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Manifestation of Heterosis for Yield and Quality Traits in Indeterminate Hybrids of Tomato (*Solanum lycopersicum* L.) Developed in the Hilly Regions for Off-season Production

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Abstract Magnitude of heterosis for yield and component traits including some of the important nutritional characters was estimated in 10 hybrids developed using five diverse and indeterminate tomato lines crossed in half-diallel during 2010-11. The study was aimed to develop suitable indeterminate tomato hybrids with good quality attributes which suits to off-season production in the north-western Himalayas. Hybrid UHFT-55 × EC-2798 Showed high significant heterobeltiosis for days to marketable maturity (-7.32%), number of fruits per plant (37.83%) and harvest duration (16.7%). For individual fruit weight (34.74%) and plant height (21.53%) hybrid Solan Vajr × EC-29414, EC-29414 × EC-2798 for ascorbic acid (53.70%) and UHFT-55 × Solan Vajr for pericarp thickness (12.87%) registered higher heterobeltiosis. In the present study, Solan Vajr × Ec-2791 manifested higher heterobeltiosis for yield (55.94%). Similarly UHF-55 × EC-2791 recorded less number of seeds (-35.68%) and locules per fruit (-35.14%).

Keywords Diallel, Heterosis, Off-season production, *Solanum lycopersicum* L., Tomato.

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Introduction

Fresh fruits of tomato are in greater demand round the year throughout the country. Hilly regions including Himachal Pradesh are the sources of supply of tomato during summer and rainy seasons when it is not available in the rest of the country, hence cultivated here for getting off-season prices. For improvement in the productivity level with good quality of produce, hybrids now a day are very common and popular in tomato. Phenotypic superiority of a hybrid over its parents with respect to traits such as growth rate, reproductive success and yield is the results of heterosis. The importance of heterosis in agriculture is evident from the dramatic increases in yield measured over the past 50 years, following the influx of hybrids to crop production also applicable to genetic improvement of tomato [1]. This hybrid vigor is determined by non-mutually exclusive mechanisms, including dominance complementation, over dominance and epistasis. The estimation of heterosis for yield and its component characters is useful to judge the best hybrid combination for exploitation of superior hybrids. The F_1 hybrids offer a several advantages such as earliness, uniformity, good quality, high yield. Therefore, it is urgent need to continue with the genetic improvement of this crop so that the new indeterminate hybrids with higher production level and good nutritional quality can be developed for the farmers of the hills.

Materials and Methods

Five diverse indeterminate tomato lines viz. UHFT-

55, Solan Vajr, EC-2791, EC-29414 and EC-2798 were crossed in half diallel to obtain ten cross combinations during *rabi* 2010-11.The F_1 seeds along with parents and check F_1 variety Solan Garima were further planted for their evaluation and generation of data during *kharif* of 2011 at the vegetable research farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP, India (lattitude 30.905^{0}N, longitude 77.097^{0}E, alt 1,502 m) in a randomized block design (RBD) with three replications at a spacing of 90 cm × 30 cm. The standard cultural practices were followed to raise the tomato crop. The observations were recorded on five randomly taken plants from each entry in each replication and their average was worked out to record the data. The observations were recorded on days to first flowering, days to marketable maturity, number of fruits per plant, number of fruits per cluster, average fruit weight, fruit yield per plant, number of seeds per fruit, number of locules per fruit, pericarp thickness, total soluble solids, ascorbic acid, plant height, harvest duration. Statistical analysis was done on the mean values as per Gomez and Gomez [2] and heterosis over better parent and check variety Solan Garima were worked out using techniques of Allard [3].

Results and Discussion

The analysis of variance for all the traits under study showed significant differences among parents and crosses. The mean performance of parents and crosses is presented in Table 1. The per cent of heterosis over better parent and the check variety Solan Garima is given in Table 2.

The line UHFT-55 (37.00 days) was earliest to flowering whereas hybrid UHFT-55 × Solan Vajr (31.00 days) exhibited minimum days in flowering. Only one hybrid EC-2791 × EC-29414 (-2.94%) flowered earlier to the respective better parent. None of the other hybrids could flower significantly earlier than their respectively early parent. Further, four hybrids showed significant negative heterosis over Solan Garima the value being highest in hybrid UHFT-55 × Solan Vajr (-13.65%). Early flowering in hybrids have also been reported earlier [4]. In this experiment the parent EC-29414 (62.47 days) was the earliest to reach marketable maturity while among hybrids UHFT-55 × EC-29414 (60.33 days) took minimum days. Only UHFT-55 × EC-2798 (-7.32%) exhibited significant negative heterobeltiosis. Similarly nine hybrids took significantly lesser number of days to marketable maturity than Solan Garima and the highest value was recorded in UHFT-55 × EC-29414 (-22.98%). Negative heterobeltiosos for earliness has also been reported by Singh and Sastry [5] which is considered desirable attributes in view of getting early harvests and fetching premium prices in tomato market of the country. The like SolanVajr recorded highest number of fruits per plant (21.51). Among hybrids, Solan Vajr × EC-2791 had maximum number of fruits per plant (29.61). Six hybrids showed significant positive heterobeltiosis among which highest value was recorded in hybrid UHFT-55 × EC-2798 (37.83%) while three hybrids showed significant positive increase over Solan Garima, the value being highest in Solan Vajr × Ec-2791 (16.90%). Positive heterosis over better parent for this trait has also been reported earlier [6]. Data recorded on number of fruits per cluster revealed that maximum were recorded in EC-2791 (5.67) among parents and EC-29414 × Ec-2798 (7.20) among hybrids. Four hybrids showed significant positive heterobeltisis the value being highest in EC-29414 × EC-2798 (54.18%) and same cross also exhibited highest significant positive heterosis (54.51%) over Solan Garima. Six hybrids were found to sufficiently surpass Solan Garima. Positive heterobeltiosis for this trait was also reported by Sharma and Sharma [7] which is an indicator of more fruit set % and increased per unit area yield in tomato. The parent UNFT- 55 (68.45g) and in the hybrids, Selan Vajr × EC-29414 (85.33g) showed maximum average fruit weight. The highest heterobeltiotic effect was observed in Solan Vajr × Ec-29414 (34.74%) out of seven hybrids which showed significant positive heterobeltiotic effect. Only two hybrids viz. Solan Vajr × EC-29414 (16.89%) and UHFT-55 × EC-2791 (5.82%) showed significant positive increase over Solan Garima. The studies corroborate with the findings of Gaikwad and Cheema [8]. Highest fruit yield per plant among lines was recorded in UHFT-55 (1338.82g) followed by Solan Vajr (1315.10g) whereas among hybrids Solan Vajr × EC-2791 (2050.75 g) yielded maximum followed by UHFT-55 × EC-2798)1950.46 g).The heterobeltiosis was found maximum in Solan Vajr × EC-2791 (55.94 %) Sig-

Table 1. Mean performance of parents and crosses and check for different horticultural traits in tomato.

Parents	Days to first flower-ing	Days to market-able maturity	Number of fruits per plant	Number of fruits per cluster	Average fruit weight(g)	Fruit yield (g/plant)	Number of seeds per fruit	Number of locules per fruit	Pericarp thickness (mm)	Total soluble solids (^{0}B)	Ascorbic acid content (mg/100g)	Plant height (cm)	Harvest duration
Lines													
UHF-55	30.37	76.97	19.53	4.50	68.45	1338.82	133.71	3.13	5.89	3.90	34.03	148.67	35.13
Solan Vajr	32.00	74.43	21.51	4.27	63.33	1315.10	60.23	2.63	6.06	4.07	31.63	138.40	37.00
EC-2791	37.00	65.30	21.49	5.67	58.27	1252.60	120.18	3.73	4.93	4.49	28.40	136.87	33.00
EC-29414	34.00	62.47	18.47	4.67	55.42	996.07	56.27	2.70	6.43	4.77	24.28	129.30	32.00
EC-2798	34.20	78.67	20.67	4.36	44.58	927.50	76.49	2.67	4.61	4.61	23.30	145.13	34.00
Crosses													
UHF-55 × Solan Vajr	31.00	75.18	18.77	5.13	65.85	1230.78	105.38	3.07	6.84	3.52	29.62	154.60	32.07
UHF-55 × EC-2791	32.32	65.97	18.82	5.77	77.25	1389.69	77.30	2.03	6.46	3.68	28.46	149.40	40.13
UHF-55 × EC-29414	34.33	60.33	22.60	5.83	76.17	1720.31	120.45	3.67	6.51	3.70	31.72	157.40	37.67
UHF-55 × EC-2798	35.00	71.33	28.49	4.97	69.86	1950.46	112.32	3.12	5.83	3.92	38.16	153.80	41.00
Solan Vajr × EC-2791	36.00	77.80	29.61	5.07	67.02	2050.75	90.71	2.90	5.75	4.10	26.75	156.80	36.70
Solan Vajr × EC-29414	36.31	68.83	19.42	6.33	85.33	1764.08	135.37	3.87	6.45	4.36	28.91	168.20	42.00
Solan Vajr × EC-2798	38.00	73.00	25.74	4.90	70.00	1766.13	115.20	3.27	5.71	4.42	33.73	147.10	40.60
EC-2791× EC-29414	33.00	61.80	28.61	6.77	68.50	1915.00	131.30	3.80	6.73	4.80	31.10	143.90	36.67
EC-2791× EC-2798	35.00	63.63	24.52	6.93	45.32	1136.11	60.42	2.77	4.67	3.96	35.44	142.50	37.97
EC-29414× EC-2798	35.00	67.67	21.81	7.20	70.59	1520.94	97.71	3.40	6.42	3.86	37.32	158.63	31.92
Solan Garima (Check)	35.90	78.33	25.33	4.66	73.00	1283.33	118.32	2.33	4.50	4.87	29.93	177.70	35.30
Population Mean	34.04	69.56	22.67	5.49	65.71	1484.96	99.54	3.12	5.95	4.14	30.86	148.73	36.52
SE(m)±	0.78	0.92	1.15	0.30	1.35	88.85	3.92	0.24	0.34	0.20	1.46	4.29	1.07
CD 0.05	2.21	2.62	3.26	0.84	3.83	251.55	11.10	0.68	0.97	0.57	4.15	12.14	3.02

nificant positive heterobeltiosis was found in srven hybrids while six hybrids showed significant positive heterosis over Solan Garima the value being highest in Solan Vajr × EC-2791 (59.80%). Positive heterosis for fruit yield per plant has also been reported by Gul et al. [9]. Less number of seeds are generally required in the fruits supplied to fresh markets especially for raw consumption and processing. Line EC-29414 (56-27) recorded minimum number of seeds per fruit and the hybrid EC-2791 × EC-2798 (60.42) exhibited minimum number of seeds per fruit. Two crosses showed significant negative heterobeltiosis and highest value was found in UHFT-55 × EC-2791 (-35.68%). Further, six crosses showed significant negative heterosis over Solan Garima the value being highest in EC-2791 × EC-2798 (-48.94%). From quality point of view, less locule number is desirable. Less number of locules per fruit among lines were found in Solan Vajr (2.63). Among the hybrids, UHFT-55 × EC- 2791 (2.03) recorded minimum number of locules per fruit. Sig-

Table 2. Heterobeltiotic effect and economic heterosis for different horticultural traits in tomato.

Crosses	Days to first flowering		Days to marketable maturity		Nuber of fruits per plant		Number of fruits per cluster	
	1	2	1	2	1	2	1	2
UHF-55 × Solan Vajr	2.07	-13.65*	-2.32	-4.02*	-12.74	-25.90*	14.00	10.08
UHF-55 × EC-2791	6.42	-9.97*	1.03	-15.78*	-12.42	-25.70*	1.76	23.82*
UHF-55 × EC-29414	13.03*	-4.37	-3.20	-22.98*	15.72*	-10.78	24.84*	25.11*
UHF-55 × EC-2798	15.25*	-2.51	-7.32*	-8.94*	37.83*	12.48*	10.44	6.65
Solan Vajr × EC-2791	12.50*	0.28	19.14*	-0.68	37.66*	16.90*	-10.58	8.80
Solan Vair × EC-29414	4.09	-7.21*	10.`18*	-12.13*	-9.72	-23.33*	35.55*	35.84*
Solan Vajr × EC-2798	18.75*	5.85	-1.92	-6.80*	19.67*	1.62	12.39	5.15
EC-2791 × EC-29414	-2.94	-8.08*	-1.07	-21.10*	33.13*	12.95*	19.40	45.28*
EC-2791 × EC-2798	2.34	-2.51	-2.56	-18.77*	14.10*	-3.20	22.22*	48.71*
EC-29414 × EC-2798	2.94	-2.51	8.32*	-13.61*	5.51	-13.90*	54.18*	54.51*
UHF-55 × Solan Vajr	16.73	31.76*	12.87	52.00*	-13.51	-27.72*		
UHF-55 × EC-2791	-35.14*	-12.88	9.68	43.56*	-18.04*	-24.44*		
UHF-55 × EC-29414	35.93*	57.51*	1.24	44.67*	-22.43*	-24.02*		
USF-55 × EC-2798	16.85	33.90*	-1.02	29.56*	-14.97*	-19.50*		
Solan Vajr × EC-2791	10.27	24.46	-5.12	27.78*	-8.69	-15.81*		
Solan Vajr × EC-29414	47.15*	66.09*	0.31	43.33*	-0.60	-10.47		
Solan Vajr × EC-2798	24.33	40.34*	-5.78	26.89*	-4.12	-9.24		
EC-2791 × EC-29414	40.74*	63.09*	4.67	49.56*	0.63	-1.44		
EC-2791 × EC-2798	3.75	18.88	-5.27	3.78	-4.81*	-18.69*		
Ec-29414 × EC-2798	27.34*	45.92	-0.16	42.67*	-19.08*	-20.74*		

Table 2. Continued.

Crosses	Average fruit weight (g)		Fruit yield (g/plant)		Number of seeds per fruit	
	1	2	1	2	1	2
UHF-55 × Solan Vajr	-3.80	-9.80*	-8.07	-4.09	74.96*	-10.94*
UHF-55 × EC-2791	12.86*	5.82*	3.80	8.29	-35.68*	-34.67*
UHF-55 × EC-29414	11.28*	4.34	28.49*	34.05*	114.06*	1.79
UHF-55 × EC-2798	2.06	-4.30	45.69	51.98*	46.84*	-5.08*
Solan Vajr × Ec-2791	5.83	-8.19*	55.94*	59.80*	50.60*	-23.34*
Solan Vajr × EC-29414	34.74*	16.89*	34.14*	37.46*	140.57*	14.40*
Solan Vajr × EC-29414	10.53*	-4.11	34.30*	37.62*	91.27*	-2.65
EC-2791 × EC-2798	17.56*	-6.16*	52.88*	49.22*	133.33*	10.96*
EC-2791 × EC-2798	22.22*	-37.92*	-9.30	-11.47	-21.00*	-48.94*
EC-29414 × EC-2798	27.37*	-3.30	52.69*	18.52	73.64*	-17.43*
UHF-55 × Solan Vajr	-12.96*	-1.03	3.99	-13.00*	-13.32*	-9.15*
UHF-55 × EC -2791	-16.37*	-4.91	0.49	-15.93*	14.23*	13.68*
UHF-55 × EC-29414	-6.79	5.98	5.87	-11.42*	7.23	6.71
UHF-55 × EC-2798	12.14	27.44*	3.45	-13.45*	16.70*	16.14*
Solan Vajr × EC-2791	-15.43*	-10.62	13.29*	-11.76*	-0.81	3.97
Solon Vajr × EC-29414	-8.60	-3.41	21.53*	-5.35	0.41*	18.98*
Solan Vajr × EC-2798	6.63	12.70	1.36	-17.22*	9.73*	15.01*
EC-2791 × EC-29414	9.50*	3.90	5.14	-19.02*	11.12*	3.88
EC-2791 × EC-2798	24.79*	18.40*	-1.81	-19.08*	11.68*	7.56
EC-29414 ×EC-2798	53.70*	24.63*	9.44*	-10.62*	-6.12	-9.58*

nificant negative heterobeltiosis was shown by UHFT-55 × EC-2791 (-35.14%). None of the hybrids revealed significant negative heterosis over check variety for this trait. Significant negative heterosis for number of

locules per fruit has been reported by Singh et al. [10].

The line EC-29414 had maximum pericarp thickness of 6.43 mm, whereas UHFT-55 × Solan Vajr (6.84 mm) exhibited maximum pericarp thickness. UHFT-55 × Solan Vajr (12.87%) was observed to be best performing hybrids which exhibited positive but non-significant heterobeltiosois. Nine hybrids showed significant positive heterosis over Solan Garima, the value being highest in hybrid UHFT-55 × Solan Vajr (52.00%). Significant positive heterosis for the character was recorded by Sharma and Thakur [11]. Maximum total soluble solids were recorded in parent EC-29414 (4.77 ^{0}B) and hybrid EC-2791 × EC-29414 (4.80 ^{0}B). Positive heterobeltiosis for this trait was recorded in EC-2791 × EC-29414 (0.63%). Positive heterosis for this trait has also been reported by Yadav et al. [12]. Bur none of the hybrids showed positive heterosis over Solan Garima. Similarly, line UHFT-55 (34.03 mg/100g) and hybrid UHFT-55 × EC-2798 (38.16 mg/100g) recorded maximum ascorbic acid content. Three hybrids showed significant positive heterobeltiosis as well as significant positive heterosis over Solan Garima. The value being maximum in hybrid EC-29414 × EC-2798 (53.70%) and UHFT-55 ×EC-2798 (27.44%) respectively. Positive heterosis for ascorbic acid over better parent or check varieties has also been reported by Anita et al.[13].

Maximum plant height was observed in UHFT-55 (148.67 cm) among lines and Solan Vajr × EC-29414 (168.20 cm) among hybrids. Three hybrids showed heterobeltiosis and highest heterotic value was found in Solan Vajr × EC-29414 (21.53%). None of the hybrids showed positive significant heterosis but nine hybrids exhibited significant negative heterosis over check. Significant positive heterosis for this trait has been reported by Singh and Asati [14]. Solan Vajr (37.00 days) in lines and Solan Vajr × EC-29414 (42.00 days) in the hybrids had longest mean harvest duration. Six hybrids exhibited significant positive heterobeltiosis for harvest duration the value being highest in UHFT-55 × EC-2798 (16.70%). Similarly four hybrids showed significant positive increased over Solan Garima and maximum increase was recorded in Solan Vajr × EC-29414 (18.98%). Positive heterosis for this trait was also reported by Thakur et al. [15].

On the basis of present studies, it is concluded that Solan Vajr × EC-2791, EC-2791 × EC-29414 and UHFT-55 × EC-2798 are the best heterotic hybrids for yield and component traits whereas EC-2791 × EC-29414 was best hybrid for quality traits and also recorded less number of days to flowering and maturity. Similarly Solan Vajr × EC-2791 recorded less number of seeds per fruits and number of locules per fruit. Hence, the hybrids viz. Solan Vajr × Ec-2791 and Ec-2791 × Ec-29414 can be recommended for commercial cultivation of tomato after multilocation testing.

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