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Heterosis for yield and yield attributing traits in tomato (*Solanum lycopersicum* L.)

Kiran Kumar[1]*, Dhananjay Sharma[1], Jitendra Singh[2] and Nisha Chandel[1]

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Abstract

Six diverse lines of tomato were crossed with four testers in line x tester (L×T) cross design to investigate the extent of heterosis for yield and its contributing traits in tomato. The present investigation was carried out under AICRP on Vegetable Crops at Horticultural Research cum Instructional Farm, Department of Vegetable Science, IGKV, Raipur (C.G.) during *rabi* 2017-18. A high degree of heterosis was observed for most of the characters under investigation. High *per se* performance with remarkable heterosis were expressed by PR x 14/TLCV-3, KA x 15/TLCV-2, H-86 x 14/TLCV-3, KA x 14/TLCV-3 and H-24 x 14/TLCV-1 for higher fruit yield, however, a high degree of heterosis for other traits in desired direction was also observed.

Key words: Heterosis, Yield, F_1 hybrids, Tomato, *Solanum lycopersicum* L.

Introduction

Tomato (*Solannum lycopersicum* L.) is one of the most important and popular vegetable crops in the world. Tomato is popular due to its nutritive and medicinal values. Nuez et al. (2004_ identified it as the horticultural crop with the highest commercial value. In India; tomato is grown across all agro-ecological zones and occupies an area of about 801 thousand hectares with an annual production of 22.33 million tonnes, respectively (Anonymous 2017). Tomato is universally treated as 'Protective Food' since it is very rich in minerals, vitamins, antioxidants, essential amino acids, sugars and dietary fibers which are important ingredients for culinary and table purpose, chutney, pickles, ketchup, soup, juice, puree etc. (Sekhar et al. 2010). Fresh fruit of tomato are in great demand round the year throughout the country. Generally, both determinate and indeterminate varieties are considered suitable for growing and for commercial production; high yielding superior F_1 hybrids are preferred. Hence, there is continuous need to strengthen the crop improvement programmes in tomato and ultimately developing new varieties/hybrids satisfying to the present day needs of farmers and consumers as well.

The presence of heterosis indicates the ability of parents to combine well in a hybrid combination. For developing hybrids, the most important task for the plant breeder is the choice of parental lines. The success of breeding procedure is determined by the useful gene combinations organised in the form of good combining lines and isolation of valuable germplasm. Some lines produce outstanding progenies on crossing with others, while others may look equally desirable, but may not produce good progenies on crossing. The lines, which perform well in combination, are eventually of great importance to the plant breeders (Gami et al. 2010). Heterosis manifestation in tomato is in the form of the greater vigour, faster growth and development, earliness in maturity and increased productivity (Yordanov 1983). There is a great scope for the improvement of this crop through hybridization. Therefore, the present study was undertaken to develop high yielding F_1 varieties having a complex of valuable attributes, *viz.,* earliness, uniformity, good quality, high yield, resistance to diseases and adaptability to wider environmental conditions.

Materials and Methods

The experiment was conducted at AICRP on Vegetable Crops, Department of Vegetable Science, Horticultural Research and Instructional Farm, IGKV, Raipur (C.G.). The experimental material comprised of 10 diverse parents viz., Pusa Ruby (PR), Punjab Chhuhara (PC), Arka Vikas (AV), Kashi Anupam (KA), H–86, H–24 as lines and 2015/TOLCVRES-4, 2015/TOLCVRES-2, 2014/TOLCVRES-3, 2014/TOLCVRES-1 as testers.

[1]Department of Vegetable Science, College of Agriculture, IGKV, Raipur-492012, Chhattisgarh
[2]Floriculture and Landscape Architecture, College of Agriculture, IGKV, Raipur-492012, Chhattisgarh
*Corresponding author, Email: kiran.nagraj90@gmail.com

The crosses were made in line×tester, during *spring-summer* season 2017. The crossing technique followed was hand emasculation and hand pollination. For hybridization, the unopened floral buds of the female parents were emasculated a day before during 3 to 5 P.M with the aid of pointed forceps and bagged to prevent cross pollination. On the next day morning between 7 to 9 A.M the pollen grains were collected from freshly opened flowers of the required male parent, gently applied to the stigma of the emasculated flowers of the female parents, then crossed flowers were covered with cotton and tagged for easy identification.

The half amount seeds of twenty-four crosses along with their parents (six lines and four testers) including standard check (Kashi Anupam) was planted in Randomized Block Design with three replications during *rabi* season 2017-18. All the recommended cultural practices were adopted to raise a healthy crop. Data were recorded on five randomly selected plants with respect to quantitative characters *viz*., Days to 50% flowering, no. of branches per plant, plant height, number of fruit cluster per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, days to first fruit harvest, fruit yield per plant, fruit length, fruit diameter, average fruit weight, number of locules per fruit, pericarp thickness and fruit yield per hectare (q). The analysis of the variance technique reviewed by Panse and Sukhatme (1967) were followed to test the significant difference between the genotypes for all the characters. Magnitude of heterosis (Using SPAR 1) was calculated as percentage of F_1 performance in favourable direction over better parent and standard check for each trait.

Results and Discussion

The analysis of variance for line x tester analysis presented in Table 1. The mean sum of squares due to parent and hybrids were highly significant for all the characters except days to first fruit harvest and total soluble solid. The mean sum of squares due to parents *vs* hybrids were highly significant for majority of the characters except no. of branches per plant, no. of fruit cluster per plant, days to first fruit harvest, fruit length (cm) and ascorbic acid (mg/100g). The mean sum of squares due to lines *vs* testers was highly significant for all the characters except no. of branches per plant, no. of fruits per plant, days to first fruit harvest, pericarp thickness and total soluble solid. The mean sum of squares due to lines and testers respectively were highly significant for majority of the characters except no. of fruits per cluster, days to first fruit harvest, total soluble solid and ascorbic acid. The mean sum of squares due to Lines x Testers were highly significant for all the characters except total soluble solid.

The range of heterosis by hybrids over their better parent and standard check were analysed. Number of hybrids showing significant desirable heterosis over better parent and standard check and superior crosses based on estimates of heterobeltiosis and standard heterosis are presented in Table 2. The heterosis in favourable direction is only considered for the characters studied. The fruit yield is the resultant manifest of its component traits, and heterosis observed for them contributes ultimately towards this complex character. The relative heterosis for fruit yield per hectare ranged from -35.18% (AV X 14/TLCV-1) to 55.75% (H-24 X 14/TLCV-1). Out of

Table 1: Analysis of variance for Line x Tester analysis for fruit yield and its component in tomato during *rabi,* 2017-18

Characters (df)	Replicat-ions	Parents	Hybrids	Parent vs Hybrid	Lines	Testers	Lines vs Testers	Lines x Testers	Errors
	2	9	23	1	5	3	1	15	66
Days to 50% flowering	0.89	5.86**	6.04**	3.77*	3.03**	6.53**	18.05**	4.91**	0.63
No of branches per plant	0.06	3.83**	7.8**	1.32	3.57**	5.54**	0.03	8.91**	0.39
Plant height(cm)	5.59	546.5**	54.39**	580.65**	616.56**	394.13**	653.36**	62.58**	10.05
No. of fruit cluster per plant	0.06	3.83**	6**	0.81	2.83**	5.83**	2.77**	7.28**	0.30
No. of flowers per cluster	0.02	0.75**	1.14**	14**	0.47**	0.92**	1.64**	0.71**	0.10
No. of fruits per cluster	0.01	0.3**	1.14**	15.24**	0.13	0.04	1.96**	0.88**	0.07
No. of fruits per plant	1.36	28.96**	37.6**	58.33**	46.81**	8.49*	1.11	38.51**	2.20
Days to first fruit harvest	2.22	2.73	6.28**	2.42	4.56	0.59	0.01	6.02**	1.68
Fruit yield per plant	0.01	1.99**	1.31**	1.93**	2.76**	0.53**	2.49**	1.26**	0.01
Fruit length (cm)	0.19	2.84**	1.23**	0.64	3.23**	1.49**	4.89**	0.8**	0.26
Fruit diameter (cm)	0.52*	2.73**	1.16**	1.56**	2.99**	0.65**	7.71**	1.15**	0.15
Average fruit wt. (g)	1.32	1427.13**	1675.8**	6004.12**	1470.73**	947.53**	2647.92**	1348.93**	10.51
No.of Locules per fruit	0.01	2.91**	1.41**	1.58**	2.86**	2.7**	3.82**	1.5**	0.05
Pericarp thickness (mm)	0.42*	1.11**	2.17**	14.61**	0.65**	2.17**	0.28	2.87**	0.11
Total soluble solid	0.02	0.62	1.05	2.74*	0.9	0.27	0.28	0.74	0.68
Ascorbic acid (mg/100g)	0.5	8.73**	9.64**	2.65	2.44	1.69	15.52**	8.05**	1.35
Dry matter % of fruit	0.04	2.19**	0.74**	1.43**	2.9**	0.56**	3.5**	0.79**	0.06
Fruit yield per hectare (q)	386.19	45287.7**	58710.43**	27330**	52209.2**	15898.89**	98846**	62812.36**	775.06

* significant at 5 % and ** significant at 1 %

twenty-four crosses, ten crosses showed positive significant relative heterosis for this trait. The top crosses that exhibited positive relative heterosis for this trait were H-24 X 14/TLCV-1 (55.75%), PR X 14/TLCV-3 (48.03%), KA X 15/TLCV-2 (44.23%), KA X 14/TLCV-3 (42.33%) and PC X 14/TLCV-1 (36.94%). Heterobeltiosis for fruit yield per hectare ranged from -47.79% (PC X 14/TLCV-3) to 45.32% (H-24 X 14/TLCV-1). Seven crosses showed positive significant heterobeltiosis for this trait. The crosses that showed significant positive heterobeltiosis were H-24 X 14/TLCV-1 (45.32%) followed by KA X 15/TLCV-2 (23.78%), KA X 14/TLCV-3 (18.51%), PC X 14/TLCV-1 (17.21%), H-86 X 14/TLCV-3 (10.29%), PR X 14/TLCV-3 (9.87%) and H-86 X 15/TLCV-4 (6.98%).The heterosis over check variety ranged from -28.66% (AV X 14/TLCV-1) to 79.03% (H-86 X 14/TLCV-3) for fruit yield per hectare (q). Fifteen crosses from twenty-four reported significant positive standard heterosis while, five crosses exhibited significant negative heterosis. The top crosses showed significant positive heterosis over check variety were H-86 X 14/TLCV-3 (79.03%), KA X 14/TLCV-3 (78.18%), H-86 X 15/TLCV-4 (73.66%), KA X 15/TLCV-2 (72.81%) and PR X 14/TLCV-3 (65.19%). The results of this investigation find close conformity with the reports of several earlier workers Gul et al. (2010), Singh et al. (2012), Agarwal et al. (2014), Ahmad et al. (2015), Marbhal et al. (2016) and Singh (2017) who also reported significant heterosis for improved fruit yield in tomato.

Negative heterosis is desirable for days to 50% flowering over mid parent, better parent and standard check. Relative heterosis among the crosses ranged from -7.26% (H-86 X 15/TLCV-4) to 9.52 % (AV X 14/TLCV-3), heterobeltiosis ranged from -4.60% (H-86 X 15/TLCV-4) to 16.25% (PR X 14/TLCV-1) and standard heterosis ranged from 5.07 (PC X 14/TLCV-1) to 12.32 (PR X 14/TLCV-1, AV X 14/TLCV-1 and KA X 14/TLCV-1). Out of 24 crosses, 3 and 1crosses, showed significant negative relative heterosis and heterobeltiosis respectively. The magnitude of relative heterosis for number of branches per plant ranged from -33.85% to 48.19%. Out of 24 crosses nine exhibits significant positive heterosis for this trait. The heterobeltiosis for this trait ranged from -38.13% to 37.26%. Seven crosses out of twenty-four crosses showed positive significant heterobeltiosis values. The top crosses showed positive heterobeltiosis for this trait *viz*., H-86 X 14/TLCV-3 (37.26%), KA X 14/TLCV-3 (16.52%), H-86 X 15/TLCV-2 (15.18%) and H-86 X 15/TLCV-4.The heterosis over check variety ranged from -28.73 % to 36.76%. Ten crosses showed significant positive standard heterosis for this trait. Top highest positive significant standard heterosis was shown by H-86 X 14/TLCV-3 (36.76%) followed by H-86 X 15/TLCV-2 & PR X 14/TLCV-3 (23.69%) and H-24 X 15/TLCV-2 (20.69%). Almost similar results have been reported by Yadav et al. (2013) and Kumar et al. (2017).

The relative heterosis for plant height among the crosses ranged from -26.46% (PR X 15/TLCV-2) to 23.18% (H-86 X 15/TLCV-4). Four crosses out of twenty-four showed significant positive relative heterosis. The heterobeltiosis for plant height ranged from -36.77% (PR X 15/TLCV-2) to 11.14% (H-86 X 15/TLCV-4). Out of twenty-four crosses, only two crosses H-86 X 15/TLCV-4 (11.14%) and KA X 15/TLCV-2 (10.18%) exhibited significant positive heterobeltiosis. The standard heterosis for plant height ranged from -16.25% (H-86 X 14/TLCV-1) to 10.25% (KA X 15/TLCV-2) showed significant standard heterosis for this trait followed by crosses, H-24 X 14/TLCV-1 (8.90%). Almost similar results have been reported by Yadav et al. (2013), Ahmad et al. (2015), Marbhal et al. (2016) and Kumar et al. (2017) who reported positive significant heterosis values for plant height in tomato. Relative heterosis for number of fruit cluster per plant was found to be highest in KA X 15/TLCV-4 (36.59%) and minimum was observed in H-86 X 14/TLCV-1 (-28.73%). The heterobeltiosis ranged from -33.18% (H-86 X 14/TLCV-1) to 36.51% (KA X 15/TLCV-4). Out of twenty-four crosses only five crosses showed positive significant heterobeltiosis values. The crosses showed positive heterobeltiosis for this trait *i.e.* KA X 15/TLCV-4 (36.51%), PR X 14/TLCV-3 (23.30%) and H-86 X 14/TLCV-3 (23.12%). The crosses, PR X 14/TLCV-3 (44.42%) showed highest positive significant standard heterosis followed by H-86 X 14/TLCV-3 (43.26%), KA X 15/TLCV-4 (37.25%) and H-24 X 14/TLCV-1 (33.60%).

Number of flowers per cluster directly affected the total fruit yield per plant, so this character is very important for fruit yield. Eighteen crosses out of twenty-four exhibited significant positive relative heterosis. Among them some were, PC X 15/TLCV-2 (40.25%), PC X 15/TLCV-4 (33.68%) and H-86 X 15/TLCV-2 (31.51%). The extent of heterobeltiosis for number of flowers per cluster ranged from -23.45% (KA X 14/TLCV-1) to 39.33% (PC X 15/TLCV-2). Thirteen crosses out of them showed significant positive heterobeltiosis. Twenty two out of twenty-four crosses manifested significant and positive standard heterosis over Kashi Anupam. The range of standard heterosis varied from -14.29% (KA X 14/TLCV-1) to 41.27% (PC X 15/TLCV-2). For number of fruits per cluster relative heterosis among the crosses ranged from -

16.90% (KA X 14/TLCV-1) to 43.31% (PC X 15/TLCV-2). The extent of heterobeltiosis for number of fruits per cluster ranged from -22.12% (KA X 14/TLCV-1) to 38.09% (PC X 15/TLCV-2 & H-24 X 15/TLCV-2). Fifteen crosses showed positive significant heterobeltiosis. Highest positive heterobeltiosis was exhibited by PC X 15/TLCV-2 & H-24 X 15/TLCV-2 (38.09%), followed by H-86 X 15/TLCV-2 (29.35%) and AV X 14/TLCV-3 (26.36%).The heterosis over check variety observed from 10.24% (PC X 14/TLCV-1) to 54.15% (PC X 15/TLCV-2 & H-24 X 15/TLCV-2). The significant positive standard heterosis was observed for twenty-two crosses out of twenty four. Significant positive standard heterosis was observed in crosses, PC X 15/TLCV-2 & H-24 X 15/TLCV-2 (54.15%), AV X 14/TLCV-3 (49.27%) and H-86 X 15/TLCV-2 (44.39%). Variable results of the present study for number of fruits per cluster by the earlier findings of Kumari and Sharma (2011), Ahmad et al. (2015), Marbhal et al. (2016) and Kumar et al. (2017).

The number of fruits per plant is one of the major parameters contributing for total fruit yield. The relative heterosis of number of fruits per plant varied from -26.06% (H-86 X 15/TLCV-2) to 38.23% (KA X 14/TLCV-1). The nine crosses exhibited significant positive relative heterosis, among them top ones were KA X 14/TLCV-1 (38.23%) and PR X 15/TLCV-2 (26.01%). Among twenty four crosses, seven crosses exhibited significant positive heterobeltiosis *viz*, PC X 14/TLCV-3 (22.90%) followed by PR X 15/TLCV-2 (20.74%), PR X 14/TLCV-3 (18.02%), KA X 14/TLCV-1 (16.54%), H-86 X 14/TLCV-3 (12.10%), AV X 14/TLCV-1 (11.86%) and PC X 15/TLCV-2 (10.37%). The standard heterosis for number of fruits per plant ranged from 24.77% (KA X 15/TLCV-2) to 74.59% (AV X 14/TLCV-1). Twenty-three crosses showed significant positive standard heterosis. Second highest significant positive standard heterosis was exhibited by KA X 14/TLCV-1 (70.45%) followed by H-86 X 14/TLCV-3 (68.96%) and PR X 15/TLCV-2 (66.58%). Biswas et al. (2016) and Renuka and Sadashiva (2016) made similar observation in tomato.

Days to first fruit harvest is a measure of earliness, as early picking gives better returns and also widen the fruiting period of the plant. Hence, heterosis in negative direction is desirable for this attribute. The range of relative heterosis for twenty-four crosses varied from -3.11% (PC X 15/TLCV-4) to 5.12% (KA X 14/TLCV-1). None of the crosses showed significant negative heterobeltiosis and standard heterosis for this trait. Similar results of heterosis for days to first fruit harvest in both positive and negative directions have been reported by Chauhan et al. (2014) and Kumar et al. (2017).

The relative heterosis for fruit yield per plant (kg) ranged from -29.33% (H-24 X 14/TLCV-3) to 69.28% (PC X 14/TLCV-1). Out of twenty-four crosses, twelve crosses showed positive significant relative heterosis for this trait. The top crosses exhibited positive relative heterosis for this trait was PC X 14/TLCV-1 (69.28%) and KA X 14/TLCV-3 (63.12%). Heterobeltiosis for fruit yield per plant ranged from -43.63% to 50.83%. Six crosses showed positive significant heterobeltiosis for this trait. The crosses which showed significant positive heterobeltiosis were H-24 X 14/TLCV-1 (50.83%) followed by PC X 14/TLCV-1 (36.51%) and KA X 14/TLCV-3 (33.29%). The heterosis over check variety ranged from -22.22% (KA X 14/TLCV-1) to 109.72% (KA X 14/TLCV-3). Seventeen crosses from twenty-four crosses reported significant positive standard heterosis. The crosses showed significant positive heterosis over check variety were KA X 14/TLCV-3 (109.72%), H-86 X 14/TLCV-3 (106.15%) and KA X 15/TLCV-2 (104.37%).

Fruit length is a growth attribute directly associated with yield, for which positive heterosis is desirable. Average heterosis for this trait ranged from -22.83% (PC X 14/TLCV-3) to 44.35% (AV X 14/TLCV-1). Only two crosses among twenty crosses showed significant positive relative heterosis i.e. AV X 14/TLCV-1 (44.35%) and H-24 X 14/TLCV-1 (25.55%). The heterobeltiosis for fruit length ranged from -32.11% (PC X 14/TLCV-3) to 29.56% (AV X 14/TLCV-1). Out of twenty-four crosses, only one crosses exhibited significant positive heterobeltiosis i.e. AV X 14/TLCV-1 (29.56%). The extent of standard heterosis for fruit length ranged from -28.61% (PC X 14/TLCV-3) to 14.40% (AV X 14/TLCV-1). Out of twenty-four crosses only one cross AV X 14/TLCV-1 (14.40%) exhibited significant positive standard heterosis. For the trait fruit diameter heterosis over mid parent ranged from -17.63 % (KA X 14/TLCV-1) to 17.73% (AV X 14/TLCV-3). Seven crosses out of twenty-four crosses manifested significant positive heterosis over mid parent. Heterobeltiosis for fruit diameter ranged from -30.14% (PC X 14/TLCV-3) to 11.31% (H-24 X 14/TLCV-1). Only one crosses exhibited positive significant heterosis over better parent i.e. H-24 X 14/TLCV-1 (11.31%). The heterosis over check variety (standard heterosis) ranged from -27.71% (PC X 14/TLCV-3) to 15.65% (KA X 15/TLCV-2). Two crosses out of twenty-four crosses exhibited positive significant standard heterosis viz., KA X 15/TLCV-2 (15.65%) and H-86 X 15/TLCV-2 (11.40%). Similar results were stated by Shende et al.

Table 2: Heterosis (Over mid parent, better parent and check variety) for yield and its components in tomato during *rabi*, 2017-18

S. No.	Hybrids	Days to 50% flowering			No. of branches per plant			Plant height(cm)			No. of fruit cluster per plant		
		RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
1	PR X 15/TLCV-4	-4.65*	2.50	-0.97	11.60*	-3.15	10.62*	-8.36	-31.23**	-5.06	22.61**	13.86**	33.37**
2	PR X 15/TLCV-2	7.23**	11.25**	7.49**	-26.38**	-28.58**	-18.43**	-26.46**	-36.77**	-12.72**	-28.56**	-32.49**	-11.16*
3	PR X 14/TLCV-3	-1.82	1.25	-2.17	15.68**	8.30	23.69**	-25.28**	-30.80**	-4.48	27.36**	23.30**	44.42**
4	PR X 14/TLCV-1	6.90**	16.25**	12.32**	-0.71	-1.14	13.89**	-19.79**	-30.33**	-3.83	-8.83*	-14.26**	13.99**
5	PC X 15/TLCV-4	2.25	5.81**	9.90**	-9.43	-20.04**	-12.26*	-1.43	-19.13**	-12.72**	7.28	5.79	6.24
6	PC X 15/TLCV-2	2.33	2.33	6.28**	-6.26	-7.27	1.76	-10.66*	-14.22**	-7.42	2.84	-10.43**	17.87**
7	PC X 14/TLCV-3	-4.09	-3.53	-0.97	-13.19**	-17.18**	-9.12	-3.72	-7.70*	8.60	-1.23	-6.65	2.36
8	PC X 14/TLCV-1	-3.33	1.16	5.07*	-13.27**	-15.32**	-2.45	-13.37**	-15.86**	-9.19*	-7.85	-20.09**	6.24
9	AV X 15/TLCV-4	0.57	6.02**	6.28**	-0.96	-11.37*	-5.72	-11.24**	-35.35**	-2.12	-0.08	-10.77**	13.99**
10	AV X 15/TLCV-2	-2.96	-1.20	-0.97	-2.62	-3.08	4.08	-20.56**	-34.22**	-0.41	-13.56**	-14.82**	12.09*
11	AV X 14/TLCV-3	9.52**	10.84**	11.11**	1.04	-2.15	4.08	-22.87**	-31.46**	3.77	-6.74	-13.35**	10.70*
12	AV X 14/TLCV-1	5.08*	12.05**	12.32**	-0.15	-3.97	10.62*	-19.88**	-33.02**	1.41	-9.57**	-11.34**	17.87**
13	KA X 15/TLCV-4	2.86	8.43**	8.70**	20.85**	11.05*	11.37*	5.95	-10.42*	-10.37*	36.59**	36.51**	37.25**
14	KA X 15/TLCV-2	5.33*	7.23**	7.49**	3.38	-0.03	7.35	10.59*	10.18*	10.25*	-1.79	-13.37**	13.99**
15	KA X 14/TLCV-3	-1.19	0.00	0.24	16.90**	16.52**	16.86**	-12.86**	-19.38**	-5.14	26.57**	21.31**	33.02**
16	KA X 14/TLCV-1	5.08*	12.05**	12.32**	-33.85**	-38.13**	-28.73**	5.61	4.74	6.55	-23.51**	-32.83**	-10.70*
17	H-86 X 15/TLCV-4	-7.26**	-4.60*	0.24	15.47**	14.85*	-2.45	23.18**	11.14*	-4.48	-6.24	-12.66**	1.63
18	H-86 X 15/TLCV-2	6.36**	6.98**	11.11**	28.63**	15.18**	23.69**	11.38*	3.88	3.18	6.64	0.47	32.21**
19	H-86 X 14/TLCV-3	-4.65*	-3.53	-0.97	48.19**	37.26**	36.76**	0.17	-13.33**	1.98	26.77**	23.12**	43.26**
20	H-86 X 14/TLCV-1	1.66	5.75**	11.11**	-26.71**	-36.34**	-26.67**	-10.76*	-17.68**	-16.25**	-28.73**	-33.18**	-11.16*
21	H-24 X 15/TLCV-4	-2.22	0.00	6.28**	19.92**	12.98*	7.35	21.72**	3.19	2.59	12.48**	7.99	17.87**
22	H-24 X 15/TLCV-2	4.60*	5.81**	9.90**	19.25**	12.39**	20.69**	5.58	5.53	4.91	7.58	-1.59	29.50**
23	H-24 X 14/TLCV-3	-4.05	-2.35	0.24	3.58	1.18	0.81	-17.42**	-23.82**	-10.37*	0.66	0.42	10.12*
24	H-24 X 14/TLCV-1	-1.10	2.27	8.70**	5.68	-3.57	11.08*	8.28	7.05	8.90*	10.37**	0.50	33.60**

*significant at 5% and ** significant at 1 % [RH (Relative heterosis), HB (Heterobeltiosis) and SH (Standard heterosis)]
Cont………………………….

Table 2: Heterosis (Over mid parent, better parent and check variety) for yield and its components in tomato during *rabi*, 2017-18

S. No.	Hybrids	No. of flowers per cluster			No. of fruits per cluster			No. of fruits per plant			Days to first fruit harvest		
		RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
1	PR X 15/TLCV-4	22.02**	21.26**	29.37**	8.29	5.96	20.00**	3.94	1.38	39.88**	-1.56	-0.49	-0.20
2	PR X 15/TLCV-2	9.09*	6.39	13.49**	-4.21	-5.61	5.37	26.01**	20.74**	66.58**	2.61	3.03*	3.32*
3	PR X 14/TLCV-3	17.75**	8.52**	37.30**	14.57**	9.84*	29.76**	19.32**	18.02**	62.83**	-2.93	-2.49	-2.21
4	PR X 14/TLCV-1	11.07**	8.45*	21.43**	15.40**	11.37**	29.76**	-11.06*	-13.58**	26.40**	1.39	2.10	2.40
5	PC X 15/TLCV-4	33.68**	30.32**	37.30**	24.23**	18.88**	34.63**	7.02	6.92	40.54**	-3.11*	-2.27	0.15
6	PC X 15/TLCV-2	40.25**	39.33**	41.27**	43.31**	38.09**	54.15**	12.52**	10.37*	45.08**	-1.94	-0.42	0.69
7	PC X 14/TLCV-3	0.18	-10.30**	13.49**	12.69**	5.71	24.88**	24.52**	22.90**	65.86**	-1.24	0.26	1.46
8	PC X 14/TLCV-1	10.79**	4.90	17.46**	0.22	-5.37	10.24*	4.31	-0.97	44.84**	0.68	1.94	3.68*
9	AV X 15/TLCV-4	16.50**	7.72*	13.49**	24.40**	14.57**	29.76**	6.62	-1.88	53.15**	3.09*	3.57*	5.15**
10	AV X 15/TLCV-2	27.23**	19.77**	21.43**	20.66**	11.87**	24.88**	-3.20	-12.40**	36.73**	-0.10	0.11	1.22
11	AV X 14/TLCV-3	19.78**	2.25	29.37**	39.83**	26.36**	49.27**	-5.57	-11.96**	37.42**	-1.98	-1.81	-0.64
12	AV X 14/TLCV-1	16.61**	4.90	17.46**	8.67	-1.19	15.12**	15.49**	11.86**	74.59**	0.68	0.77	2.31
13	KA X 15/TLCV-4	18.22**	15.25**	21.43**	25.17**	18.88**	34.63**	20.74**	6.55	39.78**	2.77	3.97**	4.11**
14	KA X 15/TLCV-2	16.61**	15.85**	17.46**	21.55**	16.24**	29.76**	10.05	-1.30	24.77**	0.15	0.64	0.77
15	KA X 14/TLCV-3	0.18	-10.30**	13.49**	9.09*	1.58	20.00**	23.11**	7.32	44.84**	-1.25	-0.72	-0.59
16	KA X 14/TLCV-1	-19.15**	-23.45**	-14.29**	-16.90**	-22.12**	-9.27	38.23**	16.54**	70.45**	5.12**	5.95**	6.09**
17	H-86 X 15/TLCV-4	28.98**	26.55**	33.33**	18.79**	10.27*	24.88**	-2.83	-9.12*	36.97**	0.66	1.84	1.97
18	H-86 X 15/TLCV-2	31.51**	31.51**	33.33**	38.43**	29.35**	44.39**	-26.06**	-32.02**	2.46	3.26*	3.77*	3.90*
19	H-86 X 14/TLCV-3	10.04**	-0.89	25.40**	29.71**	18.10**	39.51**	18.29**	12.10**	68.96**	0.65	1.19	1.32
20	H-86 X 14/TLCV-1	-1.05	-5.73	5.56	7.84	-1.19	15.12**	6.93	5.35	58.78**	2.69	3.50*	3.63*
21	H-24 X 15/TLCV-4	14.70**	10.68**	25.40**	26.83**	23.19**	39.51**	-6.46	-10.51*	28.53**	0.03	0.30	2.78
22	H-24 X 15/TLCV-2	24.21**	17.69**	33.33**	41.18**	38.09**	54.15**	-2.24	-8.09	31.99**	2.22	3.19*	4.33**
23	H-24 X 14/TLCV-3	4.58	-0.89	25.40**	15.40**	9.84*	29.76**	-8.52	-11.28**	27.42**	1.14	2.06	3.28*
24	H-24 X 14/TLCV-1	-2.76	-3.33	9.52*	7.50	3.00	20.00**	-8.25	-9.08*	32.98**	-1.65	-1.01	0.68

*significant at 5% and ** significant at 1 % [RH (Relative heterosis), HB (Heterobeltiosis) and SH (Standard heterosis)]
Cont…………………….

Table 2: Heterosis (Over mid parent, better parent and check variety) for yield and its components in tomato during *rabi*, 2017-18

S. No.	Hybrids	Fruit yield per plant			Fruit length (cm)			Fruit diameter (cm)			Average fruit wt. (g)		
		RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
1	PR X 15/TLCV-4	10.64*	-12.06**	40.28	-0.25	-21.76**	-13.44	4.76	-8.98	-7.88	-4.80	-14.81**	2.34
2	PR X 15/TLCV-2	-19.28**	-35.79**	2.18	3.35	-9.89	-23.78**	-11.41*	-24.64**	-19.78**	-25.84**	-36.17**	-16.05**
3	PR X 14/TLCV-3	47.75**	18.03**	85.71**	4.37	-16.60*	-12.31	10.67	-4.74	-1.43	16.12**	4.39	24.12**
4	PR X 14/TLCV-1	29.93**	21.47**	31.35**	1.30	-13.27	-23.42**	10.55	1.74	-9.64	5.28	-2.22	-7.22*
5	PC X 15/TLCV-4	5.10	-25.62**	18.65**	-10.32	-22.79**	-14.58*	6.10	-11.98*	-10.91*	21.70**	-13.81**	3.55
6	PC X 15/TLCV-2	34.33**	-4.86	51.39**	-0.19	-2.97	-17.92*	11.61*	-9.21	-3.36	30.64**	-9.83**	18.60**
7	PC X 14/TLCV-3	-11.27*	-36.95**	-0.79	-22.83**	-32.11**	-28.61**	-15.05*	-30.14**	-27.71**	-14.03**	-38.92**	-27.38**
8	PC X 14/TLCV-1	69.28**	36.51**	47.62**	3.65	-1.29	-12.84	14.56*	0.31	-10.91	83.87**	48.47**	20.80**
9	AV X 15/TLCV-4	23.39**	-4.85	51.79**	-1.29	-19.33**	-10.75	12.78*	-8.27	-7.16	16.06**	-5.86*	13.10**
10	AV X 15/TLCV-2	7.75	-16.83**	32.34**	6.67	-2.41	-17.44*	13.59*	-9.37*	-3.53	11.65**	-12.44**	15.16**
11	AV X 14/TLCV-3	26.44**	-2.02	54.17**	4.73	-12.68	-8.18	17.73**	-5.06	-1.76	28.73**	4.84	24.65**
12	AV X 14/TLCV-1	-5.40	-14.86**	-7.94	44.35**	29.56**	14.40*	11.83	-4.16	-14.88**	10.09*	5.63	-14.05**
13	KA X 15/TLCV-4	9.41*	-11.07**	41.87**	-13.93*	-18.04**	-9.32	-2.77	-3.38	-2.20	15.96**	6.28*	27.68**
14	KA X 15/TLCV-2	57.85**	28.43**	104.37**	5.01	-3.11	-3.05	12.07*	8.64	15.65**	53.29**	34.97**	77.52**
15	KA X 14/TLCV-3	63.12**	33.29**	109.72**	-0.15	-2.56	2.45	7.64	5.80	9.48	49.04**	37.25**	63.19**
16	KA X 14/TLCV-1	-25.19**	-28.07**	-22.22**	-19.51*	-24.24**	-24.19**	-17.63**	-22.22**	-22.26**	-23.39**	-30.55**	-30.50**
17	H-86 X 15/TLCV-4	4.38	-10.84**	100.79**	-3.50	-3.78	6.45	0.55	-0.65	0.55	28.26**	22.70**	61.39**
18	H-86 X 15/TLCV-2	-18.95**	-30.84**	55.75**	-0.34	-11.85	-3.05	8.56	4.66	11.40*	30.32**	30.32**	71.40**
19	H-86 X 14/TLCV-3	7.78*	-8.46**	106.15**	4.02	1.73	11.89	-1.28	-3.51	-0.17	15.71**	10.16**	44.89**
20	H-86 X 14/TLCV-1	-3.21	-28.37**	61.31**	6.05	-4.40	5.14	-9.78	-14.33**	-15.37**	7.59**	-12.93**	14.52**
21	H-24 X 15/TLCV-4	-22.57**	-38.56**	-1.98	4.86	-13.88*	-4.72	-0.96	-4.74	-3.58	9.69*	-6.23*	12.65**
22	H-24 X 15/TLCV-2	-8.79	-27.56**	15.28*	9.20	0.49	-14.99*	-7.85	-13.46**	-7.88	4.70**	-13.72**	13.48**
23	H-24 X 14/TLCV-3	-29.33**	-43.63**	-11.31	8.60	-8.98	-4.30	-8.42	-12.83**	-9.81	13.74	-2.35	16.11**
24	H-24 X 14/TLCV-1	61.65**	50.83**	63.10**	25.55**	13.32	0.06	14.17*	11.31*	4.08	66.65**	62.84**	38.83**

*significant at 5% and ** significant at 1 % [RH (Relative heterosis), HB (Heterobeltiosis) and SH (Standard heterosis)]
Cont…………………

Table 2: Heterosis (Over mid parent, better parent and check variety) for yield and its components in tomato during *rabi*, 2017-18

S. No.	Hybrids	No. of Locules per fruit			Pericarp thickness (mm)			Fruit yield per hectare (q)		
		RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)	RH (%)	HB (%)	SH (%)
1	PR X 15/TLCV-4	-37.62**	-44.07**	-47.36**	26.12**	21.52**	31.63**	18.60**	-7.21	19.66**
2	PR X 15/TLCV-2	-33.42**	-39.50**	-30.33**	-2.01	-3.93	0.41	-23.29**	-41.64**	-18.52**
3	PR X 14/TLCV-3	-8.95**	-16.42**	-21.33**	17.01**	5.11	32.52**	48.03**	9.87**	65.19**
4	PR X 14/TLCV-1	-3.94	-5.34*	-8.22**	36.95**	25.58**	26.12**	22.20**	2.17	10.71
5	PC X 15/TLCV-4	6.61*	-12.18**	-34.44**	15.96**	13.12**	28.84**	-4.91	-24.01**	-2.01
6	PC X 15/TLCV-2	-11.90**	-37.46**	-27.98**	-13.41**	-16.98**	-5.44	20.68**	-6.32	30.80**
7	PC X 14/TLCV-3	25.42**	1.24	-20.35**	-22.33**	-26.08**	-6.80	-30.99**	-47.79**	-21.50**
8	PC X 14/TLCV-1	26.34**	-5.34*	-8.22**	19.98**	4.10	18.57**	36.94**	17.21**	27.02**
9	AV X 15/TLCV-4	6.56*	2.56	-17.22**	32.14**	25.54**	35.99**	9.00	1.74	31.19**
10	AV X 15/TLCV-2	-33.26**	-43.24**	-34.64**	12.88**	9.09*	14.01**	-11.13*	-19.99**	11.71*
11	AV X 14/TLCV-3	-18.47**	-19.51**	-35.03**	20.85**	7.16*	35.10**	1.92	-11.16**	33.58**
12	AV X 14/TLCV-1	-4.40*	-12.40**	-15.07**	26.77**	17.84**	14.90**	-35.18**	-36.17**	-28.66**
13	KA X 15/TLCV-4	17.43**	2.54	2.54	7.14	3.44	12.04**	5.91	-5.97	21.25**
14	KA X 15/TLCV-2	-8.68**	-14.69**	-1.76	35.29**	32.92**	38.91**	44.23**	23.78**	72.81**
15	KA X 14/TLCV-3	14.13**	1.96	1.96	13.80**	2.41	29.12**	42.33**	18.51**	78.18**
16	KA X 14/TLCV-1	-33.63**	-34.64**	-34.64**	-5.59	-13.58**	-12.86**	-31.10**	-33.75**	-28.21**
17	H-86 X 15/TLCV-4	21.88**	13.25**	-15.46**	-16.73**	-17.30**	-9.18*	19.24**	6.98*	73.66**
18	H-86 X 15/TLCV-2	-6.76**	-27.44**	-16.44**	30.77**	27.61**	40.14**	-14.87**	-20.82**	28.53**
19	H-86 X 14/TLCV-3	-6.23*	-14.93**	-33.07**	15.64**	8.19*	36.39**	14.51**	10.29**	79.03**
20	H-86 X 14/TLCV-1	-12.02**	-26.94**	-29.16**	31.36**	15.78**	27.14**	-0.93	-17.39**	34.09**
21	H-24 X 15/TLCV-4	-16.44**	-16.77**	-37.38**	32.45**	19.39**	29.32**	-17.19**	-28.46**	-7.74
22	H-24 X 15/TLCV-2	-24.76**	-37.80**	-28.38**	13.91**	4.34	9.05*	-6.15	-21.53**	9.56
23	H-24 X 14/TLCV-3	-15.06**	-16.92**	-34.64**	3.65	-12.43**	10.41*	-32.10**	-44.86**	-17.09**
24	H-24 X 14/TLCV-1	-1.58	-12.61**	-15.26**	73.02**	69.83**	47.69**	55.75**	45.32**	57.48**

*significant at 5% and ** significant at 1 % [RH (Relative heterosis), HB (Heterobeltiosis) and SH (Standard heterosis)]

(2012), Islam et al. (2012) and Chauhan et al. (2014) in tomato.

Average fruit weight directly affects the total fruit yield, so this character is very important so far fruit yield is concerned. The relative heterosis for average fruit weight trait ranged from -25.84% (PR X 15/TLCV-2) to 83.87% (PC X 14/TLCV-1). The extent of heterobeltiosis for average fruit weight ranged from -38.92% (PC X 14/TLCV-3) to 62.84% (H-24 X 14/TLCV-1). Eight crosses showed significant positive heterobeltiosis. The heterosis over check variety was observed from -30.50% (KA X 14/TLCV-1) to 77.52% (KA X 15/TLCV-2). The significant standard heterosis was observed for twenty-two crosses out of twenty-four crosses .The top five crosses exhibited significant positive standard heterosis were exhibited by KA X 15/TLCV-2 (77.52%), H-86 X 15/TLCV-2 (71.40%), KA X 14/TLCV-3 (63.19%), H-86 X 15/TLCV-4 (61.39%) and H-86 X 14/TLCV-3 (44.89%). The mid parental heterosis ranged from -37.62% (PR X 15/TLCV-4) to 26.34% (PC X 14/TLCV-1). Seven crosses out of twenty-four crosses showed positive relative heterosis. The extent of heterosis over better parent (heterobeltiosis) ranged from -44.07% to 13.25%. Out of twenty-four crosses, one crosses H-86 X 15/TLCV-4 (13.25%) showed positive significant heterobeltiosis. Similar results were also reported by Singh et al. (2012) and Farzane et al. (2012). The average heterosis for pericarp thickness (mm) ranged from -22.33% (PC X 14/TLCV-3) to 73.02% (H-24 X 14/TLCV-1). Heterobeltiosis per cent for pericarp thickness ranged from -26.08% (PC X 14/TLCV-3) to 69.83% (H-24 X 14/TLCV-1). Thirteen crosses out of twenty-four crosses showed positive heterobeltiosis, where three top crosses viz., H-24 X 14/TLCV-1 (69.83%), KA X 15/TLCV-2 (32.92%) and H-86 X 15/TLCV-2 (27.61%). The standard heterosis for pericarp thickness ranged from -12.86% (KA X 14/TLCV-1) to 47.69% (H-24 X 14/TLCV-1). Out of twenty-four crosses nineteen crosses showed positive heterosis over check variety. Almost identical results have been reported by Sharma and Thakur (2008) and Kumar et al. (2013).

The identification and utilization of the most heterotic and useful crosses are very important in hybrid approach to make the commercial cultivation of hybrid beneficial. It was concluding that the cross combinations KA X 15/TLCV-2, H-86 X 14/TLCV-3, H-86 X 15/TLCV-2, PR X 14/TLCV-3, KA X 14/TLCV-3 and 86 X 15/TLCV-4 were identified as top standard heterotic crosses for multiple traits in tomato for fruit yield and its contributing characters.

Ikjka'k

वर्तमान शोध रबी 2017—18 में अखिल भारतीय सब्जी अनुसंधान परियोजना (सब्जी फसल), औद्यानिकी अनुसधांन सह अनुदेशात्मक फार्म, सब्जी विज्ञान विभाग, ई.गा.कृ.वि.वि., रायपुर (छत्तीसगढ़) के तहत की गयी। टमाटर में उपज और उपज को प्रभावित करने वाले कारकों का संकर ओज परीक्षण हेतु छः विविध वंशक्रमों को चार टेस्टर के साथ लाइन x टेस्टर संकरण विधि में जाँच किया गया। इस शोध में अधिकांश वंशक्रमों के लिए संकर ओज की एक उच्च परिणाम देखी गयी। उल्लेखनीय विषमता के साथ उच्च प्रति प्रदर्शन पीआर x 14/टीएलसीवी—3, केए x 15/टीएलसीवी—2, एच—86 x 14/टीएलसीवी—3, केए x 14/टीएलसीवी—3 एवं एच—24 x 14/टीएलसीवी—1 द्वारा उच्च फल की पैदावार के लिए व्यक्त किया गया था जबकि वांछित दिशा में अन्य लक्षणों के लिए उच्च स्तर की संकर ओज भी देखी गयी।

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