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Analysis of heterotic pattern of F_1's in tomato (*Solanum lycopersicum* L.) for the improvement of yield and quality traits

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Abstract
Consumption of vegetable with improved quality has been adopted as a strategy for ameliorating nutritional status of people. Not only improving quality but also upgrading the yield of the produce has become necessary to feed the growing population. Heterosis breeding has proven to be a quicker method in achieving this goal. The present research was conducted at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *Rabi* seasons of 2017-18 and 2018-19, to estimate the heterosis in tomato for different yield and quality traits. Eight lines and three testers were crossed in a "Line × Tester" mating fashion to obtain 24 hybrids which were then used to evaluate for different traits along with their parents. The analysis of variance revealed that the estimates of mean squares for all eight characters studied were highly significant indicating wide genetic differences among the genotypes. The heterotic pattern for number of locules per fruit indicated that maximum per cent of significant relative heterosis in cross VRT-101-A × Arka Abha (63.04 %) followed by H-88-78-1 × Arka Abha (30.69 %) and VRT-06 × Pusa-120 (16.81 %). The cross combination Solan Vajra × Arka Abha followed by CTS-07 × Arka Abha and VRT-101-A × Arka Abha were noted to exhibit maximum per cent of positive significant heterobeltiosis in the extent of 23.30, 19.22 and 16.62 % respectively, in case of total fruit yield.

Keywords: Heterosis, quality, significant, tomato, yield

Introduction
Vegetable production with improved quality and yield can be adopted as a strategy for improving livelihood and augment the nutritional status of the people. Tomato (*Solanum lycopersicum* L.) is acknowledged to be a native of Peru, Ecuador Bolivia Region of Andes, South America (Rick, 1969) [25]. It is one of the most popular warm season and day- neutral vegetable crop cultivated throughout the world owing to its wider adaptability, high productivity potential and suitable for preparation of variety of cuisines. It is a member of family Solanaceae or nightshade family and an autogamous crop with 2n = 24. It ranks second after potato but tops the list of processed vegetables in the world (Chaudhary, 1996) [9]. The family of Solanaceae also includes several other economically important crops such as potato, pepper (*Capsicum annuum* L.), and eggplant (*Solanum melongena* L.), representing one of the most valuable plant families for vegetable and fruit crops. It has increased commercial significance owing to the awareness about its nutritional and medicinal value, and has a constant demand round the year among the consumers. Tomato is globally grown for either fresh market or processing and considered as a high value crop. It also aids in increasing the income of small and marginal farmers and also contributes to the nutrition of the consumer (Singh *et al.*, 2010) [30]. Tomato fruits contain many health-promoting compounds and therefore can be easily integrated as a nutritious part of a balanced diet (Marti *et al*., 2016) [22]. The ripened fruits are consumed as raw or made into different edibles like salads, soups, preserve, pickles, ketchup, puree, paste and many other products (Chadha, 2001) [7]. Plant breeders have extensively delved into the utilization of heterosis in the recent past to boost yield levels in several cross-pollinated crops. In addition to cross pollinated species, the aspect of heterosis has also been exploited commercially in autogamous species wherever it was

technically feasible. Being a self-pollinated crop, tomato does not suffer from inbreeding depression (Allard, 1960) [3]. Tomato fruit produces numerous seeds per fruit which provide an ample opportunity to evaluate the expression of heterosis in tomato (Singh and Singh, 1993) [31]. The primary objective for breeding tomato along with developing high yielding varieties is to have attributes such as earliness, desirable fruit shape, size, attractive fruit colour, free from various diseases and other quality traits. Heterosis breeding offers the most potent tool to achieve this objective. Immense progress has been made in the development of potential hybrids since the discovery of hybrid vigour by Shull (1908) [29] in tomato. Heterosis in case of tomato was first observed for higher yield and more number of fruits by Hedrick and Booth (1907) [15]. Heterosis in plants is a phenomenon embodied itself in hybrids that are more vital and adaptive than their parents (Bai and Lindhout, 2007; Bhatt *et al*., 2001) [5, 6]. Exploitation of hybrid vigor in Tomato is economical and quite easy for hybrid seed production because of presence of more seed per fruit as compared to other vegetables as well as increased marketable fruit yield and component traits. Farmers are engrossed in growing hybrid varieties with higher yield, early harvest (short duration), and fruit with enhanced quality traits (Tamta and Singh, 2018) [34]. Though several high-yielding varieties exist, the best potential can be achieved by developing hybrids with high yield, earliness, and superior quality. Information on the degree and direction of heterosis in different cross combination is a basic requisite to assess for identifying the crosses that exhibit high amount of exploitable heterosis. In our research, our main focus is to assess the extent of heterosis for yield and yield components for different cross combinations and to find those cross combinations having high yield and quality potential to be used in further breeding programme. In the present study, the heterosis was computed over mid parent (Relative heterosis) and better parent (heterobeltiosis) for each trait under study.

Materials and methods

Eleven diverse genotypes of Tomato (*Solanum lycopersicum* L.) viz., eight lines namely CTS- 07, Angha, Solan Vajra, VRT-101-A, VRT-01, CO-3, VRT-06, H-88-78-1 and three testers namely Arka Abha, Pusa-120, Pant-T5 were used in the present study. The experimental material were collected from Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, which were selected on the basis of phenotypic observation of variability present within them. Twenty four F_1 crosses were generated through Line × Tester mating design; *Rabi* seasons of 2017-18 and 2018-19. Observations were recorded on fruit length (cm), fruit width (cm), number of seeds per fruit, number of locules per fruit, pericarp thickness (mm), total soluble solids (ºBrix), ascorbic acid content (mg/100g of edible fruit) and fruit yield (q/ha) and averaged replication wise mean data was used for statistical analysis. The experiment was conducted in Randomized Complete Block Design with three replications under study. All the standard cultural practices and plant protection methods were undertaken to raise a successful tomato crop. The analysis of variance (ANOVA) for RBD was estimated crosswise according to Panse and Sukhtame (1954) [23].

Result and discussion

The results from the analysis of variance implicates that the estimates of mean squares for all eight characters studied were highly significant indicating wide genetic differences among the genotypes. There were statistically significant differences noted among the varietals treatments. The mean sum of squares due to parents were all significant for all traits. The lines under study were also found significant for all traits under investigation. Significant differences due to testers were observed for all traits except fruit length. The mean sum of squares due to line *vs* tester exhibited significant differences for all characters whereas in case of parents *vs* crosses were also significant for all the characters except fruit length and number of locules per fruit.

The term “heterosis” is used to specify an expression of the superiority of hybrids over mean of parents compared, better parents or the standard commercial check (Hayes *et al*., 1955) [14] with respect to agriculturally propitious traits. The elementary objective of heterosis breeding is to achieve a significant increase in crop growth, increased fruit quality and yield. Exploitation of hybrid vigour for fruit length, fruit width, number of seeds per fruit, number of locules per fruit, pericarp thickness, total soluble solids and ascorbic acid by line × tester mating design provides an additional opportunity to improve and develop hybrids for quality traits. The magnitude of heterosis for different characters under study among the hybrid combinations are presented in Table.no.1, 2 and 3.

Traits like fruit size including fruit length and fruit width are directly associated with the productivity parameter of fruit production. The average heterosis estimated over the mid parent and better parent in case of fruit length varied from -19.90 (H-88-78-1 × Pusa-120) to 24.44 % (CO-3 × Pant T-5) and from -32.58 (H-88-78-1 × Pusa-120) to 5.47 % (Angha × Pusa-120) respectively. Among 24 crosses, five crosses showed significantly positive relative heterosis while in case of heterobeltiosis, only one cross Angha × Pusa-120 (5.47%) exhibited significantly positive heterosis over better parent. Maximum significant heterosis in the desired direction over mid parent was exhibited by cross CO-3 × Pant T-5 (24.44 %) followed by CO-3 × Pusa-120 (17.38 %) and Angha × Pusa-120 (8.18 %). Similar findings was reported by Singh *et al.* (2007) [32]; Chatopadhyaya *et al.* (2012) [8]; and Amin *et al.* (2017) [4].

The magnitude of relative heterosis for fruit width varied from -4.62 (H-88-78-1 × Pusa-120) to 26.83 % (VRT-101-A × Pant T-5) whereas heterosis over better parent for this trait varied between -20.92 (CO-3 × Arka abha) to 21.04 % (VRT-101-A × Pant T-5). Among 24 crosses, 17 crosses and 12 crosses exhibited significantly positive heterosis over mid parent and better parent respectively. The hybrids VRT-101-A × Pant T-5, VRT-01 × Pant T-5 and Solan Vajra × Pant T-5 were found to express significant positive heterosis over mid parent (26.83, 25.95 and 18.10 % respectively) as well as over better parent (21.04, 16.26 and 14.28 % respectively) for this attribute. This kind of results have also been reported by Singh *et al.* (2007) [32]; Chatopadhyaya *et al.* (2012) [8]; and Amin *et al.* (2017) [4].

The average number of seeds in individual fruit significantly varied among the genotypes. From seed production point of view, more number of seeds is desirable but from consumer point of view comparatively less number of seeds per fruit is preferable. The range of average heterosis for this trait was from -58.77 (CO-3 × Arka Abha) to 47.98 % (VRT-06 × Pant T-5). The selection of hybrids may be done according to the required objective. In the present study, the number of crosses exhibiting significant average heterosis in the positive direction was recorded to be only five out of 24 crosses in which highest per cent of heterosis over mid parent was noted in cross VRT-06 × Pant T-5 (47.98 %) followed by CTS-07 × Pant T-5 (18.44 %) and VRT-101-A × Pant T-5 (17.60 %). Regarding heterobeltiosis, maximum crosses showed negative significant heterosis over better parent for this trait and it ranged from -68.56 (CO-3 × Arka Abha) to 30.02 % (VRT-06 × Pant T-5). Only one of the cross VRT-06 × Pant T-5 (30.02 %) exhibited significant heterobeltiosis in the desired direction. Ahmad *et al*. (2011) also reported higher degree of heterosis for this trait. Negative heterosis is an indication of the presence of less number of seeds in tomato as expected by the consumers.

The number of locules in a fruit affects fruit size as well as shape. The relative heterosis measured over the mid parental value for number of locules per fruit implied that the values ranged from -28.30 (Angha × Pant T-5) to 63.04 % (VRT-101-A × Arka Abha) whereas it varied from -38.71 (Angha × Pant T-5) to 41.51 % (VRT-101-A × Arka Abha) over better parent. Out of 24 hybrids, highly significant heterosis over mid parent and better parent in positive direction was recorded for only three crosses and two crosses respectively. Considering the heterotic pattern for number of locules per fruit, maximum percent of significant relative heterosis was observed in cross VRT-101-A × Arka Abha (63.04 %) followed by H-88-78-1 × Arka Abha (30.69 %) and VRT-06 × Pusa-120 (16.81 %) whereas in case of heterobeltiosis, crosses VRT-101-A × Arka Abha (41.51 %) and H-88-78-1 × Arka Abha (24.53 %) only showed high significant heterosis in positive direction. Similar observations in tomato were reported by Kurian *et al.* (2006) [21]; Chatopadhyaya *et al.* (2012) [8]; and Soleiman *et al.* (2013) [33].

Pericarp thickness is one of the most important component that can manipulate processing as well as shelf life of tomato. The thickness of pericarp is a desirable trait as it imparts fruit firmness which may be suitable for canning, better storage and long distance transportation (Gonzalez, 1985 and Kalloo, 1988) [12, 16]. Thicker pericarp results in minimizing post-harvest losses, thus maintaining the quality and improved shelf life (Kumar *et al*., 2019) [19]. Pericarp thickness exhibited variation among treatments which ranged from -28.95 (VRT-01 × Pant T-5) to 52.81 % (H-88-78-1 × Pant T-5) over mid parent and from -36.82 (VRT-01 × Pant T-5) to 35.39 % (VRT-06 × Pant T-5) over better parent. Data recorded revealed that 15 crosses and 8 crosses out of 24 crosses exhibited positive significant heterosis over mid parent and better parent respectively. In order of merit, the crosses H-88-78-1 × Pant T-5, VRT-06 × Pant T-5 and H-88-78-1 × Arka Abha exhibited 52.81, 35.89 and 31.24 per cent of significant average heterosis respectively for this trait. However, maximum significant heterobeltiosis for pericarp thickness was exhibited by cross VRT-06 × Pant T-5 (35.39 %) followed by H-88-78-1 × Pant T-5 (27.26 %) and Solan Vajra × Pant T-5 (25.69 %). Similar results were reported by Kurian *et al.* (2006) [21]; Sharma and Thakur, (2008) [28]; Sekhar *et al.* (2010) [26]; Soleiman *et al.* (2013) [33]; Dagade *et al.* (2015) [11]; and Kumar and Paliwal, (2016) [17] in tomato.

High total soluble solids (TSS) is one of the major factors considered crucial for manufacture of processed products. A proper amount of TSS is important in tomato both for the purpose of fresh table use as well as processing purposes. Total soluble solids directly influence flavor of tomato. The relative heterosis measured over the mid parental value varied from -13.15 (CTS-07 × Arka Abha) to 32.66 % (H-88-78-1 × Pant T-5) for this trait. However the crosses H-88-78-1 × Pant T-5, Angha × Pant T-5 and H-88-78-1 × Pusa-120 with the extent of 32.66, 25.31 and 20.13 per cent respectively exhibited maximum positive significant heterosis over mid parent for this trait. Regarding the per cent of heterobeltiosis for this trait, the range varied from -26.07 (H-88-78-1 × Arka Abha) to 22.53 % (H-88-78-1 × Pant T-5). Highest per cent of positive significant heterobeltiosis was expressed by cross H-88-78-1 × Pant T-5 (22.53 %) followed by Angha × Pant T-5 (21.77 %) and VRT-01 × Pant T-5 (8.84 %) in case of TSS. The earlier reports of Bhatt *et al.* (2001) [6]; Hannan *et al.* (2007a) [13], Singh *et al*. (2007) [32], Kumari and Sharma (2011) [20]; Islam *et al.* (2012); Gul *et al.* (2013); Agarwal *et al. (*2014) [1]; Amin *et al.* (2017) [4]; and Salim *et al.* (2019) [27] support the present findings.

Ascorbic acid content is nutritionally an important constituent of tomato fruit. For the ascorbic acid content, the range of average heterosis and heterobeltiosis observed was from -15.92 (VRT-101-A × Arka Abha) to 35.15 % (Angha × Pusa-120) and from -16.28 (VRT-101-A × Arka Abha) to 29.01 % (Angha × Pusa-120) respectively. The number of crosses exhibiting significant average heterosis in the positive direction was recorded to be six out of 24 crosses. The cross Angha × Pusa-120 (35.15 %) enunciated maximum per cent of positive average heterosis for this trait followed by CTS-07 × Pusa-120 (22.43 %) and Angha × Pant T-5 (18.88 %). Similarly, the number of crosses exhibiting significant heterobeltiosis in the positive direction was recorded to be three out of 24 crosses in which the maximum percent was noted in cross Angha × Pusa-120 (29.01 %) followed by CTS-07 × Pusa-120 (19.09 %) and Solan Vajra × Pusa-120 (12.91 %). Earlier works by Kumar *et al*. (2013) observed positive significant heterosis over the better parent for ascorbic acid content in tomato. These findings were also similar to the investigation done by Bhatt *et al.* (2001) [6]; Kumari and Sharma (2011) [20]; Reddy *et al.* (2013) [24]; Soleiman *et al.* (2013) [33]; Yadav *et al*. (2013); and Amin *et al*. (2017) [4] in tomato.

The ultimate objective of any breeding programme is to achieve productivity maximization which is considered as the key factor that helps farmer in deciding whether to adopt or reject a variety or hybrid. Heterosis over mid parent and better parent for fruit yield was observed to be significant in both the direction. The mid parent heterosis for this character varied from -22.53 to 35.56 per cent in cross H-88-78-1 × Arka Abha and VRT-06 × Pusa-120 respectively whereas the better parent heterosis was found to be in the range of -31.69 (VRT-01 × Pant T-5) to 23.30 % (Solan Vajra × Arka Abha). For fruit yield (q/ha), relative heterosis calculated over the mid parental value indicated that highest significant fruit yield per plant was exhibited in cross VRT-06 × Pusa-120 (35.56 %) followed by Solan Vajra × Arka Abha (28.06 %) and CTS-07 × Pusa-120 (23.14 %) over mid parent. The cross combinations Solan Vajra × Arka Abha followed by CTS-07 × Arka Abha and VRT-101-A × Arka Abha expressed maximum per cent of positive significant heterosis over better parent to the extent of 23.30, 19.22 and 16.62 % respectively. Similar results in case of tomato were also reported by Bhatt *et al.* (2001) [6]; Ahmed *et al.* (2011); Agarwal *et al*. (2014) [1]; Chauhan *et al*. (2014); Dagade *et al.* (2015) [11]; Tamta and Singh (2018) [34]; Triveni *et al.* (2017); Kumar *et al.* (2018) [18]; and Salim *et al.* (2019) [27] for improved fruit yield.

From the present study, it was observed that many suitable hybrids were present exhibiting high hybrid vigour for different yield and quality parameters. Thus, this estimation of heterosis can be used to assess the hybrid vigor and selecting promising hybrids. Hybrids exhibiting highly significant heterosis in the desired direction for yield as well as quality parameters should be given focus for utilizing it in further evaluation and making it preferable for commercial cultivation.

Table 1: Estimation of heterosis (%) over mid parent and better parent for fruit length (cm), fruit width (cm) and number of seeds per fruit in tomato

Crosses	Fruit length (cm)		Fruit width (cm)		No. of seeds per fruit	
	MPH	BPH	MPH	BPH	MPH	BPH
CTS-07 x Arka Abha	-6.99 **	-14.16 **	-33.07 **	-35.77 **	-33.07 **	-35.77 **
CTS-07 x Pusa-120	-12.04 **	-16.43 **	-7.46 **	-16.60 **	-7.46 **	-16.60 **
CTS-07 x Pant T-5	2.41	-4.49	18.44 **	-9.32 **	18.44 **	-9.32 **
Angha x Arka Abha	-9.41 **	-14.28 **	-15.10 **	-23.69 **	-15.10 **	-23.69 **
Angha x Pusa-120	8.18 **	5.47 *	-3.24 *	-17.93 **	-3.24 *	-17.93 **
Angha x Pant T-5	-4.11	-8.27 **	12.13 **	-9.61 **	12.13 **	-9.61 **
Solan Vajra x Arka Abha	-0.65	-3.14	-4.43 **	-7.21 **	-4.43 **	-7.21 **
Solan Vajra x Pusa-120	-5.16 *	-10.25 **	-1.56	-10.30 **	-1.56	-10.30 **
Solan Vajra x Pant T-5	-11.89 **	-15.05 **	-21.52 **	-40.41 **	-21.52 **	-40.41 **
VRT-101 A x Arka Abha	-8.17 **	-11.36 **	-10.63 **	-21.85 **	-10.63 **	-21.85 **
VRT-101 A x Pusa-120	-7.08 **	-12.92 **	-4.09 **	-20.69 **	-4.09 **	-20.69 **
VRT-101 A x Pant T-5	8.65 **	3.73	17.60 **	-2.86	17.60 **	-2.86
VRT-01 x Arka Abha	-1.61	-8.52 **	-22.19 **	-32.52 **	-22.19 **	-32.52 **
VRT-01 x Pusa-120	-3.73	-12.99 **	8.77 **	0.14	8.77 **	0.14
VRT-01 x Pant T-5	2.66	-5.55 *	-19.48 **	-45.30 **	-19.48 **	-45.30 **
CO-3 x Arka Abha	-4.17	-22.72 **	-58.77 **	-68.56 **	-58.77 **	-68.56 **
CO-3 x Pusa-120	17.38 **	-7.51 **	-35.66 **	-53.09 **	-35.66 **	-53.09 **
CO-3 x Pant T-5	24.44 **	-0.51	-4.4	-7.73 *	-4.4	-7.73 *
VRT-06 x Arka Abha	6.75 **	5.16	-8.08 **	-24.41 **	-8.08 **	-24.41 **
VRT-06 x Pusa-120	-8.89 **	-12.92 **	-5.08 **	-25.82 **	-5.08 **	-25.82 **
VRT-06 x Pant T-5	-4.16	-6.65 *	47.98 **	30.02 **	47.98 **	30.02 **
H-88-78-1 x Arka Abha	-17.44 **	-28.70 **	-16.97 **	-42.71 **	-16.97 **	-42.71 **
H-88-78-1 x Pusa-120	-19.90 **	-32.58 **	-37.57 **	-58.43 **	-37.57 **	-58.43 **
H-88-78-1 x Pant T-5	-17.08 **	-29.07 **	-32.51 **	-39.99 **	-32.51 **	-39.99 **
S.E.Diff	0.11	0.12	1.46	1.68	1.46	1.68
CD 5 %	0.21	0.24	2.94	3.39	2.94	3.39
*Significant at p=0.05, **Significant at p=0.01						
MPH- Mid Parent Heterosis, BPH- Better Parent Heterosis						

Table 2: Estimation of heterosis (%) over mid parent and better parent for number of locules per fruit, pericarp thickness (mm) and total soluble solids (◦Brix) in tomato

Crosses	No. of locules/ fruit		Pericarp thickness (mm)		TSS (◦Brix)	
	MPH	MPH	MPH	BPH	MPH	BPH
CTS-07 x Arka Abha	5.79	5.79	-5.56 **	-6.26 **	-13.15 **	-21.39 **
CTS-07 x Pusa-120	-23.08**	-23.08**	4.71 **	2.41	8.00 **	-3.16
CTS-07 x Pant T-5	-7.46 *	-7.46 *	-20.61 **	-25.54 **	-11.89 **	-12.15 **
Angha x Arka Abha	-21.92**	-21.92**	4.12 *	-16.30 **	1.09	-10.59 **
Angha x Pusa-120	-3.23	-3.23	8.06 **	-12.15 **	19.17 **	4.44
Angha x Pant T-5	-28.30**	-28.30**	6.97 **	-9.96 **	25.31 **	21.77 **
Solan Vajra x Arka Abha	7.37	7.37	-9.81 **	-14.08 **	2.62	-0.96
Solan Vajra x Pusa-120	-7.69	-7.69	4.40 **	0.9	-6.63 **	-8.96 **
Solan Vajra x Pant T-5	-1.85	-1.85	26.83 **	25.69 **	11.06 **	-2.37
VRT-101 A x Arka Abha	63.04 **	63.04 **	-2.74 *	-2.77	5.42 *	5.02
VRT-101 A x Pusa-120	6.93	6.93	12.60 **	10.92 **	-13.05 **	-14.28 **
VRT-101 A x Pant T-5	-0.95	-0.95	-2.79	-8.20 **	11.34 **	1.39
VRT-01 x Arka Abha	6.67	6.67	-14.66 **	-19.98 **	0.36	-3.37
VRT-01 x Pusa-120	3.03	3.03	-3.45 **	-10.70 **	9.15 **	4.04
VRT-01 x Pant T-5	-0.97	-22.73**	-28.95 **	-36.82 **	15.76 **	8.84 **
CO-3 x Arka Abha	6.98	-13.21**	-6.98 **	-21.74 **	5.11 *	4.06
CO-3 x Pusa-120	-11.58 *	-32.26**	21.04 **	3.08	5.36 *	3.23
CO-3 x Pant T-5	-15.15**	-36.36**	27.94 **	13.08 **	16.55 **	6.74 *
VRT-06 x Arka Abha	-1.92	-3.77	12.88 **	6.25 **	-9.19 **	-10.32 **
VRT-06 x Pusa-120	16.81 **	6.45	22.52 **	16.97 **	7.34 **	4.92
VRT-06 x Pant T-5	-17.95**	-27.27**	35.89 **	35.39 **	18.56 **	8.82 **
H-88-78-1 x Arka Abha	30.69 **	24.53 **	31.24 **	4.46 **	-12.53 **	-26.07 **
H-88-78-1 x Pusa-120	-7.27	-17.74**	20.35 **	-3.14	20.13 **	0.67
H-88-78-1 x Pant T-5	-5.26	-18.18**	52.81 **	27.26 **	32.66 **	22.53 **
S.E.Diff	0.14	0.16	0.08	0.10	0.11	0.13
CD 5 %	0.28	0.33	0.17	0.19	0.23	0.27
*Significant at p=0.05, **Significant at p=0.01						
MPH- Mid Parent Heterosis, BPH- Better Parent Heterosis						

Table 3: Estimation of heterosis (%) over mid parent and better parent for ascorbic acid content (mg/100g of fruit) and fruit yield (q/ha) in tomato

Crosses	Ascorbic acid content (mg/100g of fruit)		Fruit yield (q/ha)	
	MPH	BPH	MPH	BPH
CTS-07 x Arka Abha	6.94	-3.06	22.18 **	19.22 **
CTS-07 x Pusa-120	22.43 **	19.09 **	23.14 **	15.09 **
CTS-07 x Pant T-5	10.57 *	1.69	-3.92 *	-13.07**
Angha x Arka Abha	13.20 *	0.85	-10.73**	-18.28**
Angha x Pusa-120	35.15 **	29.01 **	0.43	-4.12 **
Angha x Pant T-5	18.88 **	7.41	14.51 **	13.15 **
Solan Vajra x Arka Abha	-7.99	-13.22 *	28.06 **	23.30 **
Solan Vajra x Pusa-120	14.61 **	12.91 *	9.32 **	0.89
Solan Vajra x Pant T-5	-2.3	-6.46	9.09 **	-2.49
VRT-101 A x Arka Abha	-15.92 **	-16.28 **	19.87 **	16.62 **
VRT-101 A x Pusa-120	4.53	-3.17	-14.56**	-20.36**
VRT-101 A x Pant T-5	2.01	0	5.81 **	-4.52 **
VRT-01 x Arka Abha	11.59 *	8.1	18.26 **	11.80 **
VRT-01 x Pusa-120	6.41	2.02	22.63 **	11.21 **
VRT-01 x Pant T-5	-13.17 **	-14.57 **	-22.29**	-31.69**
CO-3 x Arka Abha	3.49	-6.25	-2.85	-12.04**
CO-3 x Pusa-120	9.44	6.36	17.26 **	2.06
CO-3 x Pant T-5	5.39	-3.15	6.53 **	-9.99 **
VRT-06 x Arka Abha	-6.81	-10.09	-2.93	-13.28**
VRT-06 x Pusa-120	8.66	4.59	35.56 **	16.50 **
VRT-06 x Pant T-5	-11.72 *	-13.50 *	-7.76 **	-23.01**
H-88-78-1 x Arka Abha	7.46	0.78	-22.53**	-25.98**
H-88-78-1 x Pusa-120	4.54	3.6	-13.09**	-20.38**
H-88-78-1 x Pant T-5	-3.35	-8	-16.52**	-25.91**
S.E.Diff	1.06	1.22	5.83	6.74
CD 5 %	2.13	2.45	11.74	13.56
*Significant at p=0.05, **Significant at p=0.01				
MPH- Mid Parent Heterosis, BPH- Better Parent Heterosis				

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