used to identify good combiner parents in various crops like hot pepper (Legesse, 2001), tomato (Pratta *et al*., 2003; Chishti *et al*., 2008), rice (Saleem *et al*., 2010a; Saleem *et al*., 2010b), wheat (Inamullah *et al*., 2006) and okra (Wammanda *et al*., 2010). This technique also provides information on gene action controlling the expression of desired traits. Based on information on combining ability and gene action, the selected lines can be combined either to exploit hybrid vigor by accumulating non-additive gene effects or to evolve cultivars by accumulating additive gene effects.

The rationale of the present study was to pick elite lines of tomato with different growth types (determinate and indeterminate) to develop hybrids suitable for field and tunnel cultivation. The main objective was to identify good combiner parent lines using diallel analysis (Griffing, 1956). Having recognition of such lines, hybrid varieties of tomato can be produced on commercial scale to increase yield, supply quality seed to farmers at low cost and save foreign exchange.

## Materials and Methods

Five tomato lines namely B23, B24 and B25 of determinate growth type (D) and B26 and B27 of indeterminate growth type (ID) were crossed in diallel fashion following Griffing (1956). The 25 genotypes (10 direct $F_1$ crosses + 10 reciprocal $F_1$ crosses + 5 selefed) were grown in experimental field of Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan following randomized complete block design with 3 replications during 2009. Thirty five days old nursery seedlings were transplanted and kept 50 cm apart on beds which were separated by 1.5 m from each other. Seven plants of each genotype per replication were grown by adopting standard agronomic practices to maintain healthy crop. The data were recorded on days to maturity, plant height, number of fruits per plant, fruit weight, fruit length, fruit width and fruit yield per plant in kg. Analysis of variance was performed according to Steel *et al*., (1997). Combining ability (general combining ability referred as GCA, specific combining ability referred as SCA and reciprocal combining ability referred as RCA) analysis was carried out following Model-1, Mehtod-1 of Griffing (1956). The distribution of combining ability effects in relation to selection of desired parents and hybrids were taken as under:

**Negative (-):** desirable for early days to maturity in D and ID growth types while for short PH in D growth type.

**Positive (+):** desirable for tall plants in ID growth type and for all the traits studied regardless of growth type.

## Results and Discussion

The parent genotypes used in the present study were of diverse nature of growth types i.e., determinate (single recessive *sp* allele) and indeterminate (single dominant $sp^+$ allele); $sp^+$ is dominant over sp when crossed (Opena *et al*., 2001). Analysis of variance (Table 1) indicated significant differences among genotypes for days to maturity, plant height, number of fruits per plant, fruit weight, fruit length, fruit width and fruit yield per plant as reported earlier (Saleem *et al*., 2013). The analysis of variance for combining ability partitioned genetic variation into GCA, SCA and RCA components. Mean squares from the analysis of GCA, SCA and RCA (Table 2) were significant for days to maturity, plant height, fruit length and fruit yield per plant suggesting the combined role of additive, non-additive and the influence of maternal or cytoplasmic interaction in the inheritance of these traits. The results are in agreement with those of Singh *et al*., (2010) in tomato.

**Table 1. Mean squares from the analysis of variance for different parameters among tomato genotypes.**

| SOV | df | Days to maturity | Plant height (cm) | Number of fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit width (cm) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 20.21 | 264.74 | 867.65 | 222.66 | 0.34 | 0.19 | 0.13 |
| Genotype | 24 | 105.19** | 2461.15** | 1781.01** | 605.37** | 1.07** | 1.56** | 2.63** |
| Error | 48 | 18.28 | 89.94 | 225.54 | 34.05 | 0.03 | 0.04 | 0.26 |

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

**Table 2. Analysis of variance for combining ability among tomato genotypes.**

| SOV | df | Days to maturity | Plant height (cm) | Number of fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit width (cm) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|
| GCA | 4 | 64.21** | 2952.50** | 1693.52** | 64.21** | 1.03** | 2.65** | 2.41** |
| SCA | 10 | 33.13** | 580.62** | 287.81 | 33.13 | 0.31** | 0.03 | 0.60** |
| RCA | 10 | 25.34* | 206.90** | 459.65** | 25.34 | 0.14** | 0.16** | 0.54** |
| Error | 48 | 6.09 | 29.98 | 75.18 | 11.35 | 0.01 | 0.01 | 0.09 |

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

To assess the relative importance of GCA ($\Sigma g_i^2$ ) and SCA ($\Sigma s_{ij}^2$) in the expression of different traits, the proportions of GCA and SCA were estimated (Table 3). Magnitude of SCA variance was greater than that of GCA variance for days to maturity, plant height, number of fruits per plant, fruit weight, fruit length and fruit yield per plant indicating the major control of non-additive type of gene action for these traits. However, SCA variance was less than that of GCA variance for fruit width showing supremacy of additive type of gene action in its inheritance. Present results were supported by the predictability ratio $\Sigma g_i^2 / \Sigma s_{ij}^2$ which was less than 1 for all the traits except fruit width. The current findings were in partial corroboration to some earlier studies in tomato mainly, because of diversity in experimental material and variable environmental conditions. In tomato, Saidi *et al*., (2008) reported the importance of additive effects for plant height, additive and non-additive effects for number of fruits per plant and fruit weight while dominance effects for FYPP. However, Saleem *et al*., (2009) reported non-additive effects for fruit weight, fruit length, fruit width, number of fruits per plant and fruit yield per plant.

In perusal to GCA effects of the parent lines (Table 4), B23 showed desirable GCA effects for days to maturity and short plant height (determinate type) as it had GCA values of -0.93 and -15.70, respectively. The parent B24 was attractive for fruit weight and fruit length with GCA values of 2.07 and 0.17, respectively. Line B25 had higher GCA effect for plant height, number of fruits per plant, fruit weight, fruit length and fruit yield per plant with GCA value of -8.94, 12.0, 3.13, 0.42 and 0.04, respectively. Parent B26 was favorable for days to maturity, plant height (due to desired ID type), number of fruits per plant, fruit width and fruit yield per plant having GCA effect of -1.23, 11.0, 14.70, 0.17 and 0.51, respectively. Line B27 appeared better for days to maturity, plant height (due to desired ID type), fruit width and fruit yield per plant with GCA value of -3.03, 24.73, 0.83 and 0.44, respectively. Similar results had already been reported elsewhere by various researchers in tomato (Ahmad *et al*., 2009; Singh *et al*., 2010). General combining ability has direct relationship with narrow sence heritability and represents fixable portion (additive and additive x additive interaction) of genetic variation thus helps in selection of parents suitable for hybridization (Geleta *et al*., 2006; Saleem *et al*., 2009) to develop cultivars with desired traits of interest. Lines B26 and B27 were rated as best general combiner and can be used as donors for yield and some other traits to develop early maturing and high yielding genotypes through multiple crossing programme.

**Table 3. Estimates of genetic components in tomato genotypes.**

| Components | Days to maturity | Plant height (cm) | Number of fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit width (cm) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|
| $\Sigma g_i^2$ | 5.81 | 292.35 | 161.83 | 5.28 | 0.10 | 0.26 | 0.23 |
| $\Sigma s_{ij}^2$ | 27.04 | 550.64 | 212.63 | 21.78 | 0.29 | 0.02 | 0.51 |
| $\Sigma s_{ij}^2/\Sigma g_i^2$ | 0.21 | 0.53 | 0.76 | 0.24 | 0.34 | 14.24 | 0.45 |

**Table 4. General Combining ability (GCA) effects and mean performance (in parenthesis) of parents.**

| Parents | Days to maturity | Plant height (cm) | Number of fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit width (cm) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|
| B23 | -0.93 | -15.70** | -3.78 | -0.93 | -0.07* | -0.27** | -0.56** |
| | (184) | (76) | (74) | (37.31) | (4.75) | (3.81) | (1.9) |
| B24 | 2.07** | 11.07** | -6.96** | 2.07* | 0.17** | -0.34** | -0.43** |
| | (176) | (107). | (62) | (41.10) | (4.98) | (3.62) | (2.0) |
| B25 | 3.13** | -8.94** | 12.00** | 3.13** | 0.42** | -0.39** | 0.04 |
| | (189) | (89) | (88) | (40.95) | (6.75) | (3.54) | (3.1) |
| B26 | -1.23 | 11.00** | 14.70** | -1.23 | -0.44** | 0.17** | 0.51** |
| | (178) | (120) | (95) | (56.61) | (4.04) | (4.97) | (3.7) |
| B27 | -3.03** | 24.73** | -15.95** | -3.03** | -0.08* | 0.83** | 0.44** |
| | (181) | (126) | (48) | (73.67) | (4.89) | (6.12) | (3.1) |
| S.E | 0.70 | 1.55 | 2.45 | 0.95 | 0.03 | 0.03 | 0.08 |

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

**Table 5. Specific Combining ability (SCA) effects and mean performance (in parenthesis) of tomato hybrids**

| Hybrids | Days to maturity | Plant height (cm) | Number of fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit width (cm) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|
| B23×B24 | 2.87 | -25.83** | -6.14 | 2.87 | -0.01 | 0.14 | -0.02 |
| | (189) | (55) | (58) | (42.34) | (4.56) | (4.04) | (2.2) |
| B23×B25 | 0.63 | -10.22* | 2.11 | 0.63 | 0.19* | -0.01 | -0.01 |
| | (186) | (73) | (104) | (38.11) | (5.37) | (3.69) | (3.2) |
| B23×B26 | -1.17 | 15.72** | -3.15 | -1.17 | -0.21* | -0.12 | -0.07 |
| | (183) | (113) | (81) | (41.02) | (4.00) | (4.03) | (2.8) |
| B23×B27 | -4.53* | 22.29** | 10.80 | -4.53 | -0.05 | 0.07 | 0.61* |
| | (178) | (153) | (102.54) | (48.44) | (4.45) | (4.47) | (4.5) |
| B24×B25 | -1.03 | -6.16 | 2.05 | -1.03 | -0.41** | 0.19* | 0.18 |
| | (188) | (87) | (80) | (43.58) | (4.56) | (3.92) | (3.0) |
| B24×B26 | 5.83** | -0.97 | 5.73 | 5.83* | 0.44** | -0.16 | 0.05 |
| | (192) | (99) | (80) | (48.21) | (5.56) | (4.18) | (3.3) |
| B24×B27 | 3.47 | 13.99** | 7.64 | 3.47 | 0.15 | -0.03 | 0.53* |
| | (190) | (134) | (67) | (67.41) | (5.14) | (4.91) | (3.7) |
| B25×B26 | 1.10 | 9.27* | 24.17** | 1.10 | -0.44** | 0.04 | 0.54* |
| | (188) | (95) | (109) | (45.18) | (4.52) | (4.22) | (3.8) |
| B25×B27 | 0.23 | 9.87* | -6.45 | 0.23 | -0.44** | -0.11 | -0.15 |
| | (186) | (136) | (76) | (50.00) | (4.69) | (4.15) | (3.1) |
| B26×B27 | -3.23 | -12.76** | -6.66 | -3.23 | 0.10 | 0.05 | 0.37 |
| | (185) | (127) | (79) | (70.92) | (4.42) | (5.55) | (4.8) |
| S.E. | 1.97 | 4.38 | 6.94 | 2.70 | 0.08 | 0.09 | 0.24 |

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

Specific combing ability effects of hybrids are presented in Table 5. Certain hybrids viz. B23 × B27 had desirable SCA value of -4.53 followed by B26 × B27 (-3.23), B23 × B26 (-1.17) and B24 × B25 (-1.03) for the development of early maturing hybrids. In determinate background, hybrids namely B23 × B24 had highest negative SCA effect for plant height (-25.83) followed by B23 x B25 (-10.22) and B24 × B25 (-6.16) while in indeterminate background, B23 x B27 had maximum SCA value of 22.29 followed by B23 x B26 (15.72), B24 x B27 (13.99), B25 x B27 (9.87) and B25 x B26 (9.27). Six hybrids viz. B25 x B26, B23 × B27, B24 × B27, B24 x B26, B23 x B25 and B24 x B25 had desirable SCA effect of 24.17, 10.80, 7.64, 5.73, 2.11 and 2.05 for higher number of fruits per plant respectively. Positive SCA effects for high fruit weight were exhibited by hybrid B24 x B26 with SCA value of 5.83, B24 x B27 (3.47), B23 x B24 (2.87), B25 x B26 (1.10), B23 x B25 (0.63) and B25 x B27 (0.23). Four hybrids viz. B24 x B26, B23 x B25, B24 x B27 and B26 x B27 possessed high value of SCA effect of 0.44, 0.19, 0.15 and 0.10 for fruit length respectively. In case of fruit width, hybrid B24 x B25 had high value of SCA (0.19) followed by B23 x B24 (0.14), B23 x B27 (0.07), B26 x B27 (0.05) and B25 x B26 (0.04). Six hybrids had desirable SCA effects for FYPP. Of them, hybrid B23 x B27 was the most promising with SCA value of 0.61 followed by B25 x B26 (0.54), B24 x B27 (0.53), B26 x B27 (0.37), B24 x B25 (0.18) and B24 x B26 (0.05). According to Singh and Narayanan (2004), a SCA effect refers to non-additive gene action (mainly dominance, interactions of dominance x dominance, additive x dominance and non-allelic loci) and has positive relationship with heterosis. Therefore, hybrid B23 x B27, B25 x B26 and B24 x B27 were rated as the best crosses (*p=0.05 & 0.01*) for improvement in yield and some yield components. Heterosis breeding was recommended for them since those combinations had significantly high SCA effects for fruit yield per plant.

Normally SCA effect does not contribute to the improvement of self-pollinated crops like tomato. However, the cross showing significant SCA value, provided that at least one of its parents had high desirable GCA effect, is expected to produce favorable transgrassive segregants through hybridization with delayed selection (because of dominance and epistatic interactions) if the complementary epistatic effect present in that cross acts in the same direction to maximize desirable plant attributes (Salimath & Bahi, 1985).

## Conclusion

From these results it can be concluded that tomato lines B26 and B27 proved as best general combiner and could be utilized in multiple crossing program to develop early maturing and high yielding tomato genotypes. Three crosses viz. B23 x B27, B25 x B26 and B24 x B27 had at least one good general combiner parent and had high SCA effect thus suggesting heterosis breeding as a valid strategy for the development of vigorous high yielding genotypes from the succeeding progenies.

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