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Estimation of heterosis for yield and yield attributing traits in tomato (*Solanum lycopersicon* L.)

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Abstract
An investigation was carried out to evaluate the 36 genotypes (28 F_1 and parental lines) of tomato (*Solanum lycopersicon* L.) at Main Experimental Station, Department of Vegetable Science, A.N.D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during season 2019-20 and 2020-2021. The experiment was laid out in a Randomized Complete Block Design with three replications. Eight parents (NDT-2-2 (P_1), NDT-7 (P_2), Kashi Aman (P_3), NDT-4 (P_4), NDT-5 (P_5), Arka Vikas (P_6), S_5×NDT-3-2-1-1 (P_7) and 2013/TODVAR-2-s1-1 (P_8) were crossed in diallel mating design (without reciprocals). The resultant 28 F_1's were evaluated along with their parents including one standard checks (Kashi Aman) for seventeen characters including total fruit yield. Studies on heterosis revealed that majority of the hybrids exhibited heterobeltiosis and standard heterosis in desirable direction. The potential crosses *viz*., P_5 x P_6, P_1 x P_7 in Y_1,P_2 x P_6 in Y_2 and P_1 x P_6 in pooled, exhibited high standard heterosis and high *per se* performance for fruit yield per plant, which offers scope for commercial exploitation through heterosis breeding.

Keywords: Tomato, *Solanum lycopersicon* L., heterobeltiosis and standard heterosis

Introduction
A significant impact of globalization on horticulture has been an increasing demand for quality improvement and the wider adoption of quality standards for fruit, vegetable and salad commodities. Tomato (*Solanum lycopersicum* L.) (2n = 2x = 24) is one of the most important solanaceous vegetable crops grown worldwide under outdoor and indoor conditions. It has become an important commercial crop so far as the area, production, industrial values and its contribution to human nutrition is concerned. Tomato belongs to the family solanaceae.

Tomato fruit are eaten raw or cooked called as "Protective Food" is being extensively grown as annual plant all over the world. Tomato in large quantities is used to produce several items like paste, syrup, juice, ketchup, puree and drinks etc. Green Tomato are also used for pickles and preserves. It is a rich source of vitamins, minerals and organic acid. There are various types of flavoring compounds found in the fruits, which enrich the taste.

India ranks third in terms of production of tomato after China and USA. In India the leading tomato growing states are, Karnataka, West Bengal, Maharashtra, U.P., Haryana, Punjab, Gujarat and Bihar. These states are account for 90% of the total production of the country in India. The total area covered under tomato cultivation is 0.781 Mha with production of 19.007 MT and its productivity is 24.34 tonnes per ha (NHB database, 2019).

Tomato crop has a tremendous potential for heterosis breeding. Increasing productivity through exploitation of hybrid vigour is one of the most important applications in breeding and could be successfully employed in improving the quality and productivity of crop. Exploitation of heterosis is a quick and convenient way of combining desirable characters and hence assumed greater significance in the production of hybrids. Estimates of heterosis may help in deciding whether the hybrids are of economic value and worth exploiting. Keeping these points in view the present study is undertaken with the objective to estimate the magnitude of heterosis for fruit yield and its components.

Material and Methods
The experimental materials consisted of 36 genotypes comprised of a set of 8x8 diallel cross (excluding reciprocals) and their 8 parents of tomato *viz*. NDT-2-2, NDT-7, Kashi Aman, NDT-4, NDT-5, Arka Vikas, S_5 × NDT-3-2-1-1 and 2013/TODVAR-2-1-1. Eight parents and their 28 hybrids were grown in a Randomized Complete Block Design (RBD) with three replications during *Rabi* 2019-20 and 2020-2021 at the Main Experiment Station (MES) of the

Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya (U.P.) India. Thirty days old seedlings were transplanted to the main field and irrigated just after transplanting. Each hybrids and parents were grown in rows spaced at 0.60 meters apart with a plant to plant spacing of 0.50 meter. Thus, there were 12 plants in each entry per replication in both the years and all the cultural practices regarding tomatoes were followed as recommended. The data were recorded on 5 randomly selected healthy plants from each plot on seventeen characters, *viz.*, days to 50% flowering, days to first fruit harvest, plant height (cm), number of primary branches per plant, number of fruits per cluster, number of fruits per plant, average fruit weight (g), pericarp thickness (mm), number of locules per fruit, polar diameter (cm), equitorial diameter (cm), total fruit yield per plant (kg), marketable fruit yield per plant (kg), total soluble solids (TSS), titrable acidity (%), ascorbic acid content (mg/100g) and total sugar (mg/100g) were subjected to analysis of variance (Kempthorne, 1957), nature and magnitude of heterosis (Hayes and Jones 1917).

Result and Discussion

The success in heterosis breeding depends mainly on the choice of superior parents for hybridization. Heterosis in tomato was first observed by Hedrick and Booth (1907) [5] for higher yield and more number of fruits per plant. Subsequently, heterosis for yield and its component has been demonstrated by many workers (Wellington, 1912; Power, 1945) [15, 8]. Larson and Currence (1944) [7] observed that average yield of all tested F_1 hybrids was 39% above the average yield of the parental lines. Tomato is a self-pollinated crop, the unusual high heterosis observed in it has been attributed to the fact that originally tomato was a highly cross pollinated genus which has later evolved into a self-pollinated one (Rick 1965) [10].

A perusal of Table-1 revealed standard heterosis over rest of the economic traits *viz.*, plant height, primary branches per plant, fruits per cluster, fruits per plant, average fruit weight, pericarp thickness, locules per fruit, polar diameter, equatorial diameter, marketable fruit yield per plant, total soluble solids total titrable acidity ascorbic acid content, total sugar and total fruit yield per plant were compared to early maturity traits for these characters. Considering the heterosis over standard variety (Kashi Aman), the top ranking F_1 hybrids were for days to 50% flowering P_6 x P_8, P_2 x P_3 (-28.16) in Y_1, P_5 x P_6, P_2 x P_4 (-23.64) in Y_2 and P_5 x P_6 (-24.41) in pooled; for days to first fruit harvest P_1 x P_2(-23.60%) in Y_1, P_4 x P_7 (-22.96%) Y_2 and P_5 x P_6 (-22.72%) in pooled; for plant height P_4 x P_6 (69.44%) in Y_1, P_4 x P_6 (68.76%) in Y_2 and P_1 x P_5 (55.85%) in pooled; for primary branches per plant P_5 x P_8 (36.64%) in Y_1, P_4 x P_7 (33.03%) in Y_2, P_5 x P_8 (34.38%) in pooled; for fruits per cluster P_1 x P_7 (38.14%) in Y_1, P_2 x P_6 (46.50%) in Y_2 and P_3 x P_6 (32.52%) in pooled; for fruits per plant P_1 x P_2 (39.73%) in Y_1, P_2 x P_3 (32.95%) in Y_2 and P_1 x P_2 (34.16%) in pooled; for average fruit weight P_2 x P_6 (29.70%) in Y_1, P_4 x P_8 (31.29%) in Y_2 and P_1 x P_5 (30.07%) in pooled; for pericarp thickness P_2 x P_8 (25.06%) in Y_1, P_2 x P_8 (27.61%) in Y_2 and P_2 x P_8 (26.79%) in pooled; for locules per fruit P_3 x P_4 (25.62%) in Y_1, P_1 x P_5 (27.59%) in Y_2 and P_1 x P_5 (24.99%) in pooled; for polar Diameter P_4 x P_7 (24.90%) in Y_1, P_4 x P_8 (24.14%) in Y_2 and P_1 x P_8 (21.75%) in pooled; for equitorial diameter P_4 x P_7 (25.35%) in Y_1, P_4 x P_6 (24.66%) inY_2 and P_3 x P_4 (22.83%) in pooled; for marketable fruit yield per plant P_6 x P_8 (28.67%) in Y_1, P_1 x P_5 (49.32%) in Y_2.

Table 1: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Days to 50% flowering						Days to first fruit harvest					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
P_1×P_2	-15.56**	-26.21**	-5.38	-20.00**	-10.38*	-23.00**	-22.14**	-23.60**	-19.62**	-21.11**	-20.87**	-22.35**
P_1×P_3	-1.11	-13.59**	-1.08	-16.28**	-1.09	-15.02**	1.91	0.58	2.64	0.74	2.28	0.37
P_1×P_4	-8.89	-20.39**	-8.60	-22.73**	-8.74	-21.60**	-20.61**	-22.10**	-5.66**	-7.41**	-13.09**	-14.71**
P_1×P_5	2.22	-10.68*	2.15	-13.64**	2.19	-12.21**	3.82	1.87	-21.13**	-22.59**	-8.73**	-10.43**
P_1×P_6	11.11*	-2.91	13.98*	-3.64	12.57*	-3.29	2.29	0.37	3.02	1.11	2.66	0.74
P_1×P_7	14.44**	0.32	13.98*	-3.64	14.21**	-1.88	4.58*	2.62	4.53*	2.59	4.55*	2.61
P_1×P_8	22.22**	6.80	8.60	-8.18	15.30**	-0.94	2.29	0.37	3.4	1.48	2.85	0.93
P_2×P_3	-23.71**	-28.16**	-11.65*	-17.27**	-17.50**	-22.54**	-21.43**	-21.72**	-22.59**	-22.59**	-22.16**	-22.16**
P_2×P_4	-12.09*	-22.33 **	-13.40*	-23.64**	-12.77*	-23.00**	3.01	2.62	1.84	2.59	2.42	2.61
P_2×P_5	6.38	-2.91	9.28	-3.64	7.85	-3.29	0.38	0.56	-0.74	0.35	-0.19	0.32
P_2×P_6	-3.13	-9.71*	6.93	-1.82	2.03	-5.63	4.56*	3.00	3.76	2.22	4.16*	2.61
P_2×P_7	5.15	-0.97	-17.48**	-22.73**	-6.50	-12.21**	0.35	-0.37	-0.37	0.37	-0.19	0.36
P_2×P_8	1.03	-4.85	3.88	-2.73	2.50	-3.76	-20.68**	-20.97**	-0.37	0.37	-10.41**	-10.24**
P_3×P_4	-15.38**	-25.24**	-4.12	-15.45**	-9.57	-20.19**	2.25	2.25	3.33	3.33	2.79	2.79
P_3×P_5	5.32	-3.88	-2.06	-13.64**	1.57	-8.92*	4.12*	4.12*	3.7	3.7	3.91 *	3.91*
P_3×P_6	4.17	-2.91	2.97	-5.45	3.55	-4.23	4.18*	2.62	3.76	2.22	3.97*	2.42
P_3×P_7	0.97	0.97	3.77	0.01	2.39	0.47	-22.85**	-22.85**	-21.85**	-21.85**	-22.35**	-22.35**
P_3×P_8	-16.49**	-21.28**	-23.30**	-28.18**	-20.00**	-24.88**	0.39	0.38	0.37	0.37	0.19	0.19
P_4×P_5	13.19**	-2.31	9.28	-3.64	11.17*	-1.88	-3.31	-1.52	-2.54	-0.37	-3.10	-0.93
P_4×P_6	5.49	-6.80	5.15	-7.27	5.32	-7.04	3.42	1.87	4.51 *	2.96	3.97*	2.42
P_4×P_7	-16.48**	-26.21**	-4.12	-15.45**	-10.11*	-20.66**	-3.31	-1.50	-25.18 **	-22.96 **	-14.28**	-12.29**
P_4×P_8	1.1	-10.68*	-2.06	-13.64**	-0.53	-12.21**	0.56	1.50	0.32	1.48	0.59	1.49
P_5×P_6	-18.09**	-25.24**	-13.40*	-23.64**	-15.71**	-24.41**	-22.05**	-23.22**	-21.05**	-22.22**	-21.55 **	-22.72**
P_5×P_7	2.13	-6.80	2.06	-10.00*	2.09	-8.45	-2.56	-0.37	-3.26	-1.11	-2.91	-0.74
P_5×P_8	7.45	-1.94	0.01	-11.82*	3.66	-7.04	0.35	1.50	0.89	1.48	0.32	1.49
P_6×P_7	1.04	-5.83	-0.99	-9.09	0.23	-7.51	-20.15**	-21.35**	0.57	-1.48	-10.02**	-11.28**
P_6×P_8	-22.92**	-28.16**	1.98	-6.28	-10.15*	-16.90 **	2.28	0.75	3.38	1.85	2.84	1.30
P_7×P_8	8.25	1.94	4.85	-1.82	6.50	0.38	1.11	2.62	-22.99**	-21.85**	-11.01**	-9.68**
No. of F_1 with	4	0	2	0	4	0	4	1	2	0	5	1

significant (+) heterosis												
No. of F_1 with significant (-) heterosis	8	13	5	15	7	14	7	7	8	8	10	10
Range of heterosis	-23.71 to 22.22	-28.16 to 6.8	-23.30 to 13.98	-28.18 to 0.01	-20.00 to 15.30	-24.88 to 0.47	-22.85 to 4.58	-23.60 to 4.12	-25.18 to 4.53	-22.96 to 3.70	-22.35 to 4.55	-22.35 to 3.91

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 2: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Plant height (cm)						Primary branches per plant					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-3.80	-5.48	-4.13	-5.59	-3.97	-5.54	-8.33	22.12 **	-9.01	17.58 **	-8.67	19.79**
$P_1 \times P_3$	-4.56	-4.56	-4.71	-4.71	-4.64	-4.64	-2.56	29.80 **	-2.08	26.53 **	-2.32	28.13**
$P_1 \times P_4$	-14.62**	12.92*	-14.58**	12.23**	-14.60**	12.57*	-7.69	22.97 **	-11.52 *	18.80 **	-9.66	20.83**
$P_1 \times P_5$	10.93**	53.71**	14.18**	57.97**	12.56**	55.85**	-11.54	17.85 *	-11.21 *	14.73 *	-11.37*	16.25*
$P_1 \times P_6$	-3.16	30.61**	-11.63**	19.06**	-7.41	24.81**	-17.95 **	9.31	-18.45 **	5.37	-18.20 **	7.29
$P_1 \times P_7$	-15.14 **	31.89 **	-22.63 **	19.54 **	-18.90 **	25.69 **	-8.97	21.26 *	-9.63	16.76 *	-9.31	18.96*
$P_1 \times P_8$	-2.53	-2.98	-1.81	-3.11	-2.17	-3.05	-8.33	22.12 **	2.71	32.71 **	-2.76	27.54**
$P_2 \times P_3$	-3.24	-3.24	-2.63	-2.63	-2.93	-2.93	18.00 *	31.00 **	14.94 *	25.79 **	16.45*	28.33**
$P_2 \times P_4$	7.27	41.88 **	9.49 **	43.85 **	8.38 *	42.87 **	-8.33	22.12 **	-10.91 *	19.61 **	-9.66	20.83**
$P_2 \times P_5$	-5.14	31.43 **	-5.74	30.40 **	-5.44	30.92 **	-27.27 **	-4.28	-29.34 **	-8.87	-28.32 **	-6.67
$P_2 \times P_6$	-12.78 **	17.64 **	-11.67 **	19.00 **	-12.22 **	18.32 **	-8.22	14.43	-12.09 *	9.44	-10.20	11.88
$P_2 \times P_7$	-30.34 **	8.27	-30.07 **	8.06	-30.20 **	8.17	-8.57	9.31	-6.60	8.30	-7.58	8.79
$P_2 \times P_8$	-4.94	-5.39	-4.29	-5.55	-4.61	-5.47	0.34	11.02	-1.84	8.62	-0.94	9.79
$P_3 \times P_4$	-18.04 **	8.41	-17.42 **	8.50	-17.73 **	8.45	-2.31	30.15 **	-5.52	26.85 **	-3.96	28.46 **
$P_3 \times P_5$	-23.65 **	5.78	-24.03 **	5.10	-23.84 **	5.44	-5.84	23.83 **	-6.94	20.02 **	-6.40	21.88 **
$P_3 \times P_6$	-2.75	31.16 **	-14.45 **	15.26 **	-8.63 *	23.17 **	-1.37	22.97 **	-4.25	19.20 **	-2.84	21.04 **
$P_3 \times P_7$	-24.31 **	17.64 **	-17.81 **	27.00 **	-21.05 **	22.35 **	-1.43	17.85 *	14.11 *	32.30 **	6.41	25.25 **
$P_3 \times P_8$	-3.13	-3.13	-2.93	-2.93	-3.03	-3.03	4.62	16.14	5.88	17.17 *	5.26	16.67 *
$P_4 \times P_5$	-6.65	29.34 **	-15.18 **	17.35 **	-10.93 **	23.31 **	-20.51 **	5.89	-22.12 **	4.56	-21.34 **	5.21
$P_4 \times P_6$	25.63 **	69.44 **	25.26 **	68.76 **	25.44 **	69.10 **	-1.03	31.85 **	-4.91	27.66 **	-3.02	29.71 **
$P_4 \times P_7$	-15.06 **	32.02 **	-15.23 **	30.98 **	-15.15 **	31.50 **	-6.41	24.68 **	-0.91	33.03 **	-3.58	28.96 **
$P_4 \times P_8$	-16.42 **	10.55	-15.51 **	11.01 *	-15.96 **	10.78 *	-8.33	22.12 **	-11.21 *	19.20 **	-9.81	20.63 **
$P_5 \times P_6$	-8.56 *	26.70 **	-8.97 **	25.93 **	-8.77 *	26.31 **	-16.88 **	9.31	-18.30 **	5.37	-17.60 **	7.29
$P_5 \times P_7$	-17.58 **	28.11 **	-17.94 **	26.80 **	-17.76 **	27.45 **	-14.29 *	12.72	-14.83 **	9.85	-14.56 *	11.25
$P_5 \times P_8$	-20.60 **	10.01	-20.67 **	9.75 *	-20.64 **	9.88	3.90	28.64 **	2.52	32.22 **	3.20	34.38 **
$P_6 \times P_7$	3.33	60.61 **	3.16	59.41 **	3.25	60.00 **	-8.22	14.43	-5.88	17.17 *	-7.02	15.83 *
$P_6 \times P_8$	-0.05	34.80 **	-11.72 **	18.94 **	-5.91	26.83 **	-5.48	17.85 *	6.67	32.79 **	0.74	25.50 **
$P_7 \times P_8$	-15.67 **	31.07 **	-15.63 **	30.37 **	-15.65 **	30.72 **	-3.57	15.29	-4.21	11.07	-3.89	13.13
No. of F_1 with significant (+) heterosis	2	17	3	19	3	18	1	17	2	19	1	19
No. of F_1 with significant (-) heterosis	13	0	17	0	15	0	5	0	10	1	6	0
Range of heterosis	-30.34 to 25.63	-5.48 to 69.44	-30.07 to 25.26	-5.59 to 68.76	-30.20 to 25.44	-5.54 to 69.10	-27.27 to18.00	-4.28 to 28.64	-29.34 to 14.94	-8.87 to33.03	-28.32 to 16.45	-6.67 to 34.38

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 3: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Fruits per cluster						Fruits per plant					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-14.04 **	18.64**	-15.08 **	17.06 *	-14.57 **	17.84 **	28.00 **	39.73 **	42.50 **	29.55 **	39.35 **	34.16 **
$P_1 \times P_3$	-7.02	28.33**	-5.00	30.96 **	-5.99	29.67 **	30.14 **	30.14 **	31.82 **	31.82 **	31.06 **	31.06 **
$P_1 \times P_4$	-12.28 **	21.07**	-9.58	24.65 **	-10.91 *	22.89 **	17.14 *	12.33	18.29 *	10.23	17.76 *	11.18
$P_1 \times P_5$	-14.04 **	18.64**	-13.47 **	19.28 **	-13.75 **	18.97 **	24.32 **	26.03 **	-4.85	11.28	7.34	18.01 *
$P_1 \times P_6$	-4.21	32.20**	-4.66	31.43 **	-4.44	31.81 **	5.19	10.96	12.79	10.23	9.20	10.56
$P_1 \times P_7$	0.09	38.14**	-20.59 **	9.46	-10.43 *	23.54 **	-15.48 *	-2.74	-20.00 **	-9.09	-17.93 **	-6.21
$P_1 \times P_8$	-11.40 *	22.28**	-7.97	26.87 **	-9.66 *	24.61 **	4.23	17.81 *	20.65 **	26.14 **	10.67	22.28 **
$P_2 \times P_3$	6.54	6.54	6.95	11.45	7.13	9.04	28.00 **	31.51 **	32.95 **	32.95 **	32.30 **	32.30 **
$P_2 \times P_4$	15.71 **	37.29**	5.30	25.35 **	10.41	31.21 **	18.67 *	21.92 **	29.27 **	20.45 **	25.81 **	21.12 **
$P_2 \times P_5$	4.76	6.54	5.58	10.51	5.18	8.56	2.53	2.74	-12.62 *	2.27	-6.78	2.48
$P_2 \times P_6$	10.71	12.59*	40.58 **	46.50 **	26.54 **	29.85 **	9.09	15.07	25.58 **	22.73 **	17.79 *	19.25 **
$P_2 \times P_7$	28.27 **	30.75**	25.11 **	30.37 **	27.97 **	30.56 **	-20.24 **	-8.22	-24.00 **	-13.64	-22.28 **	-11.18
$P_2 \times P_8$	-3.41	2.91	-4.02	3.15	-3.72	3.03	-1.16	16.44 *	5.43	10.23	2.25	13.04
$P_3 \times P_4$	-3.06	15.01*	-3.43	14.95 *	-3.25	14.98 *	-5.48	-5.48	-1.14	-1.14	-3.11	-3.11
$P_3 \times P_5$	8.33	10.17	2.90	7.71	5.53	8.92	18.92 *	20.55 *	3.88	21.59 **	10.17	21.12 **
$P_3 \times P_6$	17.86 **	19.85**	39.84 **	44.74 **	29.14 **	32.52 **	-2.6	2.74	-1.14	-1.14	-0.61	0.62
$P_3 \times P_7$	23.52 **	25.91**	23.00 **	25.58 **	23.25 **	25.74 **	-13.1	3.25	-20.00 **	-9.09	-16.85 **	-4.97
$P_3 \times P_8$	7.95	15.01*	11.30	19.63 **	9.67	17.28 **	-6.98	9.59	8.65	4.55	-3.37	6.83
$P_4 \times P_5$	3.35	18.64**	20.80 **	43.81 **	10.61	31.45 **	35.14 **	28.99 **	10.68	29.55 **	20.90 **	32.92 **
$P_4 \times P_6$	-2.04	16.22 *	-0.79	18.11 **	-1.4	17.18 **	-9.09	-4.11	-8.14	-10.23	-8.59	-7.45

$P_4 \times P_7$	-2.04	16.22*	-1.86	16.82 *	-1.95	16.53 *	-27.38 **	-16.44 *	-20.00 **	-9.09	-23.37 **	-12.42
$P_4 \times P_8$	13.16 *	34.26**	-5.30	12.73	3.75	23.31 **	-16.28 *	-1.37	-8.70	-4.55	-12.28	-3.11
$P_5 \times P_6$	30.24 **	32.45**	11.94	17.17 *	20.79 **	24.67 **	-14.01	5.48	-25.24 **	-12.5	-12.99	-4.35
$P_5 \times P_7$	14.01 *	16.22*	13.17	18.46 **	13.71 *	17.28 **	-15.48 *	-2.74	-16.50 **	-2.27	-14.67 *	-2.48
$P_5 \times P_8$	-9.09	-3.15	-3.20	7.48	-4.44	2.26	-9.3	6.85	-3.88	12.5	-0.56	9.94
$P_6 \times P_7$	6.89	8.96	40.97 **	45.91 **	24.51 **	27.76 **	-13.1	4.53	-18.00 **	-6.82	-15.76 *	-3.73
$P_6 \times P_8$	-2.27	4.12	-2.28	5.02	-2.28	4.58	-18.60 **	-4.11	-10.87	-6.82	-14.61 *	-5.59
$P_7 \times P_8$	26.82 **	35.11**	-6.20	0.82	9.94	17.66 **	-11.63	4.11	-15.00 *	-3.41	-12.5	5.64
No. of F_1 with significant (+) heterosis	8	21	6	19	7	22	8	9	7	8	7	9
No. of F_1 with significant (-) heterosis	4	0	3	0	5	0	6	1	9	0	7	0
Range of heterosis	-14.04 to 30.24	-3.15 to 38.14	-20.59 to 40.97	0.82 to 46.50	-14.57 to 29.14	2.26 to 32.52	-27.38 to 28.00	-16.44 to 39.73	-25.24 to 42.50	-13.64 to 32.95	-23.73 to 39.35	-12.42 to 34.16

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 4: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Average fruit weight (g)						Pericarp thickness (cm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-14.77 **	-11.38 **	-15.07 **	-3.38	-14.93 **	-7.38	-4.97	-0.86	2.38	2.99	-1.27	1.11
$P_1 \times P_3$	-9.47 *	-5.87	-14.49 **	-2.71	-12.09 **	-4.29	7.00	11.62 *	3.05	3.67	5.01	7.55
$P_1 \times P_4$	-6.19	0.56	-17.75 **	3.05	-12.42 **	1.80	-0.30	4.00	-0.30	0.30	-0.30	2.11
$P_1 \times P_5$	24.52 **	29.48 **	14.84 **	30.65 **	19.46 **	30.07 **	-4.82	-0.71	-2.98	-2.40	-3.89	-1.57
$P_1 \times P_6$	-15.97 **	-12.63 **	-18.00 **	-6.71	-17.03 **	-9.67 *	18.74 **	23.86 **	7.89	8.53	13.28 **	16.02 **
$P_1 \times P_7$	-11.10 **	-7.56	-18.01 **	-6.72	-14.71 **	-7.14	0.75	5.10	0.74	1.35	0.75	3.18
$P_1 \times P_8$	-5.28	-1.50	-13.03 **	2.41	-9.13 *	0.45	4.97	9.50	4.46	5.09	4.71	7.24
$P_2 \times P_3$	-12.52 **	-12.52 **	-12.00 *	-12.00 *	-12.26 *	-12.26 *	24.73 **	24.73 **	12.20 *	12.20 *	18.31 **	18.31 **
$P_2 \times P_4$	-11.10 **	-4.70	-20.76 **	-0.72	-16.30 **	-2.71	0.31	2.28	-1.20	-1.57	-0.46	0.31
$P_2 \times P_5$	21.48 **	9.09 *	26.78 **	16.10 **	24.16 **	12.60 **	21.39 **	26.06 **	21.67 **	21.03 **	21.53 **	23.49 **
$P_2 \times P_6$	34.73 **	29.70 **	-20.97 **	-23.35 **	6.77	3.18	7.49	7.06	6.45	2.54	7.09	4.75
$P_2 \times P_7$	-12.59 **	-21.51 **	-9.91	-17.50 **	-11.24 *	-19.50 **	10.48 *	10.05	10.20	5.91	10.34 *	7.93
$P_2 \times P_8$	1.07	4.45	-9.89 *	6.11	-4.77	5.28	25.06 **	24.57 **	27.61 **	23.50 **	26.79 **	24.02 **
$P_3 \times P_4$	10.11 **	18.03 **	4.57	31.00 **	7.12	24.52 **	3.62	5.65	1.20	1.20	2.59	3.37
$P_3 \times P_5$	-13.61 **	-13.61 **	-8.25	-8.25	-10.93 *	-10.93 *	2.49	6.44	1.72	1.72	2.38	4.02
$P_3 \times P_6$	3.02	3.02	5.75	5.75	4.38	4.38	23.70 **	23.70 **	5.54	5.54	14.41 **	14.41 **
$P_3 \times P_7$	-29.91 **	-29.91 **	31.32 **	31.32 **	0.7	0.70	-0.55	-0.55	3.67	3.67	1.61	1.61
$P_3 \times P_8$	-1.07	2.24	-9.46	6.61	-5.54	4.42	13.89 **	13.89 **	20.88 **	20.88 **	17.47 **	17.47 **
$P_4 \times P_5$	20.90 **	29.61 **	-20.98 **	-1.21	-1.67	14.30 **	10.66 *	14.91 **	11.95 *	11.53 *	11.39 *	13.18 **
$P_4 \times P_6$	2.64	10.03 *	-10.06 *	12.68 *	-4.21	11.35 *	-2.31	-0.39	5.26	4.87	1.52	2.3
$P_4 \times P_7$	20.90 **	29.61 **	-0.62	24.51 **	9.31 *	27.06 **	10.47 *	12.64 *	20.81 **	20.28 **	15.70 **	16.59 **
$P_4 \times P_8$	9.94 **	17.85 **	4.79	31.29 **	7.16	24.57 **	6.31	8.40	4.43	4.04	5.28	6.17
$P_5 \times P_6$	-6.59	-10.08 *	-4.29	-7.16	-5.44	-8.62	7.11	11.22 *	6.85	6.29	6.98	8.70
$P_5 \times P_7$	15.88 **	-0.99	16.69 **	2.41	16.29 **	0.71	19.73 **	24.33 **	20.84 **	20.21 **	20.29 **	22.22 **
$P_5 \times P_8$	-2.52	0.74	-7.73	8.65	-5.29	4.69	-4.08	-0.39	0.15	-0.37	-1.96	-0.38
$P_6 \times P_7$	34.44 **	29.41 **	26.52 **	22.72 **	30.46 **	26.07 **	8.55	6.67	5.83	1.95	7.17	4.25
$P_6 \times P_8$	16.95 **	20.86 **	11.23 *	30.98 **	13.91 **	25.92 **	7.87	6.51	25.37 **	21.33 **	16.74 **	14.10 **
$P_7 \times P_8$	-0.65	2.67	-11.23 *	4.53	-6.28	3.60	7.00	5.65	5.03	1.65	6.00	3.60
No. of F_1 with significant (+) heterosis	10	9	6	9	6	9	10	11	8	8	11	10
No. of F_1 with significant (-) heterosis	9	7	12	3	10	3	0	0	0	0	0	0
Range of heterosis	-29.91 to 34.73	-29.91 to 29.70	-20.98 to 31.32	-23.35 to 31.32	-16.30 to 24.16	-19.50 to 30.07	-4.97 to 25.06	-0.86 to 26.06	-2.98 to 27.61	-2.40 to 35.50	-3.89 to 26.79	-1.57 to 24.02

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 5: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Locales per fruit						Polar Diameter (cm)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-2.14	5.38	-2.20	5.44	-2.17	5.41	-3.09	19.32 **	-3.24	18.04 **	-3.17	18.68 **
$P_1 \times P_3$	-3.57	3.85	-3.41	4.14	-3.49	3.99	0.77	24.08 **	0.82	23.00 **	0.8	23.54 **
$P_1 \times P_4$	-15.00 **	-8.46	-14.57 **	-7.89	-14.78 **	-8.18	-6.91	14.63 **	-7.04 *	13.41 **	-6.97 *	14.02 **
$P_1 \times P_5$	13.64 **	22.38 **	18.34 **	27.59 **	16.00 **	24.99 **	-2.6	19.93 **	-1.43	20.25 **	-2.01	20.09 **
$P_1 \times P_6$	-5.71	1.54	-5.76	1.61	-5.74	1.57	-2.94	21.09 **	-2.99	19.85 **	-2.97	20.47 **
$P_1 \times P_7$	-4.29	3.08	-3.91	3.60	-4.10	3.34	-9.61 *	11.29 *	-9.51 **	10.40 **	-9.56 **	10.84 **
$P_1 \times P_8$	-1.43	6.15	13.08 **	21.92 **	5.84	14.05 **	-0.72	22.24 **	-0.6	21.26 **	-0.66	21.75 **
$P_2 \times P_3$	-5.97	-3.08	-6.15	-2.99	-6.06	-3.03	0.24	15.92 **	0.06	14.89 **	0.15	15.40 **
$P_2 \times P_4$	-2.24	0.77	-2.00	1.30	-2.12	1.04	-14.47 **	-1.09	-5.49	8.52 *	-9.96 **	3.75
$P_2 \times P_5$	-13.24 **	-9.23 *	-13.11 **	-9.12 *	-13.17 **	-9.17 *	-1.29	14.15 **	-1.69	12.88 **	-1.49	13.51 **
$P_2 \times P_6$	18.73 **	22.38 **	-9.04 *	-5.98	4.80	8.18	-3.49	20.41 **	-2.01	21.06 **	-2.75	20.74 **

$P_2 \times P_7$	0.00	3.08	0.22	3.60	0.11	3.34	-13.71 **	-0.2	0.47	15.28 **	-6.59	7.63
$P_2 \times P_8$	-0.66	3.92	19.55 **	25.13 **	9.46 *	14.55 **	-2.35	18.50 **	-2.62	17.17 **	-2.49	17.83 **
$P_3 \times P_4$	25.62 **	25.62 **	-6.13	-6.13	9.71 *	9.71 *	3.43	16.80 **	3.17	15.69 **	3.3	16.24 **
$P_3 \times P_5$	-2.21	2.31	-1.68	2.84	-1.94	2.57	-11.19 **	-1.16	-12.22 **	-3.15	-11.70 **	-2.16
$P_3 \times P_6$	-8.46	-8.46	-8.63 *	-8.35	-8.55 *	-8.41 *	-0.22	24.49 **	-2.01	21.06 **	-1.12	22.76 **
$P_3 \times P_7$	-10.77 *	-10.77 *	-11.04 **	-10.42 *	-10.90 **	-10.60 *	2.25	17.41 **	1.88	16.16 **	2.07	16.78 **
$P_3 \times P_8$	-1.47	3.08	-0.81	3.83	-1.14	3.45	-18.95 **	-1.63	-3.79	15.76 **	-11.35 **	7.13
$P_4 \times P_5$	19.12 **	24.62 **	16.41 **	21.76 **	17.76 **	23.19 **	2.41	15.65 **	10.05 **	23.41 **	6.24	19.55 **
$P_4 \times P_6$	-9.23 *	-9.23 *	-9.17 *	-8.89 *	-9.20 *	-9.06 *	-0.55	24.08 **	-7.38 *	14.42 **	-3.97	19.22 **
$P_4 \times P_7$	13.85 **	13.85 **	25.11 **	25.98 **	19.51 **	19.92 **	8.77 *	24.90 **	1.71	15.96 **	5.22	20.40 **
$P_4 \times P_8$	-2.94	1.54	-2.49	2.07	-2.71	1.80	-3.48	17.14 **	3.18	24.14 **	-0.14	20.67 **
$P_5 \times P_6$	-8.82 *	-4.62	-8.21 *	-3.98	-8.51 *	-4.30	-4.47	19.18 **	-4.23	18.31 **	-4.35	18.74 **
$P_5 \times P_7$	-8.82 *	-4.62	17.58 **	22.99 **	4.4	9.21 *	1.78	16.87 **	5.76	20.59 **	3.78	18.74 **
$P_5 \times P_8$	19.71 **	25.23 **	-4.39	0.08	7.63	12.63 **	0.28	21.70 **	-3.85	15.69 **	-1.79	18.68 **
$P_6 \times P_7$	-10.77 *	-10.77 *	-11.04 **	-10.42 *	-10.90 **	-10.60 *	-4.28	19.32 **	-4.29	18.24 **	-4.33	18.78 **
$P_6 \times P_8$	-2.21	2.31	-1.76	2.84	-1.98	2.57	-1.28	23.06 **	-5.32	16.97 **	-3.35	19.99 **
$P_7 \times P_8$	17.13 **	22.54 **	19.03 **	24.60 **	18.09 **	23.57 **	-2.69	18.10 **	1.28	21.86 **	-0.70	19.99 **
No. of F_1 with significant (+) heterosis	7	7	7	7	6	9	1	24	1	27	0	24
No. of F_1 with significant (-) heterosis	7	4	8	4	7	5	5	0	4	0	5	0
Range of heterosis	-15.00 to 25.62	-10.77 to 25.62	-14.57 to 25.11	-10.42 to 27.59	-14.78 to 19.51	-10.60 to 24.99	-18.95 to 3.43	-1.63 to 24.90	-12.22 to 10.05	-3.15 to 24.14	-11.70 to 6.24	-2.16 to 23.54

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 6: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Equitorial diameter (cm)						Marketable fruit yield per plant (kg)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-1.03	18.55**	-1.32	17.63 **	-1.18	18.09 **	-8.68	21.76	-15.04 *	12.80	-11.87	17.25
$P_1 \times P_3$	-1.21	18.34**	-1.10	17.88 **	-1.16	18.11 **	-14.51	13.99	-7.07	23.38 *	-10.77	18.71
$P_1 \times P_4$	-1.63	20.95**	-1.70	20.08 **	-1.67	20.52 **	-24.74 **	0.35	-24.16 **	0.68	-24.45 **	0.52
$P_1 \times P_5$	1.86	22.02**	1.74	21.27 **	1.80	21.64 **	-6.09	25.22 *	12.47	49.32 **	3.23	37.34 **
$P_1 \times P_6$	-4.21	14.75**	-3.98	14.45 **	-4.10	14.60 **	-5.44	26.08 *	-32.65 **	-10.58	-19.10 *	7.64
$P_1 \times P_7$	-7.07 *	11.33**	-7.15 *	10.68 **	-7.11 *	11.00 **	-40.28 **	-20.38	-39.97 **	-20.31 *	-40.13 **	-20.34
$P_1 \times P_8$	-0.18	19.58**	-0.18	18.98 **	-0.18	19.28 **	-28.92 **	-15.89	-20.69 **	5.29	-28.77 **	-5.24
$P_2 \times P_3$	-4.23	12.28**	-4.42	11.69 **	-4.33	12.02 **	-10.43	8.29	-9.89	8.87	-10.16	8.58
$P_2 \times P_4$	0.35	23.39**	-1.66	20.13 **	-0.66	21.75 **	1.71	22.97 *	6.64	28.84 **	4.19	25.92 *
$P_2 \times P_5$	0.15	17.49**	0.11	16.99 **	0.13	17.24 **	-16.86	0.52	-15.68	1.88	-16.26	1.20
$P_2 \times P_6$	-0.07	17.23**	-0.33	16.48 **	-0.20	16.85 **	11.23	22.11	-32.49 **	-18.43	-15.84	1.72
$P_2 \times P_7$	-0.15	17.14**	-0.28	16.44 **	-0.25	16.79 **	-47.71 **	-28.79 **	-47.46 **	-28.52 **	-47.59 **	-28.65 **
$P_2 \times P_8$	-0.86	18.34**	-0.75	17.84 **	-0.80	18.09 **	-18.57	-1.55	-9.24	10.58	-13.49	4.55
$P_3 \times P_4$	0.1	23.09**	0.35	22.58 **	0.23	22.83 **	18.31	18.31	16.85	24.23 *	20.67 *	21.29 *
$P_3 \times P_5$	2.22	18.34**	2.13	17.67 **	2.17	18.00 **	23.49 *	23.49 *	-1.54	-1.54	10.9	10.90
$P_3 \times P_6$	3.94	20.69**	5.09	21.69 **	4.51	21.20 **	-5.18	-5.18	-4.78	-4.78	-4.98	-4.98
$P_3 \times P_7$	1.13	15.09**	1.42	14.70 **	1.28	14.90 **	-41.28 **	-41.28 **	-39.93 **	-39.93 **	-40.60 **	-40.60 **
$P_3 \times P_8$	1.07	20.65**	1.07	20.00 **	1.07	20.32 **	-12.26	-12.26	-16.53 *	1.71	-11.96	-5.24
$P_4 \times P_5$	-2.28	20.05**	-2.15	19.53 **	-2.26	19.79 **	8.22	6.91	17.66	25.09 *	15.46	16.05
$P_4 \times P_6$	-5.77	15.86**	2.05	24.66 **	-1.86	20.28 **	5.11	-0.52	-4.65	1.37	-0.09	0.43
$P_4 \times P_7$	1.95	25.35**	-5.48	15.47 **	-1.77	20.39 **	4.93	-0.69	-6.74	-0.85	-1.28	-0.77
$P_4 \times P_8$	-1.46	21.16**	-1.32	20.55 **	-1.39	20.86 **	-8.39	-13.3	-11.48	7.85	-9.57	-2.66
$P_5 \times P_6$	3.61	20.31**	3.22	19.53 **	3.41	19.92 **	-10.31	-11.40	-10.26	-11.95	-10.29	-11.67
$P_5 \times P_7$	-3.69	11.50**	-3.71	10.93 **	-3.70	11.22 **	-15.38	-16.41	-8.35	-10.07	-11.86	-13.22
$P_5 \times P_8$	0.72	20.22**	2.21	21.28 **	1.47	20.79 **	-8.92	-10.02	-22.83 **	-5.97	-14.51	-7.98
$P_6 \times P_7$	-3.53	12.01**	-3.81	11.40 **	-3.67	11.70 **	5.86	-0.17	16.76	11.77	11.38	5.84
$P_6 \times P_8$	-1.28	17.74**	4.96	24.62 **	1.81	21.20 **	28.45 **	28.67 *	-15.83	2.56	7.34	15.54
$P_7 \times P_8$	-2.33	16.59**	-2.43	15.85 **	-2.38	16.22 **	16.3	8.46	-24.09 **	-7.51	-6.7	0.43
No. of F_1 with significant (+) heterosis	0	28	0	28	0	28	2	5	0	5	1	3
No. of F_1 with significant (-) heterosis	1	0	1	0	1	0	5	2	11	3	6	2
Range of heterosis	-7.07 to 3.94	11.33to 25.35	-7.15 to 5.09	11.69 to 24.66	-7.11 to 4.51	11.00 to 22.83	-47.71 to 28.45	-41.88 to28.67	-47.46 to 17.66	-39.93 to 49.32	-47.59 to 20.67	-40.60 to 37.34

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 7: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Total soluble solid%						Titrable acidity%					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-3.03	17.32 **	-3.08	19.56 **	-3.05	18.43 **	26.83 **	48.57 **	8.53	21.74 **	17.46 **	34.55 **
$P_1 \times P_3$	-2.06	18.48 **	-2.32	20.49 **	-2.19	19.48 **	0.95	0.95	-3.48	-3.48	-1.28	-1.28

$P_1 \times P_4$	-6.34	19.32 **	-6.05	21.84 **	-6.19	20.57 **	-1.98	-5.71	3.64	-0.87	0.95	-3.18
$P_1 \times P_5$	-1.31	19.40 **	-1.57	21.42 **	-1.44	20.40 **	0.90	6.67	-4.07	2.61	-1.71	4.55
$P_1 \times P_6$	-4.06	16.07 **	-3.76	18.72 **	-3.91	17.39 **	13.08 **	15.24 **	17.24 **	18.26 **	15.25 **	16.82 **
$P_1 \times P_7$	0.34	21.40 **	0.48	23.95 **	0.41	22.66 **	8.91	4.76	8.18	3.48	8.53	4.09
$P_1 \times P_8$	-1.31	19.40 **	-1.64	21.33 **	-1.47	20.28 **	-5.22	3.81	-4.13	0.87	-4.66	2.27
$P_2 \times P_3$	3.67	17.74 **	0.71	20.32 **	2.16	19.02 **	13.82 **	33.33 **	17.83 **	32.17 **	15.87 **	32.73 **
$P_2 \times P_4$	-6.14	19.57 **	-6.11	21.75 **	-6.13	20.65 **	-9.76 *	5.71	-9.30 *	1.74	-9.52 *	3.64
$P_2 \times P_5$	-10.56 *	5.75	-10.57 *	7.67	10.57 *	6.70	-13.01 **	1.90	-11.63 **	-0.87	-12.30 **	0.45
$P_2 \times P_6$	3.88	20.23 **	2.33	22.26 **	3.76	21.24 **	-4.07	12.38 *	10.85 *	24.35 **	3.57	18.64 **
$P_2 \times P_7$	12.32 **	30.56 **	11.08 *	32.72 **	12.29 **	31.63 **	-17.89 **	-3.81	-14.73 **	-4.35	-16.27 **	-4.09
$P_2 \times P_8$	-1.77	15.65 **	-1.68	18.21 **	-1.73	16.93 **	-4.88	11.43 *	-1.55	10.43 *	-3.17	10.91 *
$P_3 \times P_4$	-6.47	19.15 **	-6.57	21.16 **	-6.52	20.15 **	-5.71	-5.71	-6.09	-6.09	-1.19	-5.91
$P_3 \times P_5$	-0.99	17.07 **	-1.54	18.55 **	-1.26	17.80 **	0.90	6.67	-6.5	0.00	0.00	3.18
$P_3 \times P_6$	-2.09	13.32 **	-2.29	15.26 **	-2.19	14.29 **	8.41	10.48 *	2.59	3.48	6.09	6.82
$P_3 \times P_7$	-9.89 *	4.75	-9.42 *	7.08	-9.65 *	5.91	22.86 **	22.86 **	20.00 **	20.00 **	27.75 **	21.28**
$P_3 \times P_8$	-1.77	15.65 **	-2.17	17.62 **	-1.97	16.63 **	9.57 *	20.00 **	9.09	14.78 **	13.16 **	17.27**
$P_4 \times P_5$	-2.35	24.40 **	-1.24	28.08 **	-1.79	26.23 **	6.31	12.38 *	0.81	7.83	11.78 **	10.00*
$P_4 \times P_6$	-7.97	17.24 **	-7.93	19.39 **	-7.95 *	18.31 **	27.10 **	29.52 **	13.79 **	14.78 **	27.01 **	21.82**
$P_4 \times P_7$	-4.05	22.23 **	-10.27 *	16.28 **	-7.17	19.31 **	18.95 **	7.62	19.05 **	8.70	19.90 **	8.18
$P_4 \times P_8$	-3.79	22.56 **	-3.32	25.38 **	-3.55	23.96 **	-9.57 *	-0.95	-7.44	-2.61	-0.69	-1.82
$P_5 \times P_6$	-4.72	12.66 *	-4.83	14.59 **	-4.78	13.62 **	32.43 **	40.00 **	31.71 **	40.87 **	35.23 **	40.45 **
$P_5 \times P_7$	-2.54	15.24 **	-2.66	17.20 **	-2.6	16.21 **	12.61 **	19.05 **	8.94	16.52 **	19.91 **	17.73
$P_5 \times P_8$	0.92	19.32 **	1.19	21.84 **	1.05	20.57 **	-6.09	2.86	-0.81	6.09	-2.13	4.55 *
$P_6 \times P_7$	2.58	19.23 **	2.57	21.25 **	2.57	20.23 **	15.89 **	18.10 **	18.10 **	19.13 **	23.99 **	18.64
$P_6 \times P_8$	-0.85	16.74 **	-1.05	18.97 **	-0.95	17.85 **	-2.61	6.67	-2.48	2.61	0.22	4.55
$P_7 \times P_8$	-0.64	16.99 **	-0.42	19.73 **	-0.53	18.35 **	-7.83	0.95	-2.48	2.61	3.23	1.82*
No. of F_1 with significant (+) heterosis	1	26	1	26	1	26	10	13	8	11	10	12
No. of F_1 with significant (-) heterosis	2	0	3	0	3	0	4	0	2	0	2	0
Range of heterosis	-10.56 to 12.32	4.73to 30.56	-10.57 to11.08	7.08 to32.72	-9.65 to 12.29	5.91 to 31.63	-17.89 to 32.43	-5.71 to 48.57	-14.73 to 31.71	-6.09 to 40.87	-16.27 to 35.23	-5.91 to 40.45

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 8: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Ascorbic acid (mg/100g)						Total sugar(mg/100g)					
	Y_1		Y_2		Pooled		Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-2.42	4.98	-2.35	10.65 *	-2.38	7.74	-12.39 **	5.82	-12.34 **	5.38	-12.37 **	5.60
$P_1 \times P_3$	0.77	8.42 *	7.12	21.38 **	3.95	14.73 **	23.28 **	26.71 **	15.49 **	21.81 **	19.28 **	24.25 **
$P_1 \times P_4$	1.83	9.55 *	1.93	15.51 **	1.88	12.45 **	5.38	8.23 *	2.28	7.97	3.84	8.10 *
$P_1 \times P_5$	12.59 **	21.13 **	3.31	17.07 **	7.95 *	19.15 **	0.78	3.51	-1.32	4.08	-0.29	3.80
$P_1 \times P_6$	-4.38	2.87	-4.32	8.42	-4.35	5.57	-6.17	-2.21	-7.18	-2.09	-6.00	-2.15
$P_1 \times P_7$	-0.57	9.60 *	-0.44	15.61 **	-0.51	12.53 **	15.76 **	22.39 **	4.25	9.96 *	11.58 **	16.15 **
$P_1 \times P_8$	5.14	21.42 **	-0.17	21.54 **	2.48	21.48 **	-6.83	-1.41	-7.32	-1.59	-7.08	-1.50
$P_2 \times P_3$	18.80 **	21.62 **	9.52 *	18.22 **	14.16 **	19.96 **	-14.13 **	3.71	-13.67 **	3.78	-13.90 **	3.75
$P_2 \times P_4$	2.56	6.20	2.56	11.88 **	2.56	8.97 *	-17.54 **	-0.40	-17.32 **	-0.60	-17.43 **	-0.50
$P_2 \times P_5$	2.61	5.03	2.50	10.65 *	2.55	7.77	-15.38 **	2.21	-15.33 **	1.79	-15.35 **	2.00
$P_2 \times P_6$	1.53	3.93	-7.90	-0.58	-3.19	1.73	-14.63 **	3.11	-14.42 **	2.89	-14.52 **	3.00
$P_2 \times P_7$	-0.59	9.58 *	-0.56	15.47 **	-0.57	12.45 **	-17.87 **	-0.80	-17.40 **	-0.70	-17.63 **	-0.75
$P_2 \times P_8$	-5.67	8.93 *	-5.63	14.89 **	-5.65	11.84 **	3.82	25.40 **	1.91	22.51 **	2.86	23.95 **
$P_3 \times P_4$	17.50 **	21.67 **	11.10 **	21.19 **	14.29 **	21.43 **	-3.51	-3.31	-2.89	-2.89	-3.15	-3.10
$P_3 \times P_5$	4.88	4.88	8.00	10.52 *	7.63	7.63	21.33 **	22.79 **	9.69 *	10.46 *	15.50 **	16.60 **
$P_3 \times P_6$	7.78	7.78	7.95	13.59 **	7.96 *	10.61 *	-4.91	-0.90	-4.89	-1.10	-4.90	-1.00
$P_3 \times P_7$	-9.45 *	-0.18	-9.44 *	5.16	-9.45 *	2.42	-4.46	1.00	1.10	1.10	-1.51	1.05
$P_3 \times P_8$	6.80	23.33 **	-0.29	21.40 **	3.25	22.39 **	-8.25 *	-2.91	-7.88 *	-2.19	-8.07 *	-2.55
$P_4 \times P_5$	-6.53	-3.22	-6.48	2.02	-6.51	-0.67	-4.07	-2.91	-2.87	-2.19	-3.47	-2.55
$P_4 \times P_6$	1.67	5.28	1.70	10.95 *	1.69	8.04	-3.56	0.50	-3.26	0.64	-3.41	0.55
$P_4 \times P_7$	-1.77	8.28	-1.77	14.07 **	-1.77	11.10 **	0.95	6.73	7.38	7.27	4.29	7.00
$P_4 \times P_8$	-5.27	9.40 *	-0.85	20.72 **	-3.06	14.91 **	-3.42	2.21	15.38 **	22.51 **	6.04	12.40 **
$P_5 \times P_6$	6.19	6.02	6.18	11.73 **	6.19	8.80 *	6.45	10.94 **	6.42	10.66 *	6.44	10.80 **
$P_5 \times P_7$	-8.06 *	1.35	-8.05 *	6.77	-8.06 *	3.99	15.29 **	21.89 **	21.17 **	22.01 **	18.86 **	21.95 **
$P_5 \times P_8$	-9.21 *	4.85	-19.13 **	-1.54	-14.17 **	1.73	-0.47	5.32	-0.38	5.78	-0.42	5.55
$P_6 \times P_7$	-4.19	5.62	-4.18	11.26 **	-4.19	8.37 *	-5.03	0.41	-3.45	0.40	-3.55	0.40
$P_6 \times P_8$	-6.77	7.67	-6.81	13.45 **	-6.79	10.49 *	16.60 **	23.39 **	-3.85	2.09	6.32	12.70 **
$P_7 \times P_8$	7.81 *	24.50 **	1.04	23.01 **	4.42	23.78 **	-1.90	3.82	15.57 **	22.71 **	6.89	13.30 **
No. of F_1 with significant (+) heterosis	4	12	2	22	4	18	5	8	5	8	4	10
No. of F_1 with significant (-) heterosis	3	0	3	0	3	0	7	0	7	0	7	0
Range of heterosis	-9.45 to	-3.22 to	-19.13 to	-1.54 to	-14.17 to	-0.67 to	-17.87 to	-3.31 to	-17.40 to	-2.89 to	-17.63 to	-3.10 to

	18.80	24.50	11.10	23.01	14.29	23.78	23.28	26.71	21.17	22.71	19.28	24.25

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

Table 9: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Kashi Aman during two seasons (Y_1, Y_2) and pooled.

Crosses	Total fruit yield per plant (kg)					
	Y_1		Y_2		Pooled	
	BP	SV	BP	SV	BP	SV
$P_1 \times P_2$	-3.24	8.84	-13.64 *	-2.09	-8.48	3.35
$P_1 \times P_3$	-8.35	3.09	-9.58	2.51	-8.97	2.80
$P_1 \times P_4$	-14.96 *	-4.35	-20.27 **	-9.61	-17.64 **	-6.99
$P_1 \times P_5$	3.62	16.55 *	12.16	27.16 **	7.92	21.87 **
$P_1 \times P_6$	9.10	22.72 **	-31.20 **	-22.01 **	-11.20	0.28
$P_1 \times P_7$	12.72	26.79 **	-28.24 **	-27.72 **	-11.94	-0.56
$P_1 \times P_8$	-37.91 **	-30.15 **	-19.16 **	-8.28	-28.47 **	-19.22 *
$P_2 \times P_3$	-18.11 *	-8.70	-8.80	-7.66	-13.67	-8.18
$P_2 \times P_4$	-9.81	0.56	5.23	6.55	-2.63	3.56
$P_2 \times P_5$	-3.02	8.13	-13.07	-11.98	-7.82	-1.96
$P_2 \times P_6$	-10.69	-0.42	26.69 **	28.27 **	7.16	13.98
$P_2 \times P_7$	-39.50 **	-32.54 **	-43.05 **	-42.34 **	-41.20 **	-37.46 **
$P_2 \times P_8$	-49.43 **	-43.62 **	-8.74	-4.04	-28.32 **	-23.76 **
$P_3 \times P_4$	-5.05	-5.05	23.96 **	23.96 **	9.50	9.50
$P_3 \times P_5$	3.09	3.09	-17.55 *	-17.55 *	-7.27	-7.27
$P_3 \times P_6$	-19.07 *	-19.07 *	-17.13 *	-17.13 *	-18.10 *	-18.10 *
$P_3 \times P_7$	-17.39 *	-17.39 *	-44.85 **	-44.85 **	-31.17 **	-31.17 **
$P_3 \times P_8$	-46.42 **	-46.42 **	15.50 *	21.45 **	-12.37	-12.37
$P_4 \times P_5$	-4.15	-12.62	17.67 *	6.69	11.48	-2.94
$P_4 \times P_6$	31.60 **	9.82	-6.45	-15.18 *	11.72	-2.73
$P_4 \times P_7$	-1.68	-17.95 *	-10.29	-18.66 **	-6.18	-18.31 *
$P_4 \times P_8$	-3.28	-19.35 *	15.76 *	21.73 **	11.72	1.26
$P_5 \times P_6$	34.00 **	22.16 **	-10.66	-26.46 **	12.73	-2.24
$P_5 \times P_7$	-19.08 *	-26.23 **	-7.45	-23.82 **	-13.54	-25.02 **
$P_5 \times P_8$	-18.00 *	-25.25 **	-18.81 **	-14.62 *	-11.64	-19.92 **
$P_6 \times P_7$	2.57	-16.13	25.64 **	2.37	14.13	-6.85
$P_6 \times P_8$	30.19 **	6.45	-13.51	-9.05	8.87	-1.33
$P_7 \times P_8$	14.39	-9.68	14.44 *	20.33 **	16.27 *	5.38
No. of F_1 with significant (+) heterosis	3	4	6	5	1	1
No. of F_1 with significant (-) heterosis	10	10	10	11	6	8
Range of heterosis	-49.43 to 34.00	-46.42 to 26.79	-44.85 to26.69	-44.85 to28.27	-41.20 to 16.27	-37.46 to 21.87

*, ** Significant at 5 per cent and 1 per cent probability levels, respectively.

and P_1 x P_5 (37.34%) in pooled; for total soluble solid P_2 x P_7 (30.56%) inY_1, P_2 x P_7 (32.72%) in Y_2 and P_2 x P_7 (31.63%) in pooled; for titrable Acidity P_1 x P_2 (48.57%) in Y_1, P_5 x P_6 (40.87%) in Y_2 and P_5 x P_6 (40.45%) in pooled; for ascorbic acid P_7 x P_8 (24.50%) in Y_1, P_7 x P_8 (23.01%) in Y_2 and P_7 x P_8 (23.78%) in pooled; for total sugar P_1 x P_3 (26.71%) in Y_1, P_7 x P_8 (22.71%) in Y_2 and P_1 x P_3 (24.25%) in pooled; for total fruit yield per plant P_1 x P_7 (26.79%) in Y_1, P_2 x P_6 (28.27%) in Y_2 and P_1 x P_5 (21.87%) in pooled. The similar results were recorded by Kattegodar *et al.* (2018) [6], Rehana *et al.* (2019) [9], Gowda *et al*. (2019) [4], Sah *et al.* (2020) [12], Soresa *et al.* (2020) [14].

Fruits per plant are one of the most important components of fruit yield in respect of which hybrids with positive heterosis are desirable. The findings of the present study revealed that the cross $P_1 \times P_2$ expressed significant heterosis in desirable direction over better parent while nine crosses in Y_1, eight crosses in Y_2 and nine crosses in pooled showed significant heterosis over standard variety. In general, the hybrids with significant heterosis for yield also expressed significant heterosis either for fruit weight or for fruits per plant. Fruit yield per plant being a complex trait and is a multiplicative product of several basic component traits of yield. The improvement in heterosis for yield component may not necessarily be reflected in increased yield. Contrarily the increased fruit yield will definitely because of increase in one or more component traits. In the present study the top performing F_1 hybrids for yield also showed significant heterosis either for fruit weight or fruits per plant along with some other yield component traits. Likewise, crosses showing heterosis for other yield component did not necessarily show heterosis for fruit yield. This showed that heterosis depends upon nicking for genes. Similar results have also been reported by Dishri *et al.* (2017) [2], Savita and Singh (2015) [13] and Sah *et al.* (2020) [12].

On the basis of above results it could be concluded that the potential crosses *viz*., P_5 x P_6, P_1 x P_7, P_2 x P_6 and P_1 x P_6 exhibited high standard heterosis for fruit yield per plant, which offers scope for commercial exploitation of heterosis in tomato in future.

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