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Short communication

Combining ability analysis for yield and other horticultural traits in tomato

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The tomato production scenario in India has changed tremendously over the past decade with the increase in popularity of hybrids in commercial cultivation. Keeping in view the pace with which the hybrids of tomato are gaining popularity, it is imperative to obtain such hybrids having a complex of valuable attributes, *viz.,* earliness, uniformity, high yield, resistance to diseases and adaptability to different environmental conditions. The present investigation was undertaken to study the combining ability and gene action with regard to yield and other horticultural traits in tomato.

The experimental material consisted of ten lines, *viz.,* EC-15998, AI-9, EC-174023, FT-5, Solan Vajr, UHF-656, UHF-553, UHF-659, UHF-612 and UHF-663, which were crossed in a diallel fashion, excluding reciprocals to obtain 45 hybrid combinations. These F_1's were evaluated along with parents for various horticultural traits and were also compared with a commercial hybrid Naveen. The experiment was laid out in a Randomized Block Design (RBD) with three replications at the Experimental Farm of the Department of Vegetable Crops, Dr Y.S. Parmar University of Horticulture & Forestry, Nauni, Solan (HP). Eighteen plants of each genotype were transplanted at a spacing of 90 cm × 30 cm. Observations were recorded on plant height, days to first picking, number of fruits per cluster, number of fruits per plant, fruit shape index, average fruit weight, pericarp thickness and yield per plant. Yield data was recorded according to the method of Thompson and Kelly (8). The data was statistically analyzed as suggested by Kempthorne (4).

Analysis of variance for general (gca) and specific combining ability (sca) showed highly significant differences for all the traits under study (Table 1), suggesting importance of both additive and non-additive components of gene action. Though the ratio of Vg/Vs indicated greater role of non-additive gene effects in the inheritance of most of the traits except fruit shape index. The estimates of effects due to gca of parents and sca of crosses have been presented in Tables 2 & 3, respectively. The lines Solan Vajr, FT-5 and UHF-656 were found to be good general combiners for plant height and can be used for breeding tall cultivars. The cross combination, FT-5 × UHF-659 exhibited the highest positive sca estimates, which involves good × poor combining lines. The variance ratio of gca and sca (Vg/Vs) was less than unity, indicating the preponderance of non-additive gene effects for plant height. These results are in agreement with the findings of Sharma (6) and Barar *et al.* (1). Early maturity is a desirable trait as it results in early supply of the produce without much competition and consequently making the crop more profitable to the farmers. General combining ability of the parents revealed that the lines UHF-612, UHF-659 and UHF-553 were found to be good general combiners for days to first picking. However, the cross combination UHF-656 × UHF-553 exhibited highest negative sca estimates followed by UHF-659 × UHF-663 and AI-9 × EC-174023 for this trait. Similar results has also been reported by Cheema *et al.* (2). For the trait, number of fruits per cluster, the lines AI-9, Solan Vajr and FT-5 were showed with good general combining ability. The crosses, EC-15998 × AI-9, FT-5 × UHF-612 and FT-5 × Solan Vajr were the best three specific combiners for number of fruits per clusters. All these crosses had atleast one parent as good general combiner. Numbers of fruits per plant directly contribute to total yield per plant in tomato (Shrivastava *et al*., 7). Preponderance of non-additive effects for this trait was observed as the variance ratio (Vg/Vs) was less than unity. Similar results were put forth by Gunasekara and Parera (3). General combining ability estimates of the lines UHF-659, AI-9, Solan Vajr and FT-5 were positive and significant which in turn appeared to be good general combiners. Hybrids, Solan Vajr × UHF-659, Solan Vajr × UHF-553 and EC-15998 × AI-9 exhibited high sca effects for number of fruits per plant. Fruit shape specifications in tomato vary with end use of the fruits. Round fruits are generally preferred for fresh market. However, for processing oblong fruits are desirable as they are more firm. Pre-dominance of additive effect of genes were observed for this trait as the variance ratio was greater than unity. The significant positive gca was observed in parents UHF-659, EC-174023 and UHF-656 while the cross EC-174023 × UHF-663 showed

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Table 1. Analysis of variance for combining ability and genetic components of variation for various characters in tomato.

Source of variation	d.f.	Mean sum of squares							
		Plant height (cm)	Days to first picking (days)	No. of fruits per cluster	No. of fruits per plant	Fruit shape index	Av. fruit weight (g)	Pericarp thickness (mm)	Fruit yield per plant (g)
gca	9	4938.08*	49.86*	0.12*	19.67*	0.047*	193.09*	2.592*	184688.56*
sca	45	601.18*	11.46*	0.26*	8.97*	0.005*	55.60*	0.569*	55566.32*
Error	108	23.26	2.00	0.02	1.33	0.002	1.27	0.006	1840.35
Genetic components of variation									
V_g		409.15	3.98	0.008	1.53	0.004	15.99	0.22	15237.35
V_s		577.92	9.46	0.240	7.64	0.003	43.78	0.56	53725.97
V_g/V_s		0.71	0.42	0.033	0.20	1.333	0.37	0.39	0.28
V_A		818.30	7.96	0.016	3.06	0.008	31.98	0.44	30474.70
V_D		577.92	9.46	0.240	7.64	0.003	43.78	0.56	53725.97
V_A/V_D		1.41	0.84	0.067	0.40	2.666	0.73	0.78	0.57

*Significant at 5% level

Table 2. Estimates of general combining ability effects of parents for different traits in tomato.

Parent	Plant height (cm)	Days to first picking (days)	No. of fruits per cluster	No. of fruits per plant	Fruit shape index	Av. fruit weight (g)	Pericarp thickness (mm)	Fruit yield per plant (g)
EC-15998	7.61*	-0.69	-0.09*	-0.80*	-0.01	-0.99*	0.03	-69.73*
AI-9	-0.93	-1.00*	0.12*	0.89*	-0.04*	6.55*	0.19*	195.34*
EC-174023	0.30	3.09*	-0.18*	-0.94*	0.04*	-1.18*	-0.72*	-81.16*
FT-5	30.14*	-0.97*	0.08*	0.81*	-0.03*	4.74*	0.69*	146.87*
Solan Vajr	30.42*	2.51*	0.10*	0.89*	0.02*	4.85*	0.34*	120.86*
UHF-656	9.18*	3.14*	-0.10*	-1.91*	0.03*	0.22	-0.26*	-133.93*
UHF-553	-26.09*	-1.22*	0.05	0.14	-0.01	-2.35*	-0.47*	-18.14
UHF-659	-5.68*	-1.30*	-0.03	2.42*	0.08*	-4.70*	-0.11*	76.32*
UHF-612	-22.38*	-1.77*	-0.08*	-0.38	-0.05*	-4.10*	-0.32*	-99.60*
UHF-663	-22.56*	-1.58*	-0.03	-1.13*	-0.01	-3.04*	0.63*	-136.82*
SE(gi) ±	1.32	0.39	0.03	0.31	0.01	0.31	0.02	11.75
SE(gi-gj) ±	1.97	0.57	0.04	0.47	0.02	0.46	0.03	17.51

*Significant at 5% level

the highest sca estimate for fruit shape index. For fruit weight, the lines AI-9, Solan Vajr and FT-5 were found to be good general combiners. These fruits therefore can be used for developing cultivars with bigger fruits. The hybrids, EC-15998 × Solan Vajr, EC-174023 × Solan Vajr and FT-5 × Solan Vajr showed significant positive sca estimates for fruit weight. For pericarp thickness, highest positive gca was apparent in line FT-5 followed by UHF-663 and Solan Vajr, whereas highest sca estimate was recorded in the cross EC-15998 × AI-9, which involved medium x good general combiners.

Every breeding programme is aimed at achieving high fruit yield along with superior quality. The lines AI-9, FT-5 and Solan Vajr were observed to be good general combiners for fruit yield per plant. Hybrids, FT-5 × Solan Vajr, EC-15998 × AI-9 and AI-9 × Solan Vajr exhibited high sca effects. The combining ability

Table 3. Estimates of specific combining ability effects of cross combinations for different traits in tomato.

Cross	Plant height (cm)	Days to first picking (days)	No. of fruits per cluster	No. of fruits per plant	Fruit shape index	Av. fruit weight (g)	Pericarp thickness (mm)	Fruit yield per plant (g)
EC-15998 × AI-9	22.43*	-3.17*	0.94*	4.43*	0.00	1.41	1.37*	361.75*
EC-15998 × EC-174023	2.07	-3.36*	0.44*	-1.07	0.02	-0.32	0.02	-57.54
EC-15998 × FT-5	-4.77	-0.31	-1.11*	-1.49	0.10*	-9.81*	-0.70*	-252.61*
EC-15998 × Solan Vajr	10.03*	-1.78	-0.10	-4.91*	0.11*	12.58*	-0.27*	-125.34*
EC-15998 × UHF-656	11.43*	-0.42	-0.47*	-3.10*	0.04	6.33*	0.03	-229.05*
EC-15998 × UHF-553	-30.76*	0.94	-0.72*	-0.49	-0.00*	-11.32*	-0.42*	-306.71*
EC-15998 × UHF-659	5.98	4.03*	0.28*	-1.10	-0.11*	1.43	-0.31*	-50.83
EC-15998 × UHF-612	-20.52*	1.94	0.21	3.37*	0.00	8.66*	-0.69*	210.23*
EC-15998 × UHF-663	-34.30*	1.30	-0.07	-1.21	-0.10*	6.64*	0.50*	62.77
AI-9 × EC-174023	14.17*	-4.08*	0.53*	1.23*	-0.01	3.93*	-0.41*	117.72*
AI-9 × FT-5	4.32	-1.22	0.26	2.14	-0.06	-7.36*	0.63*	3.33
AI-9 × Solan Vajr	2.78	-0.70	0.64*	2.40*	-0.02	5.23*	-0.14*	342.91*
AI-9 × UHF-656	1.80	0.66	-0.34*	-4.80*	0.04	1.53	-0.53*	-256.71*
AI-9 × UHF-553	-22.29*	0.03	-0.62*	-3.85*	0.12*	-10.54*	-0.92*	-82.26*
AI-9 × UHF-659	-33.86*	-2.89*	0.17	2.87*	0.03	-1.66	0.24*	157.37*
AI-9 × UHF-612	-18.24*	1.03	-0.42*	-6.32*	-0.05	7.41*	0.17*	-264.95*
AI-9 × UHF-663	8.67	3.39*	-0.60*	-0.91	-0.02	-6.00*	-0.34*	-148.89*
EC-174023 × FT-5	-14.55*	-0.09	-0.14	1.32	-0.13*	3.85*	-1.14*	143.40*
EC-174023 × Solan Vajr	-17.82*	2.44*	-0.10	-0.77	0.07	10.59*	-0.84*	135.11*
EC-174023 × UHF-656	17.18*	5.14*	0.32*	0.04	0.09*	2.47*	-0.58*	20.08
EC-174023 × UHF-553	8.17	2.50*	0.26*	-2.35*	-0.02	-6.15*	0.64	-298.71*
EC-174023 × UHF-659	37.96*	2.25*	-0.02	0.70	-0.12*	-6.67*	-0.61*	-47.22
EC-174023 × UHF-612	-34.77*	0.16	-0.84*	4.18*	-0.01	-10.67*	0.67*	-90.44*
EC-174023 × UHF-663	20.12*	-2.47*	-0.72	-2.07	0.17*	8.27*	0.09	-61.73
FT-5 × Solan Vajr	25.52*	-3.50*	0.70*	0.82	-0.08*	9.64*	0.98	363.70*
FT-5 × UHF-656	18.20*	-0.14	0.27*	-2.05	0.12*	-0.93	1.17*	-87.00*
FT-5 × UHF-553	-30.69*	-0.78	0.11	-0.43	0.01	1.97	-0.15*	-115.30*
FT-5 × UHF-659	40.31*	-2.70*	-0.16	2.62*	-0.07*	3.25*	0.82*	214.36*
FT-5 × UHF-612	-11.05*	3.22*	0.87*	0.09	-0.02	-6.93*	0.51*	-112.65*
FT-5 × UHF-663	-2.18	1.58	0.14	2.51*	0.09*	-4.05*	-0.90*	119.20*
Solan Vajr × UHF-656	17.17*	4.39*	-0.05	0.87	-0.11*	-7.08*	-0.95*	-150.80*
Solan Vajr × UHF-553	-22.77*	5.75*	-0.10	5.15*	-0.04	-10.06*	0.87*	115.94*
Solan Vajr × UHF-659	36.90*	-0.17	-0.08	5.54*	0.15*	-5.20*	0.60*	173.82*
Solan Vajr × UHF-612	22.92*	0.75	-0.02	-3.32*	-0.08*	-7.18*	-0.14*	-356.71*
Solan Vajr × UHF-663	-10.27*	-1.89	-0.21	-0.57	0.09*	-3.80*	-0.86*	26.85
UHF-656 × UHF-553	-26.35*	-6.89*	-0.05	0.95	0.03	7.18*	-0.10	150.09*
UHF-656 × UHF-659	1.39	-1.81	0.42*	0.01	-0.05	-0.64	-0.12	-22.27
UHF-656 × UHF-612	-7.14	-2.89*	0.11	4.30*	-0.01	-7.01*	0.78*	194.51*
UHF-656 × UHF-663	-0.86	-3.53*	0.32*	1.23	-0.12	-2.63*	0.69	103.75*
UHF-553 × UHF-659	-9.36*	-0.45	0.27*	-2.05	-0.04	-1.38	0.98*	-105.70*
UHF-553 × UHF-612	8.70	-1.47	0.60*	3.43*	-0.01	8.84*	0.35*	378.69*
UHF-553 × UHF-663	-3.72	-1.50	0.69*	1.84	0.00	0.06	0.41*	130.11*
UHF-659 × UHF-612	8.50	0.55	0.30*	-0.52	0.04	9.06*	-1.03*	40.79
UHF-659 × UHF-663	-25.39	-4.09*	-0.28*	-2.77*	0.02	6.35*	-1.05*	-37.99
UHF-612 × UHF-663	-12.28*	4.83*	-0.61*	-2.30*	0.03	0.74	0.46*	-143.47*
SE(sij) ±	4.44	1.09	0.11	1.06	0.03	1.04	0.06	39.52
SE(sij-sik) ±	6.53	1.60	0.16	1.56	0.05	1.53	0.10	58.08
SE(sij-skl) ±	6.22	1.52	0.15	1.48	0.04	1.45	0.09	55.38

*Significant at 5% level

analysis revealed the preponderance of non-additive gene action for the expression of this trait. Similar results were put forth by Saeed *et al.* (5). The combining ability analysis revealed that both additive and non-additive components of variation were important for all the traits. Preponderance of non-additive gene action was observed for most of the traits except fruit shape index. Hence, heterosis breeding would be the best option for improvement of these traits. The trait fruit shape index showed additive type of gene action therefore can be improved efficiently using pure line or pedigree selection.

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