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Combining Ability Estimates in Heat Tolerant Tomato (*Solanum lycopersicum* L.) Genotypes

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Abstract

The experiment was conducted at the experimental farm of Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur from May to August 2003. Combining ability effects were estimated for yield and component traits in a 8 x 8 diallel design excluding reciprocals in tomato. The variances for general combining ability (GCA) and specific combining ability (SCA) were highly significant indicating the presence of additive as well as non-additive gene effects in the traits studied. The relative magnitude of these variances indicated that additive gene effects were more prominent for all the characters under study. The tomato genotype P1 (TM051) proved to be the best general combiner for yield followed by P2 (TM053) and the combinations P_1xP_3, P_1xP_5 and P_5xP_7 were identified as the best specific combiner for earliness, yield per plant, number of fruits per plant and individual fruit weight.

***Keywords*:** Tomato (*Solanum lycopersicum* L.), combining ability.

1. Introduction

In Bangladesh, bulk quantity of tomatoes are produced mainly in winter months starting from December to February mainly with a little bit in early and late winter months but no summer production. That is, the production of tomato in Bangladesh is confined only in the winter season. There are many varieties, such as Ratan and Roma VF which are exclusively grown in winter. All these varieties are heat sensitive and usually fail to set fruit under high temperature conditions. Because of the high popularity vis-a-vis high demand of the crop, variety development for summer production is very much desired.

Combining ability studies are more reliable as they provide useful information for the selection of parents in terms of performance of the hybrids and elucidate the nature and magnitude of various types of gene actions involved in the expression of quantitative traits. Diallel cross analysis provides the estimates of genetic parameters regarding combining ability as well as a rapid overall picture of the dominance relationship of the parents studied using the first filial generations (F_1) with or without reciprocals. It also gives additional information as presence or absence of epistasis, average degree of dominance, distribution of dominant and recessive genes in the parents. Application of diallel technique in a self-pollinated crop like tomato for this purpose may be appropriate.

Villareal and Lai (1979) reported that heat tolerance is controlled by largely recessive genes and inherited in a complex fashion with low heritability, which are typical of polygenetic traits. They also suggested that the heat tolerant genes are easily influenced by environment. In another observations (AVRDC, 1988) pointed out that heat tolerance in tomato may not be as complex as had been reported previously by Villareal and Lai in 1979. Genetic information of tomatoes in this respect under the hot humid conditions of Bangladesh is not available. Therefore, the present study was undertaken with the objective to generate information for identification of good general and specific combiners for the improvement of yield and its attributes.

2. Materials and Methods

The experiment was conducted at the experimental farm of Olericulture Division, HRC, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur from May to August 2003. The average minimum and maximum temperature during the crop period was 25.47^{0}C and 32.16^{0}C respectively. A diallel cross of 8 x 8 excluding reciprocals were constructed from the eight parental lines viz., P_1 (TM051), P_2 (TM053), P_3 (TM017), P_4 (TM026), P_5 (TM025), P_6 (TM041), P_7 (TM044), P_8 (TM002). Seeds of the eight selfed parents and their twenty-eight F_1 hybrids were sown in seed bed on 03 May 2003. Then at the age of 35 days, seedlings were transplanted in the main experimental plots. The experiment was set up in a randomized complete block design (RCBD) with four replications. Thirty-six genotypes (28 F_1`s + 8 parents) of tomato were considered as the 36 treatments of the experiment. The unit plot size was 5.0 x 1.0m and the plants were spaced 50cm on row. Each unit plot contained single row accommodating 10 plants where data were collected from randomly selected five plants leaving two border plants. The experimental plots were covered by transparent polytuunel with minimum interruption of photosynthesis. The polytuunels were 2.3 meter wide having two 1.0 meter wide bed with 30 cm drain in between, which serves as irrigation channel. The tunnels were used to protect the plants from high rainfall. All the sides of tunnel were open for good aeration. The recommended dosage and method of application of manure and fertilizers were used. Weeding and mulching was done followed by top-dressing and irrigation was applied at 15 days interval. Data on days to 50% flowering, fruit set (%), fruit length (cm), fruit diameter (cm), fruits per plant, individual fruit weight (g), yield per plant (g) and brix (%) were recorded. All the quantitative data taken were subjected to ANOVA. Combining ability analysis of the traits with significant genotypic differences was done according to the Model 1 and Method 2 of Griffing (1956a, b). This analysis partitioned the variation due to genotypic differences into general combining ability (GCA) and specific combining ability (SCA) effects.

3. Results and Discussion

The analysis of variance for combining ability (general and specific combining ability) were found to be highly significant for all the characters studied (Table 1) indicating that both additive and non-additive gene actions played significant role for the expression of these characters. Opena *et al.* (1987) also reported to obtain similar result for fruit setting at high temperature. GCA variances were higher in magnitude than the SCA variances for all the characters studied indicating the predominance of the additive gene effects for the characters. El-Ahmadi and Stevens (1979), Dane *et al.* (1991), Hanna *et al.* (1982), El-Mahdy *et al.* (1990) and E-Metwally *et al.* (1996) also reported that additive gene effects appeared to be more important than non-additive gene effects for fruit set, early yield, total yield, average fruit weight and total soluble solid (TSS)%.

3.1. General combining ability (GCA) effects

The GCA component is primarily a function of the additive genetic variance. GCA and SCA variances with each parent play significant role in the choice of parents. A parent with higher positive significant GCA effects is considered as a good general combiner. The magnitude and direction of the significant effects for the eight parents provide meaningful comparisons and would give indications to the future breeding programme. The results of GCA effects for eight different characters are presented in the Table 2.

Table 1. Analysis of variance results for combining ability.

Source of variation	d f	Mean sum of square							
		Days to 50 % flowering	Percent of fruit set	Fruit length (cm)	Fruit diameter (cm)	Fruits per plant	Individual fruit weight (g)	Yield per plant (g)	Brix (%)
GCA	7	7.67**	246.74**	1.21**	0.42**	650.27**	148.31**	787933.31**	0.20**
SCA	28	6.24**	18.02**	0.09**	0.15**	132.85**	39.27**	250209.42**	0.09**
Error	105	0.55	1.89	0.00	0.00	5.35	1.43	5909.91	0.01
SCA/GCA	-	0.81	0.07	0.07	0.36	0.20	0.26	0.32	0.45

** Significant at 1% level of probability

Table 2. Estimates of GCA effects of the parents for combining ability of heat tolerant tomato genotypes.

Parents	Days to 50 % flowering	Percent of fruit set	Fruit length (cm)	Fruit diameter (cm)	Fruits per plant	Individual fruit weight (g)	Yield per plant (g)	Brix (%)
P_1	0.34	7.60**	0.17**	0.08**	12.44**	2.56**	539.41**	-0.18**
P_2	1.01**	2.70**	-0.04**	0.01	7.46**	-1.28**	170.39**	0.02
P_3	0.11	-2.12**	-0.59**	-0.15**	-1.66*	-5.79**	-157.23**	-0.01
P_4	-1.36**	1.67**	-0.20**	-0.24**	5.11**	-3.26**	47.57*	-0.13**
P_5	0.19	-1.47**	0.09**	0.45**	-6.44**	7.03**	-23.10	0.12**
P_6	-0.14	-2.24**	-0.00	-0.07**	-1.21	-0.64	-95.61**	0.12**
P_7	-0.39	3.04**	0.64**	-0.05**	-2.86**	1.35**	-41.97	-0.14**
P_8	0.24	-9.17**	-0.06**	-0.04	-12.84**	0.03	-439.46**	0.21**
SE (gi)	0.22	0.41	0.01	0.02	0.68	0.35	22.74	0.04
SE (gi-gj)	0.33	0.62	0.01	0.02	1.04	0.54	34.38	0.05

* Significant at 5% level of probability

** Significant at 1% level of probability

3.1.1. Days to 50% flowering

Parent P_2 showed the highest positive GCA effect (1.01**) while P_4 had the highest negative significant effect (- 1.36**) (Table 2). The other parents P_7 and P_6 also showed negative value but were statistically similar. So, the parent P_4 was the best general combiner for earliness. The other parents with positive value were not desirable as general combiners for this trait. El-Mahdy *et al.* (1990) reported highly significant GCA effect for early yield in certain lines under heat stress in tomato. E-Metwally *et al.* (1996) also found similar effect in heat tolerant tomato lines.

3.1.2. Percent of fruit set

Parents P_1, P_2, P_4 and P_7, the heat tolerant lines showed highly significant GCA effect for fruit setting which agree with E-Metwally *et al.* (1996). The other parents showed either insignificant or negatively significant GCA values for this trait. Hence, parent P_1 performed as the best general combiner for higher fruit set per cent followed by P_7, P_2 and P_4 since these parents had the higher and significant positive GCA effects.

3.1.3. Fruit length (cm)

Highest significant and positive GCA effect for the trait was found in P_7 (0.64**) followed by

P_1 (0.17**) and P_5 (0.09**) (Table 2). Rest of the parents showed negatively significant GCA effects for the trait except P_6. So, P_7 was the best and followed by P_1, P_5 with respect good general combining ability.

3.1.4. Fruit diameter (cm)

In case of fruit diameter, parent P_5 showed to highest and positively significant GCA effect (0.45**) followed by P_1 (0.08**). Other parents (P_3, P_4, P_6 and P_7) showed negatively significant effect for GCA value.

3.1.5. Fruits per plant

Parent P_1 had the highest positively significant GCA effects (12.44**) followed by P_2 (7.46**) and P_4 (5.11**) indicating that these parents may be used in hybridization programme for improving the number of fruits per plant.

3.1.6. Individual fruit weight (g)

The parent P_5 showed the highest significant positive GCA effects (7.03**) for this trait. This was followed by P_1 (2.56**) and P_7 (1.35**). E-Metwally (1996) also reported higher GCA values for individual fruit weight in heat tolerant parents. The other parents showed either positively insignificant or negatively significant and insignificant GCA values for this character. Thus parent P_5 followed by P_1 and P_7 might be used in crosses for the improvement of individual fruit weight as indicated by their significant and higher GCA effects.

3.1.7. Yield per plant

GCA effect of yield per plant as presented in Table 2 shows that parent P_1 had the highest positively significant values (539.41**) followed by parent P_2 (170.39**). Parent P_4 also showed positively significant values. Other parents showed either insignificantly positive or negative and significantly negative GCA values. So, parents P_1 and P_2 were the best general combiners in crosses for the improvement of this trait. E-Metwally *et al.* (1996) and Shalaby *et al.* (1983) reported that heat tolerant lines had greater GCA than heat sensitive cultivars and opined that both additive and non-additive genetic variances were important in the inheritance of total yield under high temperature conditions, but additive genetic variance was more important than the non-additive genetic variance.

3.1.8. Brix percent

The results as evidenced from Table 2 for this trait show that, P_8 was the best general combiner with the highest positive significant GCA value (0.21**) followed by P_5. Parent P_6 also showed positively significant GCA effect. The other parents had either insignificant positive or negative and significant negative GCA value for the trait.

Wessel-Beavar and Scott (1992) reported that fruit set, fruit weight and yield were to be at least partially under common genetic control under the high temperatures. Hanna *et al.* (1982) reported that the crosses involving the parent S6916 with the highest GCA values gave the highest percentage of fruit set in general where the maximum day temperature ranged from 32.4^0 to 36.1^0C and the lowest night temperature ranged from 22.6^0 to 25.3^0C. This indicates that certain parents like S6916 transmitted good fruit setting ability to its progenies. In the present study P_1 might be the best such combiner. Stevens (1979) reported that percent fruit set is under the control of a largely additive genetic system with moderate heritability under high temperature.

3.2. Specific combining ability (SCA) effects

The SCA effects related to a particular cross signify the role of non-additive gene action in the expression of the characters. It indicates the highly specific combining ability leading to the highest performance of some specific cross combinations. Highest SCA effects may arise not only in crosses involving high combiners but also in those involving low combiners. Thus in practice, some of the low combiners should also be accommodated in hybridization programme. The SCA effects of 28 F_1 crosses for eight different characters studied are presented in Table 3.

Table 3. Estimates of SCA effects of the cross combinations for combining ability of heat tolerant tomato genotypes.

Cross	Days to 50% flowering	Percent of fruit set	Fruit length (cm)	Fruit diameter (cm)	Fruits per plant	Individual fruit weight (g)	Yield per plant (g)	Brix (%)
P_1 x P_2	0.25	2.03	0.16**	0.08	-1.19	5.10**	259.22**	0.08
P_3	-8.35**	2.30*	0.24**	0.32**	21.18**	11.13**	1219.36**	0.11
P_4	1.37*	3.89**	0.32**	-0.09*	-10.34**	1.65	-304.74**	0.18
P_5	-2.18**	-0.81	0.62**	0.77**	6.96**	8.57**	756.83**	0.13
P_6	2.90**	-.96	-0.15**	0.29**	-6.52**	-0.67	-239.53**	-0.40**
P_7	2.90**	1.00	-0.06**	-0.25**	-3.37	-0.80	-256.00**	-0.26**
P_8	0.27	-1.84	-0.36**	0.22**	7.11**	-3.43**	94.09	0.19*
P_2 x P_3	-1.78**	-1.42	0.08**	0.24**	1.41	1.14	-20.65	0.23*
P_4	-8.05**	1.50	-0.17**	-0.16**	6.88**	-1.23	124.88*	-0.08
P_5	0.90	1.37	0.09**	-0.24**	-3.82*	-0.91	-91.90	-0.05
P_6	2.72**	3.46**	-0.26**	-0.16**	11.46**	-3.24**	252.90**	0.20*
P_7	-0.03	0.78	0.10**	0.36**	-6.64**	3.02**	-100.68	-0.14
P_8	2.35**	1.57	0.41**	0.47**	0.33	7.16**	263.06**	-0.54**
P_3 x P_4	0.85	-0.82	0.11**	0.22**	15.01**	1.74	347.15**	0.48**
P_5	0.05	0.38	-0.03	-0.26**	3.31	-6.41**	-141.68*	-0.12
P_6	-2.13**	1.89	-0.17**	-0.25**	8.58**	-1.20	138.93*	-0.09
P_7	-0.13	5.92**	-0.16**	0.36**	0.23	5.42**	79.94	0.62**
P_8	-0.75	-2.38*	-0.00	0.10*	-8.79**	1.12	-245.15**	-0.28**
P_4 x P_5	4.02**	-2.84*	-0.13**	-0.32**	2.03	-5.74**	-75.58	-0.00
P_6	-3.40**	2.06	-0.12**	0.25**	15.31**	1.12	50.48**	-0.53**
P_7	1.35*	3.22**	0.20**	-0.09*	-1.04	2.71**	59.09	-0.22*
P_8	0.22	3.51**	-0.46**	-0.38**	11.18**	5.93**	609.58**	0.29**
P_5 x P_6	-3.70**	4.52**	-0.06**	-0.11**	-1.89	-2.51**	-113.94	0.08
P_7	-5.20**	1.25	0.23**	0.63**	12.26**	9.18**	823.14**	0.14
P_8	1.67**	2.93**	-0.28**	-0.75**	-3.52	-11.13**	-364.44**	0.27**
P_6 x P_7	-0.38	3.33**	0.22**	-0.09*	13.03**	0.89	513.25**	0.11
P_8	-0.75	3.05**	0.37**	0.24**	-9.24**	9.06**	-162.13**	-0.06
P_7 x P_8	0.25	4.23**	-0.53**	-0.20**	14.16**	-9.08**	169.25**	0.08
SE (sij)	0.59	1.09	0.02	0.04	1.83	0.94	60.64	0.09
SE (sii-sjj)	0.81	1.51	0.03	0.05	2.54	1.31	84.21	0.13

* Significant at 5% level of probability

** Significant at 1% level of probability

3.2.1. Days to 50% flowering

Of the twenty eight F_1s, thirteen showed negative SCA values (Table 3) indicating that 50% of the hybrids flowered earlier than their parental means. Out of these crosses, eight crosses showed highly significant negative SCA values with the largest negative values in crosses P_1 x P_3, P_2 x P_4, P_5 x P_6, P_5 x P_7 and seemed to be the best specific combiner for early flowering. El-Mahdy *et al.* (1990) and E-Metwally *et al.* (1996) also reported significant SCA effect for early yield in tomato under heat stress condition.

3.2.2. Percent of fruit set

F_1s in general had positive SCA values for the trait. Eleven F_1s showed positive significant SCA values indicating that these hybrids had higher fruit set than the means of their parents, among them P_1 x P_4, P_2 x P_6, P_3 x P_7, P_4 x P_8, P_5 x P_6 and P_7 x P_8 showed the desirable combination to enhance percent fruit set in the crop under high temperature conditions.

3.2.3. Fruit length (cm)

Thirteen combinations showed significant positive SCA effects (Table 3). Out of these, four combinations which showed higher significant positive effects were P_1 x P_5, P_2 x P_8, P_6 x P_8, P_1 x P_4 indicating consistency in the improvement of fruit length over parental means.

3.2.4. Fruit diameter (cm)

Thirteen combinations showed significant positive SCA effects. Out of these, four combinations viz., P_5 x P_7, P_2 x P_8, P_2 x P_7, P_1 x P_5 showed higher significant positive effects.

3.2.5. Fruits per plant

Of the F_1s, 12 showed significant positive SCA values indicating that these F_1s produced more number of fruits per plant than the means of their parents. Eight combinations showing highly significant positive SCA values were P_1 x P_3, P_4 x P_6, P_3 x P_4, P_7 x P_8, P_6 x P_7, P_5 x P_7, P_4 x P_8, P_2 x P6. These combinations may be considered as the best specific combiner to increase the number of fruits per plant under high temperature conditions.

3.2.6. Individual fruit weight (g)

Among the cross combinations, about 50% F_1s showed positive SCA values, of which ten had significant positive values for the trait (Table 3). This indicates that these F_1s produced larger fruit weight compared to the mean of their parents. Five F_1s which produced significantly larger positive SCA values were P_1 x P_3, P_5 x P_7, P_6 x P_8, P_1 x P_5 and P_2 x P_8. These are the F_1s with best specific combinations and considered as the best specific combiner for the improvement of the trait.

3.2.7. Yield per plant (g)

Out of the 28 F_1s, eleven showed significant positive SCA values (Table 3) indicating that these hybrids produced more yield per plant than the means of their parents. The cross combinations P_1 x P_3, P_5 x P_7, P_1 x P_5, P_4 x P_8 and P_6 x P_7 exhibited higher significant and positive SCA effects of which P_1 x P_3 provided maximum value (1219.36**) for yield per plant. Thus P_1 x P_3 was the best specific combinations followed by other ten hybrids for the improvement of yield per plant in tomato under high temperature conditions.

3.2.8. Brix percent

Seven combinations, out of 15 SCA values had significant positive SCA effects for the trait. But only four combinations (P_3 x P_7, P_3 x P_4, P_4 x P_8 and P_5 x P_8) exhibited higher significant positive SCA values indicating as very good specific combiner for the trait.

Hanna *et al.* (1982) reported that the cross combinations L401 x S6916 and Chico III x Floradel have displayed significant positive SCA effects for fruit set. E-Metwally *et al.* (1996) reported that both GCA and SCA were highly significant for fruit set percentage under high temperature growing conditions. These results suggest that both additive and non-additive genetic effects were important for inheritance of fruit set under high temperature conditions. They also reported that both additive and non-additive genetic effects were important for the control of number of seeds per fruit. Younis *et al*. (1988) found that additive effects were greater in magnitude than non-additive gene effects. Shalaby *et al*. (1983) and E-Metwally *et al*. (1990) reported both additive and non-additive genetic variances were important in the inheritance of total yield under high temperature conditions. They also reported the same trend of genetic control for early yield. About average fruit weight under high temperature conditions, Omara *et al*. (1988) supported the findings of Shalaby *et al*. (1983) and E-Metwally *et al*. (1996) that the additive genetic variance formed the major part of the total genetic variation, but non-additive variance was also significant.

4. Conclusions

It was observed from the results of this study, that the parents P_1, P_2, P_4 and P_5 showed relatively higher GCA effects for yield and yield components. The combinations P_1 x P_3, P_1 x P_5, P_2 x P_8 and P_5 x P_7 were identified as the best specific combiner for earliness, yield per plant, number of fruits per plant and individual fruit weight. It can thus be concluded that these four parents P_1, P_2, P_4, P_5 and P_7 can be used extensively in cross breeding programmes for deriving desirable genotypes in the segregating generations. These findings along with other information on combining ability in heat tolerant tomato are expected to help plant breeders to plan an effective hybrid variety development programme of heat tolerant tomato under Bangladesh conditions. The information may also help plant breeders working under similar tropical environments in other parts of the world.

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