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# GENETIC ANALYSIS TO FIND SUITABLE PARENTS FOR DEVELOPMENT OF TOMATO HYBRIDS

## SUMMARY

Line × Tester analysis was used to identify the potential parents and their hybrids from a set of 12 crosses derived from three lines (LA-2661, LA-2662 and 017899) and four testers (BL-1078, BL-1079, CLN-2413 and CLN-2418-A). Results showed that parents and $F_1$ hybrids differed significantly for general combining ability and specific combining ability effects, respectively. The values of general combining ability (GCA) and specific combining ability (SCA) variances depicted non-additive and additive gene action with predominance of non-additive gene action in the genetic determination of all characters except fruit yield per plant. Parent lines LA-2662 and CLN-2418-A provided the best general combining ability in more than one yield contributing traits. Specific combining ability effects, heterosis and heterobeltiosis in desired direction were recorded in two crosses viz. "LA-2662 × CLN-2418-A" and "LA-2662 × BL-1078". $F_1$ hybrid "LA-2662 × CLN-2418-A" proved to be the best cross in overall performance and should be further exploited in breeding plans for hybrid vigour and commercial utilization.

**Keywords:** Tomato, GCA, SCA, heterosis, gene action

## INTRODUCTION

Pakistan is an agriculture based country and to fulfill the food demand of ever increasing population, there is an urgent need to improve the yield potential of crops. Among the various crops grown in Pakistan, importance of tomato as a food crop cannot be under estimated. Tomato *(Lycopersicon esculentum* L. 2n=2x=24) is considered as second most important vegetable crop after potato in the world and is widely being used in domestic as well as industrial products. It plays a pivotal part in human diet as major contributor of potassium, phosphorous, magnesium and iron as well as antioxidants such as carotenoids, lycopene and phenolics. Of vitamins, it contains small amounts of ascorbic acid, vitamins B1, B6, PP vitamin and vitamin E (Rai *et al.*, 2012) and (Cota *et al.*, 2013). It also plays an important part in improving nutrition of poor population as

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compared to milk, meat, fruits and other high priced items. Recent studies suggest that tomatoes markedly reduce the risk of prostate cancer (Kucuk, 2001). It is reported that a 100 g of tomato can supply about 20% and 40% of the recommended daily allowances of vitamin A and C, respectively (Grierson and Kader, 1986). In many countries its juice is used as a substitute for orange juice for children fed on pasteurized milk and a home remedy suffering from rickets and helps in digestion of food. Currently, Pakistan ranks $35^{th}$ in tomato production on the globe. During 2011, tomato was grown on an area of 52.3 thousand hectares which is about 20% of the total area under vegetable cultivation with total production 529.6 thousand tones (Govt. of Pakistan, 2011-12).

Average yield of tomato in Pakistan is very low comparing to other countries like India, Iran and Bangladesh due to lack of focus on its genetic improvement for yield contributing traits, secondary importance in crop husbandry and lack of good combiner parents to be crossed for exploitation of heterosis. To cope with the problems hybrid development is one of the best ways to meet the ever increasing demand and improving the yield potential of crops. The hybrid crops lead to several benefits like quick and convenient way of combining desirable characters, higher productivity, earliness, improved quality, resistance to biotic and abiotic stresses etc. But in Pakistan only one local tomato hybrid (Salar $F_1$) has been brought to market for commercial cultivation yet and thus a huge amount of foreign exchange is spent on the import of tomato seeds every year. According to an estimate during the last two years, the import of tomato seed has been increased from 38 metric tons to 57 metric tons which amounts 83 million to 185 million rupees, respectively (Anon., 2011).

Therefore, the available germplasm must be replaced with newly evolved hybrids with attractive quality traits to attain high yield potential. Considering the present scenario, development of hybrid is inevitable to enhance the crop yield. For this purpose, choice of parents is an important step that promotes a well-planned hybridization programme. In this direction, Line × Tester design proposed by Kempthorne (1957) helps the breeders to determine combining ability status of genotypes and nature of gene action, which places heterosis breeding on further scientific footing.

## MATERIALS AND METHODS

The research work was conducted in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad 2011-12 and 2012-13. The plant material used for present study was generated by crossing seven tomato pure lines in line × tester mating fashion by keeping three varieties as lines and four as testers. Twelve $F_1$ hybrids were developed and evaluated along with seven parents in triplicated randomized complete block design (RCBD). Each entry was planted in a single row of 5.5 meter length with inter-row and intra-row distance of 125 cm and 50 cm, respectively. A single non-experimental row was planted on both sides of each plot to minimize experimental error due to border effects. Agronomic and plant protection practices were applied as per recommendations to raise healthy and vigorous crop. Data on the following traits was recorded as number of flower clusters per plant, number of fruits per plant, fruit weight (g), fruit length (cm), fruit diameter (cm), fruit yield per plant (kg), fruit firmness (g/cm$^2$), number of locules per fruit and total soluble solids (meL$^{-1}$). The recorded data of all characters were analyzed statistically according to Steel *et al.* (1997). General and specific combining ability analysis and their effects were estimated following the method described by Kempthorne (1957). Percent heterosis over mid parent and better parent was computed after calculating heterosis of respective parent by using formula proposed by Falconer and Mackay (1996).

## RESULTS AND DISCUSSION

Mean performance of three lines and four testers used as parents in the present study indicated that there were highly significant differences among all genotypes for most of the observed traits (Table 1). The testers showed non-significant differences for all the traits, except fruit firmness while the lines exhibited highly significant differences for fruit yield per plant, significant differences for fruit weight and fruit diameter. Highly significant differences were observed in all twelve hybrids for all traits. The significant differences among parent crosses are in accordance with results reported by Chandha *et al.* (2001) and Dhaliwal *et al*. (2003).

### General Combining Ability Effects of Parents:

Estimation of general combining ability (GCA) provides basic and important information for exploiting genetic potential of parents for development of superior and elite lines. As expression of significant and high GCA effects of a parent line reflect the presence of favorable additive genes with additive genetic effects that lead to selection in early generations for developing widely adapted hybrids (Roy *et al.* 2002). Estimation of GCA effects of lines and testers represented that no single line or tester exhibited good general combining ability for any of the trait under consideration (Table 2).

Among the lines, highest values of GCA effects were shown by the line 017899 for number of fruits per plant and number of locules per fruit and the line LA-2661 for fruit length while the line LA-2662 has highest GCA effects for all other traits. Similarly among the testers, BL-1079 has highest GCA effects for fruit length, CLN-2413 for fruit diameter and BL-1078 for flower clusters per plant and number of fruits per plant while CLN-2418-A exhibited the highest GCA effects for all other traits (Table 2).

According to these results, line LA-2662 and the tester CLN-2418-A showed maximum positive GCA effects for most of the traits so these parents could be successfully used in future breeding plans. High GCA effects are attributed to additive gene action and additive × additive gene interaction as Harer & Bapat (1982) and Premalatha *et al*. (2006) reported.

Table 1. Mean squares values for various yield related traits from L × T ANOVA

| | TRAITS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CROSSES** | Flower clusters Per plant | No. of Fruits per plant | Fruit Weight (g) | Fruit Length (cm) | Fruit diameter (cm) | Fruit yield per Plant (kg) | Fruit Firmness ($g/cm^2$) | No. of locules per fruit | Fruit TSS ($meL^{-1}$) |
| Replications | $0.063^{N.S}$ | $6.089^{N.S}$ | $0.376^{N.S}$ | $0.002^{N.S}$ | $0.005^{N.S}$ | $0.004^{N.S}$ | $27935.01^{N.S}$ | $0.031^{N.S}$ | $0.05^{N.S}$ |
| Genotypes | $5.797^{**}$ | $886.8^{**}$ | $122.3^{**}$ | $0.409^{**}$ | $0.128^{**}$ | $0.936^{**}$ | $6141363^{**}$ | $1.09^{**}$ | $423.4^{**}$ |
| Parents | $1.623^{*}$ | $355.2^{**}$ | $37.26^{**}$ | $0.75^{**}$ | $0.063^{**}$ | $0.157^{**}$ | $1014343^{**}$ | $1.206^{**}$ | $80.24^{**}$ |
| Crosses | $6.599^{**}$ | $1185^{**}$ | $170.7^{**}$ | $025^{**}$ | $0.142^{**}$ | $1.381^{**}$ | $5891504^{**}$ | $0.854^{**}$ | $643.1^{**}$ |
| Parents vs. Crosses | $22.03^{**}$ | $791.2^{**}$ | $100.9^{**}$ | $0.115^{**}$ | $0.368^{**}$ | $0.729^{**}$ | $39651930^{**}$ | $2.995^{**}$ | $64.81^{**}$ |
| Tester | $6.22^{N.S}$ | $817^{N.S}$ | $83.3^{N.S}$ | $0.13^{N.S}$ | $0.003^{N.S}$ | $0.71^{N.S}$ | $12310053^{*}$ | $0.44^{N.S}$ | $413^{N.S}$ |
| Lines | $1.57^{N.S}$ | $584^{N.S}$ | $554.7^{*}$ | $0.54^{N.S}$ | $0.505^{*}$ | $5.86^{**}$ | $7408421^{N.S}$ | $1.00^{N.S}$ | $568^{N.S}$ |
| Lines × Tester | $8.464^{**}$ | $1570^{**}$ | $86.33^{**}$ | $0.213^{**}$ | $0.091^{**}$ | $0.227^{**}$ | $2176590^{**}$ | $1.013^{**}$ | $783.2^{**}$ |
| Error | 0.505 | 6.734 | 1.156 | 0.008 | 0.011 | 0.005 | 11715.76 | 0.252 | 1.4 |
| Total | 2.19 | 289.6 | 40.07 | 0.137 | 0.048 | 0.304 | 1982539 | 0.513 | 137 |

**= Highly significant * = Significant N.S = Non significant

Table 2. General Combining Ability estimates of various yield related traits of lines and testers in tomato

| PARENTS | TRAITS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flower clusters Per plant | No. of Fruits per plant | Fruit Weight (g) | Fruit Length (cm) | Fruit diameter (cm) | Fruit yield per Plant (kg) | Fruit Firmness (g/cm$^2$) | No. of locules per fruit | Fruit TSS (meL$^{-1}$) |
| LA-2661 | -0.19 | 1.87 | -3.31 | 0.24 | -0.122 | -0.63 | -347.82 | -0.077 | 0.22 |
| LA-2662 | 2.03 | 5.85 | 7.82 | 0.14 | 0.237 | 0.76 | 899.61 | -0.243 | 6.77 |
| 017899 | -0.23 | 10.3 | -4.51 | -0.10 | -0.115 | -0.13 | -551.78 | 0.313 | -6.99 |
| BL-1078 | 0.77 | 9.51 | -1.31 | 0.02 | -0.004 | -0.19 | -1261.97 | -0.23 | -4.38 |
| BL-1079 | -0.12 | -2.45 | 0.56 | 0.17 | -0.017 | 0.22 | 135.84 | -0.007 | 5.60 |
| CLN-2413 | -1.12 | -12.22 | -3.19 | -0.10 | 0.024 | -0.29 | -400.85 | -0.06 | -7.18 |
| CLN-2418-A | 0.47 | 5.16 | 3.94 | -0.06 | -0.003 | 0.26 | 1526.98 | 0.30 | 5.96 |

**Specific Combining Ability Effects of Hybrids:**

Accumulation of additive gene effects for desired characters is the basic need for hybrid development and hybrids with high SCA effects for various traits involving either one or both of the parents with good GCA indicating the preponderance of additive genetic effects. On the other hand, Hybrids with significant and positive SCA involving the parents with low or non-significant GCA showed the worth of non-additive genetic effects.

Many hybrids present high significant SCA effects in high × low or high × high general combining phenomenon due to the interaction of dominant alleles from good combiners and recessive alleles from poor combiner (Roy *et al.*, 2002).

Significant superior SCA effects for all observed traits were not shown by a single hybrid. Cross LA-2662 × BL-1078 exhibited significant SCA effect for flower clusters per plant and fruit firmness while the hybrids LA-2661 × CLN-2413, 017899 × CLN-2418-A, LA-2661 × BL-1079, LA-2661 × BL-1078, LA-2662 × CLN-2413, O17899 × BL-1079, LA-2662 × CLN-2418-A showed the highest significant SCA effects for number of fruits per plant, fruit weight, fruit length, fruit diameter, fruit yield per plant, number of locules per fruit and fruit TSS respectively (Table 3).

SCA represents the deviation from additivity i.e. the dominance gene action ignoring the epistatic effect. Among all hybrids, only LA-2661 x BL-1078 exhibited significant SCA effects for seven characters except fruit length and fruit firmness. So this hybrid can be used in future breeding purposes. These results are also in accordance with the study of Sharma *et al.* (2002), Chisti *et al.* (2007) and Saleem *et al.* (2009).

**Heterosis and Heterobeltiosis:**

Significant efforts have been made for exploitation of heterosis in different yield contributing traits to find the feasible cross for the production of $F_1$ hybrids. The hybrids with high heterotic effects may offer better chances for identification of desirable pure lines in the following advanced generations as compared to hybrids with low heterosis (Sharif *et al.*, 2001).

All the crosses exhibited significant mid parent heterosis for majority of the traits indicating a predominance of non-additive gene action in the genetic control of these traits. The highest mid parent heterosis were exhibited by the hybrids viz : LA-2662 × BL-1078, 017899 × BL-1078, LA-2661 × CLN-2418-A, LA-2661 × BL-1078, LA-2662 × CLN-2413, 017899 × CLN-2413, 017899 × BL-1079 for traits including flower clusters per plant, number of fruits per plant, fruit weight, fruit length, fruit diameter, fruit firmness and number of locules per fruit, respectively while the hybrid LA-2662 × CLN-2418-A showed highest significant heterosis for fruit yield per plant and fruit TSS (Table 4).

Similarly the highest better parent heterosis observed in hybrid LA-2661 × BL-1078 for number of fruits per plant and fruit length, cross LA-2662 × BL-1078 for flower clusters per plant and fruit firmness, hybrid LA-2662 × CLN-2418-A for fruit diameter and fruit TSS and the hybrid LA-2662 × CLN-2413 for fruit weight, fruit yield per plant and number of locules per fruit (Table 5).

Table 3. Specific Combining Ability Effects for various yield related traits of crosses among parents

| CROSSES | TRAITS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flower clusters Per plant | No. of Fruits per plant | Fruit Weight (g) | Fruit Length (cm) | Fruit diameter (cm) | Fruit yield per Plant (kg) | Fruit Firmness (g/cm$^2$) | No. of locules per fruit | Fruit TSS (meL$^{-1}$) |
| LA-2661 × BL-1078 | 0.35 | 5.22 | 2.56 | -0.044 | 0.25 | 0.18 | -645.6 | 0.52 | 6.00 |
| LA-2661 × BL-1079 | 0.49 | -11.03 | 4.69 | 0.394 | 0.03 | 0.17 | 52.6 | -0.70 | 13.04 |
| LA-2661 × CLN-2413 | -1.42 | 28.84 | -2.39 | -0.028 | -0.08 | -0.17 | 10.8 | -0.23 | -12.14 |
| LA-2661 × CLN-2418A | 0.58 | -23.04 | -4.86 | -0.322 | -0.20 | -0.18 | 582.2 | 0.41 | -6.91 |
| LA-2662 × BL-1078 | 1.83 | 12.01 | 0.51 | 0.041 | -0.06 | 0.07 | 1374.9 | 0.19 | -6.70 |
| LA-2662 × BL-1079 | -0.11 | -9.26 | -0.60 | -0.103 | -0.06 | -0.37 | -226.3 | 0.13 | -14.11 |
| LA-2662 × CLN-2413 | -0.19 | -15.90 | 3.32 | -0.017 | 0.02 | 0.25 | -652.5 | 0.02 | -1.47 |
| LA-2662 × CLN-2418A | -1.53 | 13.15 | -3.24 | 0.080 | 0.10 | 0.06 | -496.1 | -0.34 | 22.28 |
| O17899 × BL-1078 | -2.19 | -17.23 | -3.07 | 0.003 | -0.20 | -0.25 | -729.3 | -0.71 | 0.70 |
| O17899 × BL-1079 | -0.38 | 20.28 | -4.10 | -0.291 | 0.03 | 0.20 | 173.7 | 0.57 | 1.07 |
| O17899 × CLN-2413 | 1.62 | -12.94 | -0.93 | 0.045 | 0.07 | -0.08 | 641.7 | 0.21 | 13.61 |
| O17899 × CLN-2418-A | 0.95 | 9.88 | 8.10 | 0.242 | 0.10 | 0.13 | -86.1 | -0.07 | -15.37 |

Table 4. Estimates of heterosis for various yield related traits in tomato

| CROSSES | TRAITS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flower clusters per plant | No. of Fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit diameter (cm) | Fruit yield per plant (kg) | Fruit firmness (g/cm$^2$) | No. of locules per fruit | Fruit TSS (meL$^{-1}$) |
| LA-2661 × BL-1078 | 19.31 | 13.92 | 4.41 | 38.23 | 9.50 | -12.70 | -35.22 | 13.51 | 3.32 |
| LA-2661 × BL-1079 | 15.56 | 11.83 | 34.83 | 9.64 | 1.29 | 1.82 | 37.58 | -28.57 | 27.44 |
| LA-2661 × CLN-2413 | -14.80 | -7.41 | -26.48 | 23.26 | 2.54 | -28.20 | 39.46 | 6.06 | -21.72 |
| LA-2661 × CLN-2418-A | 16.95 | 13.70 | 74.32 | 19.53 | -3.55 | -14.20 | 14.53 | 14.63 | -4.47 |
| LA-2662 × BL-1078 | 43.23 | -16.41 | 28.96 | 13.92 | 7.49 | 26.95 | 84.33 | 16.13 | 0.88 |
| LA-2662 × BL-1079 | 17.65 | 3.37 | 47.76 | -1.06 | 5.80 | 24.39 | 75.09 | 5.56 | 4.69 |
| LA-2662 × CLN-2413 | 6.85 | -2.41 | 22.81 | 14.05 | 12.31 | 32.52 | 67.87 | 33.33 | 11.80 |
| LA-2662 × CLN-2418-A | 3.45 | 11.51 | 33.56 | 16.69 | 11.72 | 35.09 | 15.81 | 2.86 | 53.47 |
| 017899 × BL-1078 | -0.92 | 17.21 | -20.55 | 14.45 | -2.39 | -6.38 | -29.20 | 10.34 | -14.44 |
| 017899 × BL-1079 | 13.33 | -9.81 | -6.55 | 4.08 | 2.48 | 26.49 | 74.14 | 47.06 | 0.22 |
| 017899 × CLN-2413 | 25.96 | 4.54 | -25.63 | 20.65 | 7.87 | -1.37 | 115.27 | 8.00 | 6.42 |
| 017899 × CLN-2418-A | 28.51 | -8.10 | 51.86 | 21.87 | 5.73 | 19.17 | 18.62 | 39.39 | -25.80 |

Table 5. Estimates of heterobeltiosis for various yield relating traits in tomato

| CROSSES | TRAITS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flower clusters per plant | No. of Fruits per plant | Fruit weight (g) | Fruit length (cm) | Fruit diameter (cm) | Fruit yield per plant (kg) | Fruit firmness (g/cm$^2$) | No. of locules per fruit | Fruit TSS (meL$^{-1}$) |
| LA-2661 × BL-1078 | 14.88 | 7.41 | -2.28 | 12.46 | 5.73 | -15.61 | -39.49 | 0.00 | 2.13 |
| LA-2661 × BL-1079 | 15.04 | -5.61 | 18.48 | -0.21 | -3.36 | -2.45 | 29.87 | -28.57 | 26.08 |
| LA-2661 × CLN-2413 | -15.18 | 1.12 | -20.18 | 4.28 | 0.71 | -29.00 | 10.73 | -16.67 | -27.31 |
| LA-2661 × CLN-2418-A | 11.29 | -4.84 | -17.23 | -1.91 | -7.08 | -21.20 | 9.33 | 11.90 | -7.28 |
| LA-2662 × BL-1078 | 35.54 | -7.87 | 21.83 | -22.53 | 7.00 | 22.19 | 75.38 | 12.50 | -4.31 |
| LA-2662 × BL-1079 | 15.04 | 7.21 | 24.26 | -22.57 | 4.03 | 20.81 | 68.38 | -9.52 | -0.78 |
| LA-2662 × CLN-2413 | 5.41 | -3.41 | 24.80 | -25.97 | 10.88 | 24.78 | 35.25 | 20.00 | 10.57 |
| LA-2662 × CLN-2418-A | -3.23 | -1.52 | 22.72 | -22.32 | 10.96 | 33.02 | 10.67 | -10.00 | 40.02 |
| 017899 × BL-1078 | -10.74 | 5.76 | -25.64 | 0.28 | -6.42 | -12.52 | -41.27 | 0.00 | -15.39 |
| 017899 × BL-1079 | 5.31 | -10.81 | -17.88 | -26.37 | -2.91 | 17.19 | 43.17 | 19.05 | -0.80 |
| 017899 × CLN-2413 | 18.02 | -2.54 | -19.27 | -4.55 | 5.18 | -5.81 | 112.18 | 7.87 | -1.15 |
| 017899 × CLN-2418-A | 14.51 | -1.32 | 14.06 | 5.18 | 1.14 | 6.01 | 18.50 | 15.00 | -95.67 |

Among all hybrids, LA-2662 × CLN-2418-A was the only cross that showed positive significant mid parent heterosis in all traits (Table 4) while the hybrid LA-2662 × CLN-2413 exhibited positive significant heterobeltiosis for all traits except fruit length and number of fruits per plant (Table 5).

Observed significant heterosis over better parent in the majority of the crosses for all traits indicated the involvement of non-additive gene action in the genetic control of that trait. Assuming that epistasis is absent, the cause of heterosis can only be attributed to the dominance gene action. This was in agreement with previous findings of Sharma *et al*. (1996), Padma *et al*. (2002), Patgaonkar *et al*. (2003), Premlakshmi *et al*. (2006), Sharma *et al.* (2006), Kumar *et al*. (2009) and Komori and Sharma (2011).

The hybrids (H × H) involving both parents (male and female parents) having high overall GCA status and hybrids (H × L) involving high (female) and low (male) overall GCA status produced hybrids with overall high (H) heterotic status. On the other hand, hybrids involving L × H and L × L overall GCA status had low (L) overall heterotic status. This clearly indicated the need for using parents having high overall GCA status or at least using the parents having high GCA status as female to produce hybrids with overall heterosis status.

## CONCLUSION

From this experiment it can be concluded that LA-2662 × CLN-2418A proved to be best cross for heterosis breeding and as a valid strategy for the development of vigorous high yielding genotypes from the succeeding progenies.

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