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The Estimate of Combining Ability and Heterosis for Yield and Yield Components in Tomato (*Lycopersicon esculentum* Mill.)

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ABSTRACT

A study was conducted on a 10×10 diallel cross set of tomato including reciprocals to find out the extent of heterosis, combining ability for yield per plant (kg) and yield components (number of fruits per plant, individual fruit weight (g)) and locule number. Significant differences among genotypes were obtained for all of traits. 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 except the number of fruits per plant and relative magnitude of these variances indicated that additive gene effects were more prominent for all of the traits. The tomato genotype Mb3 proved to be the best general combiner for yield and number of fruits per plant.

Key Words: Combining ability, diallel, GCA, SCA

INTRODUCTION

Nowadays tomato is grown in most of the countries around the globe except the colder regions (Hannan *et al.* 2007). Tomato being a moderate nutritional crop is considered as an important source of Vitamin A and C and minerals which are important ingredients for table purpose, sambar preparation, chutney, pickles, ketchup, soup, juice pure etc (Sekhar *et al*. 2010). By the phenomenon of heterosis in 1907, many studies on the hybrid approaches, heterosis and combining ability estimates in tomatoes started. 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 (Ahmad *et al*. 2009). Today, applications and effects of heterosis in a hybrid tomato in terms of viability, better speed development of fruit, increase of yield has been identified (Hannan *et al.* 2007). The present investigation was undertaken to study and generate information about hybrid vigor, combining ability which would help to assess the prepotency of parents in hybrid combinations.

MATERIALS AND METHODS

The experiment was conducted at Ferdowsi Agricultural Research field, Mashhad, Iran during the months of January to September 2009 and 2010. A diallel cross of 9 × 9 including reciprocals was carried out involving nine parental lines: Supc (P1), Pte12 (P2), Mb3 (P3), Supl44 (P4), Vfj (P5), Ptk (P6), Sps (P7), Csh74 (P8) and Prg (P9). Seeds of the nine selfed parents and their seventy-two F_1 hybrids were sown in seed bed on 19^{th} March 2009. Then seedlings were transplanted in to experimental units at the 3-4 leaf stage. The experiment was set up in a randomized complete block design (RCBD) with three replications. Eighty-one genotypes (72 F_1`s + 9 parents) of tomato were considered as treatments of the experiment. Each unit plot contained single row accommodating 4 plants where data were collected from randomly selected 3 plants. The recommended dosage and method of application of manure and fertilizers were used. Weeding was done followed by top-dressing and irrigation at 15 days interval. Data on number of fruits per plant (NF/P), individual fruit weight (IFW), yield per plant (Y/P) and locule number were recorded. All the quantitative data were analyzed by Diallel 98 software. Combining ability analysis of the traits with significant genotypic differences was undertaken according to the Method 3 of Griffing (1956a, b). This analysis partitioned the variation due to genotypic differences into general combining ability (GCA) and specific combining ability (SCA) effects. Heterosis (H) and Heterosis percentage (%H) were calculated over-mid parents and genetic parameters obtained by Hayman (1954) method.

RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) showed the existence of significant variation for all four characters, indicating a wide range of variability among the genotypes. Highly significant variation due to

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general combining ability (GCA) as well as specific combining ability (SCA) indicated the importance of additive as well as non-additive types of gene action in inheritance of all characters except the number of fruits per plant.

Table 1. Mean squares from a combining ability analysis for yield and yield components in a diallel cross of Tomato.

Source	df	NF/P	IFW(g)	Y/P(kg)	NL
Replication	2	305.33 non	1927.37**	22/49**	0.20 non
GCA	8	689.94 non	1386.99**	4/47**	6.45 **
SCA	27	371.72 **	193.86 non	1/04*	0.99**
Reciprocal	36	266.68 *	219.10*	1/49**	0.76**

* Significant at P=0.05, ** Significant at P=0.01

Table 2. Parental and F1 means for yield and yield components in a tomato diallel crosses.

	Characters			
	NF/P	**IFW(g)**	**Y/P(kg)**	**LN**
Hybrids				
Supc ×Pte12	42.33	57.15	2.81	5.13
Supc ×Mb3	28.50	45.68	1.82	4.62
Supc ×Supl44	54.33	62.74	3.23	5.24
Supc ×Vfj	31.50	51.57	1.53	5.41
Supc ×Ptk	48.25	76.28	3.48	5.79
Supc ×Sps	25.00	70.30	2.06	5.82
Supc ×Csh74	30.95	60.74	1.85	4.17
Supc ×Prg	29.33	49.89	1.57	5.16
Pte12 ×Mb3	40.78	47.32	1.83	3.13
Pte12 × Supl44	43.67	54.54	2.19	4.05
Pte12 × Vfj	39.97	47.10	1.71	3.57
Pte12 × Ptk	48.04	57.97	3.64	5.30
Pte12 × Sps	49.77	50.73	2.52	3.58
Pte12 × Csh74	38.19	42.41	2.20	3.87
Pte12 × Prg	43.42	44.22	2.66	5.56
Mb3× Supl44	75.71	48.32	3.41	4.16
Mb3× Vfj	76.22	51.41	3.40	4.28
Mb3× Ptk	42.22	68.89	3.06	5.62
Mb3× Sps	26.92	82.66	1.84	5.45
Mb3× Csh74	40.50	38.40	1.80	5.65
Mb3× Prg	75	49.70	2.90	5.11
Supl44× Vfj	39.80	54.51	2.12	4.49
Hybrids	**NF/P**	**IFW(g)**	**Y/P(kg)**	**LN**
Supl44× Ptk	50.89	59.56	2.15	4.49
Supl44× Sps	31.33	57	2.82	6.08
Supl44× Csh74	59	58.09	4.33	4.98
Supl44× Prg	45.22	54.30	2.32	5.63
Vfj × Ptk	35.44	67.07	2.64	4.70
Vfj ×Sps	39	57.30	3.11	4.92
Vfj × Csh74	55.13	64.92	2.92	4.54
Vfj × Prg	44.50	65.89	2.78	5.27
Ptk ×Sps	32.99	78.76	2.08	5.54
Ptk × Csh74	59	58.23	2.36	4.69
Ptk × Prg	35.50	53.24	1.72	5.58
Sps × Csh74	45.75	81.89	3.33	5.30
Sps × Prg	41.19	65.84	2.28	6.59
Csh74× Prg	43.55	59.53	2.04	6.39

parents	NF/P	IFW(g)	Y/P(kg)	LN
Supc	43	56.64	1.39	6
Pte12	31.33	41.09	1.25	4.39
Mb3	32.33	72.53	3.69	5.22
Supl44	43.33	47.89	1.79	4.42
Vfj	45.25	48.72	2.40	5.25
Ptk	57	59.06	1.64	5.93
Sps	47.50	67.10	2.48	4.75
Csh74	45.55	61.41	2.40	5.12
Prg	48	59.94	2.11	6.35

The highest significant general combining ability (GCA) effect for number of fruits per plant was recorded in Mb3 (9.79), individual fruit weight in Sps (13.10), for yield per plant in Mb3 (0.29) and for locule number in Prg (0.59), (Table 3). These observations revealed that yield per plant and number of fruits per plant could be improved by using Mb3 and the best combiner for increasing yield was Mb3.

Table 3. General combining ability (GCA) of parents for different traits in tomato

	Characters			
parents	NF/P	IFW	Y/P	LN
Supc	-8.30	-0.96	-0.20	0.10
Pte12	0.66	-9.74	-0.06	-0.87
Mb3	9.79	-4.02	0.29	-0.10
Supl44	1.04	-6.89	-0.03	-0.29
Vfj	-2.61	-1.43	0.11	-0.27
Ptk	0.99	4.03	-0.24	0.11
Sps	-2.37	13.10	0.12	0.56
Csh74	1.30	3.20	-0.17	0.16
Prg	-0.50	2.72	0.18	0.59

The analysis of variance for specific combining ability (SCA) showed the existence of significant variation between seventy-two crosses for all of traits (Table 1). Highly significant variation due to SCA indicated the importance of non-additive gene action in inheritance of these characters. The highest significant SCA effect for number of fruits per plant was obtained in Mb3×Prg, for individual fruit weight in Mb3×Sps, for yield per plant in Prg×Supl44 and for locule number in Supl44×Sps crosses.

Table 4. Maximum and Minimum of Heterosis (H), Heterosis percentage (%H), Reciprocal effects (Rec. eff.) and Specific combining ability (SCA) in 72 hybrids of tomato

	H		H (%)		Rec. eff.		SCA	
Traits	Max	Min	Max	Min	Max	Min	Max	Min
NF/P	37.87	-19.26	25.03	-9.21	41.26	0.33	20.50	-17.88
IFW	32.04	-28.58	14.98	-10.67	25.96	0.44	20.34	-14.74
Y/P	2.87	-1.25	36.82	-10	2.49	0.02	2.87	-1.08
LN	1.5	-1.67	8.18	-8.71	2.08	0.01	1.05	-0.83

Table 4 indicated that mean heterosis (H) over mid-parent was highest for number of fruits per plant (37.87) followed by individual fruit weight (32.04), yield per plant (2.78) and locule number (1.5). The range of heterosis percentage (%H) over mid-parent was wide among number of fruits per plant (-9.21 to 25.03 %), individual fruit weight (-10.67 to 14.98 %), yield per plant (-10 to 36.82 %) and locule number (-8.71 to 8.18 %). The maximum of Reciprocal effects were observed in number of yield per plant (41.26), IFW (25.96), Y/P (2.49) and LN (2.08), (Table 4). The best combiner who expressed high significant positive GCA effect for yield per plant and number of fruits per plant in desirable direction was Mb3 but it had negative GCA effect in other traits. The Sps line was the best general combiner for individual fruit weight. On the other hand Prg and Sps were the first and second best combiner for locule number.

However none of the parents was best general combiner for all the traits indicating differences in genetic variability for different characters among the parents. The combining ability is the measure of nature of gene action. General combining ability variances largely involve additive gene action, while specific combining ability variances indicate presence of non-additive gene action which offers good scope for exploitation of heterosis. So it is significanted for both GCA and SCA expressed the role of both additive and in individual fruit weight, yield per plant and locule number non-additive gene active in control of these traits. Similar reports were also reported by Mirshamsi *et al*. (2005), Hannan *et al.* (2007), Sekhar *et al.* (2010) Govindarasu *et al* (1981). But the significance of SCA by itself showed the importance of non-additive gene in respect to the number of fruits per plant. This result supported the findings of Sekhar *et al*. (2010).

Table 5. Components of variation and Genetic parameters for yield and yield components in tomato

	Characters			
parameters	**NF/P**	**IFW**	**Y/P**	**LN**
D	9.15	49.32	36.28	42.20
H_1	189.31	78.66	57.51	33.54
H_2	136.59	46.47	40.11	9.34
F	44.32	-10.75	51.69	64.59
H_1/D	4.55	1.26	1.26	0.89
Kd	0.77	0.46	0.78	0.93

The results presented in Table 5 indicate the genetic parameters. Higher values of H_1 and H_2 compared to D show that non-additive gene effects have a greater role than additive gene effects in the genetic control of trait. But these values $H_1<D$, $H_1/D<1$, showed that the additive gene effects are the highest in the genetic control of a trait. In number of fruits per plant, significant SCA showed the non-additive gene effects (over dominance and epistasy) in control of this trait (Table 1). Because of values $H_1>D$ and on the other hand the curve was dissected by the regression line in negative part of Wr axis (Fig.1), confirmed the over dominance effects in control of this trait. These results were supported by Sekhar *et al.* (2010). In addition to over dominance effects, scattered parents (Pte12, Ptk, Sps and Csh74) out-side of curve (Fig.1) revealed the epistasy effects in control of this trait.

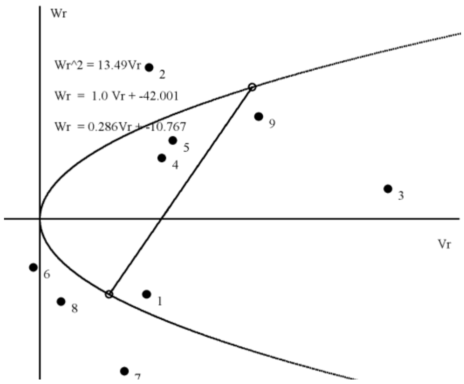

Figure 1. Regression of Wr to Vr for number of fruit per plant.
{ Supc (P_1), Pte12 (P_2), Mb3 (P_3), Supl44 (P_4), Vfj (P_5), Ptk (P_6), Sps (P_7), Csh74 (P_8) and Prg (P_9)}

Because both of SCA and GCA effects were significant, it showed that there were additive and non-additive effects (over dominance and gene effects in control of individual fruit weight (Table 1). Values $H_1>D$, $H_1/D>1$ (Table 5) and dissected curve and Wr axis by regression line in negative part of Wr axis (Fig.2), showed the over dominance effects. The same results were reported by Atanssova and Shtereva (2002), Mirshamsi *et al*. (2006), Ahmad *et al*. (2009) and Sekhar *et al.* (2010). Negative F and value Kd (Kd=0.46, Kd<0.5) confirmed higher abundance of recessive allels more than dominance allels in all of parents (Table 5). Mb3 had farthest distance to origin of coordinates (Fig.2) and had the most individual fruit weight (Table 2), which suggested that recessive allels lead to increasing individual fruit weight.

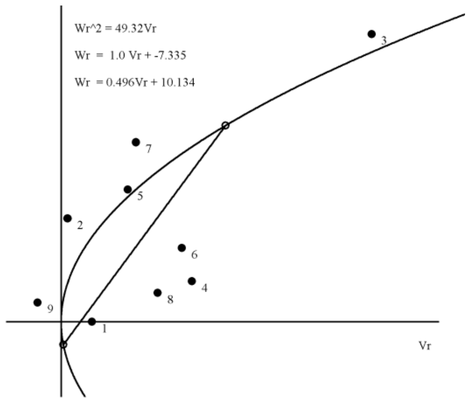

Fig.2. Regression of Wr to Vr for individual fruit weight.
{Supc (P_1), Pte12 (P_2), Mb3 (P_3), Supl44 (P_4), Vfj (P_5), Ptk (P_6), Sps (P_7), Csh74 (P_8) and Prg (P_9)}

In study of yield per plant, highly significant variation due to GCA as well as SCA indicated the importance of additive as well as non-additive types of gene action in inheritance of this trait. This finding is in close agreement with Mital and Singh (1977), Johnson and Hernandez (1980), Prata *et al.* (2003), Mirshamsi *et al.* (2006), Ahmad *et al.* (2009) and Sekhar *et al.* (2010). Positive F, value Kd (Kd=0.78, Kd>0.5) and $H_1/D>1$ showed over dominance effects in control of this trait. Also dissected curve by regression line in negative part of Wr axis (Fig.3) confirmed these results.

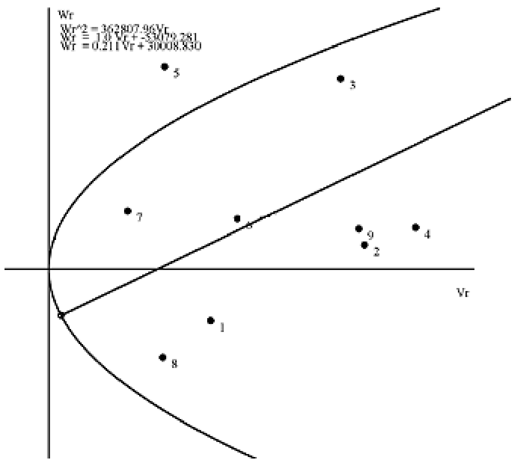

Figure 3. Regression of Wr to Vr for yield per plant.
{Supc (P_1), Pte12 (P_2), Mb3 (P_3), Supl44 (P_4), Vfj (P_5), Ptk (P_6), Sps (P_7), Csh74 (P_8) and Prg (P_9)}

Highly significant variation in both GCA and SCA indicated the both role of additive and non-additive gene action in inheritance of locule number. Govindarasu *et al.* (1981) reported the same result for this character. The regression line dissected the cure at positive part of Wr axis (Fig.4) showed additive effects have greater role than non-additive gene effects in genetic control of this trait. However all of parents placed in out-side of the curve (Fig.4), which showed present of epistasy effects.

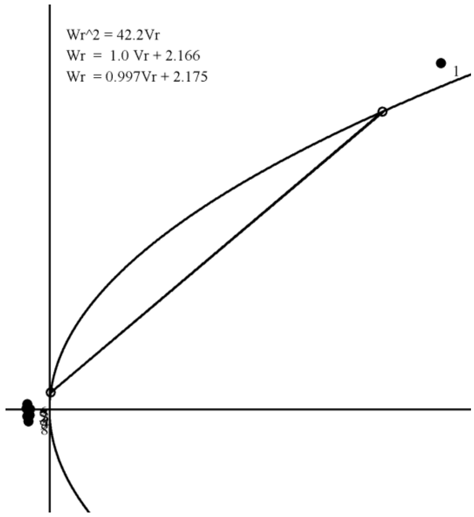

Figure 4. Regression of Wr to Vr for locule number.
{Supc (P_1), Pte12 (P_2), Mb3 (P_3), Supl44 (P_4), Vfj (P_5), Ptk (P_6), Sps (P_7), Csh74 (P_8) and Prg (P_9)}

CONCLUSIONS

The best cross combinations are Supl44×Csh74 (for yield per plant), Mb3×Vfj (for number of fruit per plant), Mb3×Sps (for individual fruit weight) and Sps×Prg (for Locule number)**.** Also the tomato genotype Mb3 proved to be the best general combiner for yield and yield components.

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