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Reciprocal cross differences and combining ability studies for some quantitative traits in tomato (*Lycopersicon esculentum* Mill.) under mid hill conditions of Western Himalayas

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ABSTRACT

Six horticulturally superior lines *viz*., Solan Vajr, AI-11, AI-14, FT-5, UHF-571 and UHF-566 were crossed in full diallel fashion including reciprocals to obtain 30 hybrids. The investigation was undertaken with the view to explore the possibility of developing high yielding tomato hybrids coupled with desirable horticultural traits. The mean sum of squares between F_1's and reciprocal F_1's were significant for all the traits including fruit yield per plant suggesting the influence of maternal effects or cytoplasmic interaction for the inheritance of these characters. For fruit yield, the range of reciprocal differences varied from -220.95 (AI-11 x UHF-566) to 279.71 g (AI-11 x FT-5). Considerable non-additive gene action was observed for this character. The parents AI-11 (130.90), UHF-571 (109.91), UHF-566 (88.05) and FT-5 (26.99) were good general combiners for fruit yield per plant. The highest positive SCA was exhibited by AI-14 x UHF-566 (512.20), followed by AI-11 x UHF-571 (425.01) and Solan Vajr x FT-5 (335.38). All the characters including fruit yield per plant showed preponderance of V_{SCA} suggesting heterosis breeding as the best approach for developing vigorous hybrids with the desirable characters.

Key words : Tomato, *Lycopersicon esculentum*, Reciprocal differences, Combining ability, Quantitative traits.

Tomato (*Lycopersicon esculentum* Mill.) a solanaceous vegetable, originated in Peruvian and Mexican region (Tigchelear, 1986) is an important vegetable crop grown in mid hills of the western Himalayas. The hybrid cultivars in tomato have generated increased interest among the breeders for the last few years due to possibility of combining complex of valuable attributes in the genotype *viz*., earliness, uniformity, high yield and strong adaptability to different environments. Differences depending on the direction of crossing in tomato have been reported by many workers. For the development of F_1 hybrids, the selection of the parents is of paramount importance. Parents are generally selected on the basis of their combining ability. The diallel cross analysis serves as a useful progeny testing technique (Christie and Shattuck, 1991). Therefore, the present investigation was undertaken with the view to explore the possibility of developing high yielding tomato hybrids coupled with desirable horticultural traits.

MATERIALS AND METHODS

The present investigation was carried out during March, 2004 to August, 2005 at the experimental farm of the Department of Vegetable Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan. The experimental site is situated at an altitude of 1270 m above the mean sea level with an average annual rainfall of 1100-1300 mm annually. During March, 2004, six horticulturally superior genotypes *viz*., Solan Vajr, AI-11, AI-14, FT-5, UHF-571 and UHF-566 were crossed in full diallel fashion including reciprocals to obtain 30 hybrids. All the genotypes and their F_1 crosses were planted during March, 2005 along with the standard check Naveen in the randomized complete block design (RCBD) with three replications. Eighteen plants per replication were transplanted at a recommended spacing of 90 x 30 cm. The standard cultural practices were followed to raise the crop. The observations on number of seeds per fruit, harvest duration (days), number of fruits per plant, average fruit weight and fruit yield per plant were recorded on ten randomly selected plants in parents as well as their crosses. The reciprocal differences and combining ability were worked out according to Griffing's (1956) Model-I and Method-I.

RESULTS AND DISCUSSION

The analysis of variance revealed significant genotypic differences for all the characters under study suggesting the presence of sufficient genetic diversity. Like wise, the mean sum of squares between F_1's and reciprocal F_1's were also significant for all the characters suggesting importance of cytoplasmic inheritance for these characters.

Significant reciprocal differences (Table 1) were exhibited by all the crosses for the number of fruits per plant except AI-14 x FT-5 (-0.16 fruits) and the range of reciprocal differences varied from -6.00 (AI-11 x UHF-566) to 7.94 (AI-14 x UHF-566); similar findings have also been reported by Trinkelein and Lamberth (1975). In tomato fruits having lesser number of seeds per fruit are desired. The reciprocal differences for the character varied from -36.84 (AI-11 x FT-5) to 38.95 seeds (AI-14 x UHF-571). Reciprocal differences for number of seeds per fruit has also been reported by Lapushner and Frankel (1979). It was observed that less number of seeds per fruit were obtained when AI-11 and Solan Vajr were taken as female parents. The maximum magnitude of reciprocal difference was found between the combination AI-14 x UHF-571 and its reciprocal (38.95 seeds), followed by Solan Vajr x UHF-566 (38.07). In case of average fruit weight, UHF-566 proved to be better in majority of combinations when it was taken as female parent than vice versa. Average fruit weight exhibited range of reciprocal differences from -24.81 (AI-14 x UHF-566) to 32.06 g (Solan Vajr x UHF-566). For harvest duration, the reciprocal differences varied from -18.12 (AI-11 x UHF-566) to 12.95 days (AI-14 x UHF-571). Fruit yield is the most important character in any breeding programme and the range of reciprocal differences for this character varied from -220.95 (AI-11 x UHF-566) to 279.71 g (AI-11 x FT-5). Reciprocal differences for this trait have also been reported by Trinkelein and Lamberth (1975), Sklyaravskaya and Drokin (1981) and Vidyasagar (1998). In most of the crosses, the fruit yield per plant was maximum when AI-11, AI-14 and Solan Vajr were used as female parents.

The combining ability analysis revealed significant GCA and SCA mean sum of squares for all the characters under study indicating the importance of both additive and non additive components of gene action for the expression of these traits (Table 2.). Reciprocal mean sum of squares were significant for all the characters suggesting the importance of reciprocal differences for these characters. The V_{GCA}/V_{SCA} ratio for all the characters under study being less than one revealed the preponderance of additive variance and thus suggesting heterosis breeding as the best approach for the improvement of these traits.

Positive GCA effects are desirable for all the characters except for number of seeds per fruit (Table 3.). The parent UHF-566 was observed as the best general combiner for number of fruits per plant followed by the parents A-11 and UHF-571. The parent UHF-571 was the best general combiner for number of seeds per plant followed by the AI-11 and Solan Vajr. Only three parents revealed significant positive GCA for average fruit weight with FT-5 as the best general combiner and Solan Vajr as the poorest general combiner with maximum negative GCA, superior positive GCA was shown by the parents UHF-566 for harvest duration followed by UHF-571, AI-11 and FT-5. Significant positive GCA values for fruit

Table 1 : Differences between F_1 means and reciprocal F_1 means for various characters in different hybrid combinations of tomato (*Lycopersicon esculentum* Mill.)**

Cross combination	Number of fruits per plant	Number of seeds per fruit	Average fruit wt. (g)	Harvest duration (days)	Fruit yield per plant (g)
Solan Vajr x AI-11	4.88*	-18.03*	-11.98*	0.57*	6.84*
Solan Vajr x AI-14	-3.19*	14.71*	14.04*	-0.08	23.88*
Solan Vajr x FT-5	-3.18*	-9.86*	-0.89*	-4.19*	-212.04*
Solan Vajr x UHF-571	-2.94*	-1.92*	0.26	-2.82*	-155.91*
Solan Vajr x UHF-566	-3.99*	38.07*	32.06*	-7.94*	197.93*
AI-11x AI-14	-4.08*	-15.83*	0.07	-9.35*	-210.36*
AI-11x FT-5	7.01*	-36.84*	-11.96*	11.78*	279.71*
AI-11x UHF-571	4.25*	-25.90*	-3.97*	10.00*	197.96*
AI-11x UHF-566	-6.00*	-20.77*	6.91*	-18.12*	-220.95*
AI-14x FT-5	-0.16	-5.20*	7.00*	3.17*	133.87*
AI-14x UHF-571	-2.15*	38.95*	14.01*	12.95*	105.56*
AI-14x UHF-566	7.94*	21.92*	-24.81*	-3.85*	-213.87*
FT-5x UHF-571	4.18*	25.85*	-7.99*	11.86*	190.09*
FT-5x UHF-566	2.03*	1.98*	-14.06*	-3.83*	-188.03*
UHF-571x UHF-566	5.09*	2.14*	-10.41*	0.81*	30.23*
C.D. (P=0.05)	0.39	0.27	0.41	0.41	0.31

* indicates significance of value at P=0.05

Table 2 : Analysis of variance for combining ability and components of variance for various characters in Tomato (*Lycopersicon esculentum* Mill.)

Source of variation	df	Mean sum of squares				
		Number of fruits per plant	Number of seeds per fruit	Average fruit wt. (g)	Harvest duration (days)	Fruit yield per plant (g)
GCA	5	94.01*	1844.15*	291.84*	71.94*	352653.10*
SCA	15	30.42*	522.16*	187.45*	73.14*	185735.20*
Reciprocal	15	10.12*	250.10*	93.55*	36.39*	15558.71*
Error	70	0.02	0.01	0.02	0.02	0.01
V_{GCA}		7.83	153.67	24.31	5.99	29387.76
V_{SCA}		30.40	522.15	187.43	73.12	185735.20
$V_{Reciprocal}$		5.05	125.04	46.76	18.18	7779.34
V_{GCA}/V_{SCA}		0.25	0.29	0.12	0.08	0.15

* indicates significance of value at P=0.05

Table 3 : Estimates of the general combining ability effects of parents for different traits in tomato (*Lycopersicon esculentum* Mill.)

Parents	Number of fruits per plant	Number of seeds per fruit	Average fruit wt. (g)	Harvest duration (days)	Fruit yield per plant (g)
Solan Vajr	-4.04*	-3.59*	-5.10*	-4.44*	-329.45*
AI-11	2.91*	-9.94*	-2.78*	0.92*	130.90*
AI-14	-0.79*	12.17*	0.48*	-0.79*	-26.41*
FT-5	-1.74*	17.27*	7.31*	0.45*	26.99*
UHF-571	0.45*	-14.40*	4.17*	1.21*	109.91*
UHF-566	3.22*	-1.49*	-4.08*	2.64*	88.05*
$SE(g_i)$	0.03	0.02	0.04	0.04	0.03
$SE(g_i-g_j)$	0.05	0.04	0.06	0.06	0.05

* indicates significance of value at P=0.05

yield per plant were observed in four parents only and parent AI-11 was adjudged as the best general combiner followed by UHF-571, UHF-566 and FT-5.

The positive significant SCA effects were shown by five cross combinations for number of fruits per plant (Table 4.). The highest positive SCA was observed by AI-14 x UHF-566 (6.51) followed by Solan Vajr x FT-5 (5.08), which involved medium x high and low x medium general combiners, respectively. Nine cross combinations exhibited significant negative SCA effects for number of seeds per fruit. The range of SCA effects varied from AI-14 x UHF-566 (-20.79) to Solan Vajr x UHF-571 (21.97), which involved parents with low x medium, medium x high GCA effects, respectively. The SCA values for the average fruit weight among the crosses ranged from Solan Vajr x AI-11 (-13.04) to AI-14 x UHF-571 (15.50), which involved parents with low x medium and medium x high GCA values, respectively. The SCA values for harvest duration ranged from -8.23 (AI-11 x UHF-566) to 10.47 (AI-14 x UHF-566). The highest positive SCA effect for fruit yield per plant was exhibited by cross AI-14 x UHF-566 (512.20) followed by AI-11 x UHF-571 (425.01) and Solan Vajr x FT-5 (335.38), which involved parents with low x medium, high x high and low x medium GCA values, respectively.

Reciprocal effects are important in the proper selection of the male and female parents for making hybrid cross combinations. Only seven cross combinations showed positive significant reciprocal effects for number of fruits per plant (Table 5), suggesting that these combinations produced better progenies. Eight cross combinations showed significant negative reciprocal effects for number of seeds per fruit. In most of the crosses the progeny produced lesser number of seeds per plant when lines Solan Vajr, AI-11 and AI-14 were used as female parent. While in case of harvest duration most of the cross combinations exhibited superior performance when Solan Vajr and AI-11 were used as the female parents. Prolonged harvest duration is an important character for the longer availability of produce. Highest positive reciprocal effect was exhibited by the cross AI-14 x UHF-571 (6.47) which revealed that the

Table 4 : Estimates of specific combining ability effects of cross combinations for different traits in tomato (*Lycopersicon esculentum* Mill.)

Crosses	Number of fruits per plant	Number of seeds per fruit	Average fruit wt. (g)	Harvest duration (days)	Fruit yield per plant (g)
Solan Vajr x AI-11	-2.51*	-4.77*	-13.04*	-6.57*	-366.27*
Solan Vajr x AI-14	-0.70*	-3.14*	5.78*	-0.29*	30.62*
Solan Vajr x FT-5	5.08*	19.22*	0.61*	5.43*	335.38*
Solan Vajr x UHF-571	-1.78*	21.97*	-5.79*	-3.95*	-211.58*
Solan Vajr x UHF-566	-5.07*	6.91*	10.23*	1.25*	-140.74*
AI-11x AI-14	-2.16*	4.79*	-4.42*	-4.11*	-232.66*
AI-11x FT-5	-0.64*	-4.94*	9.47*	2.08*	148.78*
AI-11x UHF-571	2.59*	14.23*	9.79*	9.14*	425.01*
AI-11x UHF-566	-4.19*	-5.16*	4.49*	-8.23*	-141.66*
AI-14x FT-5	2.46*	2.97*	-9.09*	1.43*	-15.54*
AI-14x UHF-571	-0.60*	-15.33*	15.50*	1.56*	235.85*
AI-14x UHF-566	6.51*	-20.79*	5.18*	10.47*	512.20*
FT-5x UHF-571	-2.77*	-0.75*	7.63*	-3.11*	-75.08*
FT-5x UHF-566	1.39*	-3.97*	-0.21*	3.42*	145.74*
UHF-571x UHF-566	-1.20*	-8.09*	-11.98*	-5.02*	-302.19*
SE(s_{ij})	0.08	0.06	0.09	0.09	0.07
SE (s_{ij}-s_{ik})	0.12	0.09	0.13	0.14	0.11
SE (s_{ij}-s_{kl})	0.11	0.08	0.12	0.13	0.10

* indicates significance of value at P=0.05

Table 5 : Estimates of reciprocal effects of cross combinations for different traits in tomato (*Lycopersicon esculentum* Mill.)

Crosses	Number of fruits per plant	Number of seeds per fruit	Average fruit wt. (g)	Harvest duration (days)	Fruit yield per plant (g)
Solan Vajr x AI-11	2.44*	-9.01*	-5.99*	0.28*	3.41*
Solan Vajr x AI-14	-1.59*	7.35*	7.02*	-0.04	11.93*
Solan Vajr x FT-5	-1.59*	-4.93*	-0.44*	-2.09*	-106.01*
Solan Vajr x UHF-571	-1.46*	-0.96*	0.12	-1.40*	-77.95*
Solan Vajr x UHF-566	-1.99*	19.03*	16.03*	-3.97*	98.96*
AI-11 x AI-14	-2.04*	-7.91*	0.03	-4.67*	-105.18*
AI-11 x FT-5	3.50*	-18.41*	-5.97*	5.89*	139.85*
AI-11 x UHF-571	2.12*	-12.95*	-1.98*	5.00*	98.98*
AI-11 x UHF-566	-2.99*	-10.38*	3.45*	-9.06*	-110.47*
AI-14 x FT-5	-0.08	-2.59*	3.50*	1.58*	66.93*
AI-14 x UHF-571	-1.07*	19.47*	7.00*	6.47*	52.78*
AI-14x UHF-566	3.97*	10.96*	-12.40*	-1.92*	-106.93*
FT-5 x UHF-571	2.08*	12.92*	-3.99*	5.93*	95.04*
FT-5 x UHF-566	1.01*	0.99*	-7.03*	-1.91*	-94.01*
UHF-571 x UHF-566	2.54*	1.07*	-5.20*	0.40*	15.11*
SE(r_{ij})	0.10	0.07	0.10	0.11	0.08
SE (r_{ij}-r_{kl})	0.14	0.10	0.15	0.16	0.12

* indicates significance of value at P=0.05

cross performed well only when AI-14 was used as the female parent. On the other hand, the highest negative reciprocal effect was observed in AI-11 x UHF-566 (-9.06), and this combination offered great potential for improvement in terms of harvest duration when AI-11 is used as the pollen parent. For the fruit yield per plant the combination AI-11 x UHF-566 (-110.47) was observed profitable if the crossing order of the parents is reversed.

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