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

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Abstract
Heterosis breeding is used to improve yield quantity and quality of tomato because traditional methods cannot be used to achieve this goal. A half diallel design was used to estimate the magnitude of heterosis for yield and its yield attributing traits in tomato. Twenty one F_1 hybrids were generated by using seven local and exotic lines. These 21 F_1 hybrids along with 7 parents and one standard check 'Abhinav' were evaluated at Regional Horticultural Research Station, NAU, Navsari (Gujarat) in randomized block design with three replications. The analysis of variance showed significant differences among the genotypes for all the traits except days to last picking and plant height in parents and hybrids, respectively. The maximum heterosis over standard check was exhibited by the hybrids AVTO-2 x AT-4 followed by AVTO-3 x AVTO-4 for fruit yield and its one or more important yield attributing traits. Hence, these hybrids exhibited commercial potential to replace the check after further testing.

Keywords: Heterosis studies, yield, attributing traits, tomato (*Solanum lycopersicum* L.)

Introduction
Tomato (*Solanum lycopersicum* L., 2n=24), a fruit that is universally treated as a vegetable and a perennial plant, which is commonly cultivated as an annual (Rick, 1978), is a member of the family *Solanaceae*. It is one of the most important vegetable crop grown all over the world and believed to be originated from Andean region that includes the parts of Colombia, Ecuador, Peru, Bolivia and Chile. It is typically a day neutral plant and self-pollinated crop, but certain percentage of cross pollination also occurs.

Exploitation of hybrid vigor in tomato is economical and easy for hybrid seed production because each fruit contains more seed compared to other vegetables as well increased marketable fruit yield, component traits and resistance to biotic and abiotic stresses. Farmers are interested in growing hybrid varieties with high yield, early and prolonged harvest with good quality trait. Good hybrids are lacking. It is also important to develop a quick, convenient way of combining desirable characters in production of F_1 hybrids in tomato. However, commercial usefulness of a hybrid would depend on its performance compared to the best commercial variety available. Though several high-yielding varieties have been developed, the best potential can be achieved by developing hybrids with high yield, earliness, superior quality and resistance to diseases and pests. A wide range of variability in vegetative and fruit characters is available in genotypes. Choice of suitable parents and the method used is important to breeding for improvement of traits in tomato.

Increasing production per unit area by even a small degree is important because, due to ever-increasing demand for tomato, there is a need for development of genotypes with improved quality and yield. Exploring natural diversity as a sources of novel allels to improve productivity, quality and nutritional value of the crop is important in breeding (Fernie *et al*., 2006) [8]. Commercial exploitation of hybrid vigor in tomato is important because hybrids have several advantages over pure line varieties regarding yield and yield contributing traits. Tomato hybrid cultivars are used in commercial production because growers prefer to grow tomato hybrids, despite the relatively high price of seed to maximize net return on investment (Solieman *et al*., 2013) [28]. Hybrids usually have good quality characters and high yield.

Heterosis and hybrid vigor in tomato was first observed in tomato by Hedrick and Booth (1907) [10] for higher yield and more fruit. Choudhary (1965) [6] emphasized extensive utilization of heterosis to improve tomato production. Wellington (1912) [31] pointed out commercial possibilities of F_1 hybrid production in tomato. the term ''heterosis'' was coined by Shull

(1914). Heterosis in plants is a phenomenon manifesting itself in hybrids that are more vital and adaptive than their parents (Bai and Lindhout, 2007; Bhatt *et al*., 2001) [2, 5].
The success of any breeding program lies in the choice of appropriate parents and the breeding method. For exploitation of heterosis, choice of parents is important. Combining ability analysis facilitates partitioning of genotypic variation of crosses into variation due to general combining ability (main effects) and specific combining ability (interactious), which are measures of additive and non-additive gene actions, respectively. Information obtained from general combining ability of parents and specific combining ability of crosses helps in selection of suitable parents and related cross-combinatious. The experiment was carried out to estimate heterosis in tomato F_1 hybrids compared to parents and to identify the best F_1 hybrids.

Materials and methods

The study of heterosis in tomato was carried out at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, NAU, Navsari (Gujarat) during 2016-17. The study material comprised of seven lines AVTO-2, AVTO-3, AVTO-4, AVTO-7, AT-4, JTL-12-12 and JT-3, their 21 F_1 hybrids and standard check (Abhinav). The experiment was laid out in a randomized block design with three replications. Each of the 29 genotypes was accommodated at a spacing of 90 cm between the rows and 60 cm between the plants. Recommended cultural practices were followed to raise a good crop. Observations were recorded on five randomly selected plants of parents and F_1's for the characters *viz*., Days to 50 % flowering, Days to first picking, days to last picking, plant height at final harvest (cm), number of branches per plant at final harvest, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg), fruit polar diameter (cm), fruit equatorial diameter (cm), number of locules per fruit**,** TSS (°Brix), alcoholic insoluble solids (%), titrable acidity (%), fruit pH, ascorbic acid (mg/100g), reducing sugar (%), non reducing sugar (%), total sugar (%), lycopene content (mg/100g) and viscosity (cSt).

Results and discussion

The result from analysis of variance of parents and their hybrids for various characters revealed that mean squares due to genotypes were found to be significant for all the traits except days to last picking and plant height in parents and hybrids. This indicated that the selected material was appropriate for the study of manifestation of heterosis.
An examination of mean performance of parents (Table 1) for different traits revealed that among parents, AVTO-7 (2.52 kg) recorded higher fruit yield per plant with highest average fruit weight, ascorbic acid, reducing sugar and total sugar among all the parents. It also recorded minimum days for 50 % flowering and first picking. AVTO-2 registered highest for number of fruits per plant and also had high TSS and lycopene content. Parent AVTO-3 (108.21 cm) recorded highest plant height with high alcoholic insoluble solids, fruit pH and viscosity. Parents *viz*., AVTO-4 (5.79 cm) and JT-3 (5.15 cm) recorded highest polar and equatorial diameter, respectively while AT-4 recorded more number of branches per plant.
A perusal of mean performance of hybrids (Table 1) revealed that AVTO-2 x AT-4 recorded maximum fruit yield per plant and highest number of fruits per plant. AVTO-3 x AT-4 and AVTO-4 x JT-3 occupied first position for polar and equatorial diameter, respectively. Hybrid JTL-12-12 x JT-3 recorded highest fruit weight, while AT-4 x JT-3 recorded highest number of locules per fruit. Parent AVTO-7 x JT-3 stand first for plant height and number of primary branches per plant.
Heterosis is an expression of the superiority of hybrids over mean of parents compared to better parents or the standard check (Hayes *et. al*., 1956) [9] with respect to agriculturally useful traits. The primary objective of heterosis breeding is to achieve a significant increase in crop growth and yield. Number of fruits per plant, average fruit weight and fruit size together form the most important closely related productivity parameters in tomato.
A high magnitude of heterosis occurred in many crosses for all the characters in positive or negative directions. Positive and negative heterosis of F_1 for characters agrees with Kumar *et. al*. (2014) [4] and Dasi *et. al*., (2009) [7] who studied these in eggplant and chilli, other plants in the family Solanaceae, indicating that the response may be universal in this family.
In the present investigation, standard heterosis for fruit yield (Table 2) ranged from -31.38 % (AVTO-2 x JT-3) to 34.73 % (AVTO-2 x AT-4). The maximum standard heterosis recorded by a hybrids AVTO-2 x AT-4 (34.73 %) followed by AVTO-3 x AVTO-4 (21.44 %). It is interesting to note that top ranking hybrids based on *per se* performance and standard heterosis was same. Almost identical result have been reported by Kumar and Singh (2016) [4], Kumar *et al*. (2016) [4], Renuka and Sadashiva (2016) [4], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].
Top two hybrids, *viz*., AVTO-2 x AT-4 and AVTO-3 x AVTO-4 showed high order standard heterosis for number of fruits per plant, a major yield component. Almost identical results have been reported by Khan and Jindal (2016) [15], Kumar and Singh (2016) [4], Kumar *et al*. (2016) [4], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].
Early flowering is generally an indication of early yield. In case of 50 per cent flowering, none of the hybrid recorded significant standard heterosis in desirable direction. A similar result was reported by Josna Jose *et al*. (2016) [13], Khan and Jindal (2016) [15], Marbhal *et al*. (2016) [21], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].
With regard to days to first picking, none of the hybrids showed significant negative standard heterosis. Similar result was reported by Sankhla (2015) [25], Jadav *et al*. (2016) [11], Khan and Jindal (2016) [15], Kumar and Singh (2016) [4] and Krishna Patel (2017) [16]. None of the hybrids recorded significant positive standard heterosis for days to last picking. The similar results were reported by Kumari and Sharma (2011) [19], Jadav *et al.* (2016) [11] and Krishna Patel (2017) [16].
Heterosis for growth parameters is an indication of heterosis for yield because growth and yield parameters are strongly associated. The ideal plant type should have longer plant height and number of branches per plant was the major parameters which act as source trait to support yield and its components. The heterosis in positive direction for plant height is desirable. The magnitude of standard heterosis ranged from -6.33 % (AVTO-2 x AVTO-3) to 16.21 % (AVTO-7 x JT-3) for this trait. Hybrid AVTO-7 x JT-3 (16.21 %) recorded significant positive standard heterosis in desirable direction for plant height. This result revealed that plant height may be considered as a major yield component in tomato. Almost identical results have been reported by Jadav *et al.* (2016) [11], Josna Jose *et al*. (2016) [13], Khan and Jindal (2016) [15], Kumar *et al*. (2016) [4] and Krishna Patel (2017) [16].

Number of branches per plant is another important growth parameter contributing for productivity. The heterosis in positive direction for number of branches per plant is desired. The range of standard heterosis varied from -13.31 % (AT-4 x JT-3) to 20.40 % (AVTO-7 x JT-3). In relation to number of branches per plant, only one hybrid AVTO-7 x JT-3 (20.40 %) showed significant positive standard heterosis. Similar result was reported by Sankhla (2015) [25], Jadav *et al.* (2016) [11], Josna Jose *et al*. (2016) [13], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

Yield component greatly influenced by the expression of heterosis for number of fruit per plant, average fruit weight, average fruit polar diameter and average fruit equatorial diameter can greatly contributed towards for fruit yield per plant. Heterosis for yield was chiefly attributed to heterosis for number of fruits per plant (Singh *et al*. 1995). The heterotic effect is supported by genetic analysis that defined the presence of dominance and complementary gene action for yield in tomato (Kanthaswamy *et. al*. 1995). Standard heterosis varied from -24.85 % (AVTO-3 x JT-3) to 32.75 % (AVTO-2 x AT-4) for number of fruits per plant. The hybrids *viz*., AVTO-2 x AT-4 (32.75 %) and AVTO-3 x AVTO-4 (27.49 %) showed significant positive standard heterosis for number of fruits per plant. Similar result was reported by Khan and Jindal (2016) [15], Kumar and Singh (2016) [4], Kumar *et al*. (2016) [4], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

With respect to average fruit weight, standard heterosis were ranged from -30.19 % (AVTO-2 x JT-3) to 23.87 % (JTL-12-12 x JT-3). Two hybrids *viz*., JTL-12-12 x JT-3 (23.87 %) and AVTO-4 x JTL-12-12 (15.01 %) showed significant positive standard heterosis. These results were in agreement with those reported by several workers like Khan and Jindal (2016) [15], Kumar and Singh (2016) [4], Kumar *et al*. (2016) [4], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

Fruit polar diameter and fruit equatorial diameter are very closely related productivity parameters which determine consumer's acceptability. Hybrid AVTO-3 x AT-4 (16.60 %) hybrid showed significant positive standard heterosis in desirable direction for fruit polar diameter. Similar observations were reported by Bharathkumar *et al*. (2016) [4], Jadav *et al*. (2016) [11], Josna Jose *et al*. (2016) [13], Kumar and Singh (2016) [4] and Krishna Patel (2017) [16].

For fruit equatorial diameter, one hybrid AVTO-4 x JT-3 (15.31 %) showed significant positive standard heterosis. Similar result was reported by Jadav *et al.* (2016) [11], Jaiprakashnarayan *et al*. (2016), Josna Jose *et al*. (2016) [13], Kumar and Singh (2016) [4] and Krishna Patel (2017) [16].

Heterosis for marketable yield is more important and is determined by the total productivity and quality of the produce (Riggs, 1988). In tomato, quality parameters, *viz*., number of locules per fruit, total soluble solids, alcoholic insoluble solids, titrable acidity, fruit pH, ascorbic acid, reducing sugar, non reducing sugar, total sugar, lycopene content and viscosity determine the quality related to taste, flavor and utility for processing or fresh market.

With respect to number of locules per fruit, the hybrids *viz*., AT-4 x JT-3 (58.99 %), AVTO-3 x AVTO-4 (52.30 %), AVTO-7 x JT-3 (44.08 %), JTL-12-12 x JT-3 (37.61 %), AVTO-4 x AT-4 (37.06 %), AVTO-2 x AVTO-4 (34.32 %) and AT-4 x JTL-12-12 (30.15 %) showed positive significant standard heterosis. Similar result was reported by Vilas (2015), Bharathkumar *et al*. (2016) [4], Jadav *et al.* (2016) [11], Khan and Jindal (2016) [15] and Krishna Patel (2017) [16].

None of the hybrids showed significant positive standard heterosis for total soluble solids. Similar result has been reported by Jadav *et al.* (2016) [11], Josna Jose *et al*. (2016) [13], Khan and Jindal (2016) [15], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

In case of alcoholic insoluble solids, all the hybrids showed significant positive standard heterosis for this trait. The similar result was found by Jadav *et al.* (2016) [11] and Krishna Patel (2017) [16].

Four hybrids *viz.,* AVTO-3 x JTL-12-12 (37.56 %), AVTO-3 x AVTO-7 (33.50 %), AVTO-3 x AVTO-4 (30.96 %) and AVTO-2 x JT-3 (28.43 %) showed significant positive standard heterosis for titrable acidity. Similar, results was reported by Bhakti Panchal (2015), Vilas (2015), Jadav *et al.* (2016), Savale *et al*. (2017) [26] and Krishna Patel (2017) [16].

For fruit pH, hybrids *viz*., AVTO-3 x JTL-12-12 (9.95 %), AVTO-7 x JTL-12-12 (9.78 %) and AVTO-4 x JT-3 (7.96 %) exhibited significant positive standard heterosis. Similar result was reported by Virupannavar *et al*. (2010), Angadi and Dharmatti (2012), Sankhla (2015) [25], Jadav *et al.* (2016) and Krishna Patel (2017) [16].

In relation to ascorbic acid, none of the hybrid showed significant negative standard heterosis for this trait. Similar result was reported by Vilas (2015), Bharathkumar *et al*. (2016) [4], Jadav *et al.* (2016), Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

With respect to reducing sugar, twenty hybrids showed highly significant negative standard heterosis for this trait. Similar result was reported by Jadav *et al.* (2016) [11], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

Out of twenty one hybrids, AVTO-3 x JTL-12-12 (160.41 %), AVTO-3 x AVTO-7 (148.57 %), AVTO-7 x JTL-12-12 (126.94 %), AVTO-2 x AT-4 (88.16 %), AVTO-7 x JT-3 (72.65 %), AVTO-2 x AVTO-4 (70.61 %) and AVTO-2 x JTL-12-12 (69.80 %) showed significant positive standard heterosis for non-reducing sugar. This result is in harmony with Jadav *et al.* (2016) [11], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

For total sugar, AVTO-7 x JTL-12-12 (11.27 %) showed positive significant standard heterosis. Similar result was reported by Jadav *et al.* (2016) [11], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

With respect to lycopene content, hybrids *viz*., AVTO-4 x AT-4 (28.51 %), AVTO-4 x AVTO-7 (21.38 %), AVTO-2 x JTL-12-12 (17.32 %), AVTO-3 x AT-4 (15.04 %) and AVTO-3 x AVTO-4 (9.62 %) showed significant positive heterosis. Similar result was reported by Bharathkumar *et al*. (2016) [4], Jadav *et al.* (2016) [11], Khan and Jindal (2016) [15], Krishna Patel (2017) [16] and Savale *et al*. (2017) [26].

In case of viscosity, hybrids *viz*., AVTO-4 x AVTO-7 (26.29 %), AT-4 x JT-3 (24.63 %), AT-4 x JTL-12-12 (23.30 %), AVTO-2 x AT-4 (22.20 %) and AVTO-2 x AVTO-7 (12.43 %) showed significant positive heterosis. Similar result was reported by Jadav *et al.* (2016) [11] and Krishna Patel (2017) [16].

Table 1: Mean performance of parents, their hybrids and standard check for different traits in tomato

Parents	Days to 50 % flowering	Days to first picking	Days to last picking	Plant height (cm)	Number of branches per plant	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (kg)	Fruit polar diameter (cm)	Fruit equatorial diameter (cm)
AVTO-2	36.97	99.79	150.85	105.89	12.40	40.70	54.65	2.23	2.94	2.97
AVTO-3	38.59	102.29	143.66	108.21	10.23	30.00	79.79	2.39	4.53	4.56
AVTO-4	36.76	93.31	155.64	106.79	11.57	32.33	72.81	2.35	5.79	5.06
AVTO-7	34.68	92.68	144.66	99.00	10.93	30.73	81.84	2.52	3.79	4.38
AT-4	36.41	93.48	147.34	107.10	12.77	29.80	54.21	1.61	5.06	4.32
JTL-12-12	40.42	102.08	148.62	92.32	11.20	31.70	74.62	2.36	5.26	4.39
JT-3	43.07	104.25	145.84	85.21	10.17	29.07	51.48	1.50	4.28	5.15
Hybrids										
AVTO-2 x AVTO-3	29.79	92.13	143.43	90.18	10.87	34.80	83.36	2.90	4.75	4.72
AVTO-2 x AVTO-4	35.70	95.03	159.94	95.06	12.33	37.33	65.75	2.46	4.17	3.76
AVTO-2 x AVTO-7	31.27	91.60	147.28	92.55	11.13	34.03	70.97	2.42	4.13	4.83
AVTO-2 x AT-4	30.37	87.71	153.23	96.29	13.20	45.40	82.34	3.75	4.83	4.55
AVTO-2 x JTL-12-12	32.71	86.04	148.36	92.53	10.97	33.70	76.52	2.57	5.21	3.93
AVTO-2 x JT-3	33.60	94.60	159.22	95.39	10.73	33.67	56.96	1.91	4.33	4.72
AVTO-3 x AVTO-4	29.63	89.96	155.02	102.83	13.07	43.60	77.82	3.38	4.37	3.94
AVTO-3 x AVTO-7	37.05	95.38	150.12	92.77	11.17	33.37	60.24	2.00	4.41	3.92
AVTO-3 x AT-4	29.82	102.49	155.09	101.79	12.73	38.97	84.56	3.29	5.76	4.71
AVTO-3 x JTL-12-12	35.34	93.71	158.34	95.97	10.43	27.60	74.95	2.07	4.92	4.40
AVTO-3 x JT-3	36.12	87.83	148.72	93.73	10.70	25.70	76.37	1.96	5.09	4.92
AVTO-4 x AVTO-7	30.28	86.95	159.56	105.68	10.27	33.07	86.90	2.87	5.23	4.78
AVTO-4 x AT-4	34.61	95.61	151.69	98.81	12.10	36.13	81.91	2.95	4.71	4.49
AVTO-4 x JTL-12-12	29.46	89.46	148.72	95.34	11.27	33.60	93.83	3.15	5.23	4.97
AVTO-4 x JT-3	37.69	97.02	146.54	97.31	12.93	34.37	75.22	2.57	4.64	5.35
AVTO-7 x AT-4	30.44	89.77	145.49	106.97	11.60	31.93	79.77	2.54	3.62	3.77
AVTO-7 x JTL-12-12	37.59	88.75	147.20	104.45	12.20	35.57	80.34	2.86	5.10	4.87
AVTO-7 x JT-3	34.68	96.68	148.72	111.89	14.17	34.73	89.77	3.11	4.32	4.76
AT-4 x JTL-12-12	30.65	85.32	140.58	100.18	11.87	33.63	79.90	2.68	4.38	4.29
AT-4 x JT-3	32.78	94.45	148.74	93.56	10.20	35.47	71.53	2.53	4.85	4.82
JTL-12-12 x JT-3	40.61	99.61	147.57	103.63	12.23	31.63	101.06	3.20	4.98	5.16
Standard check										
Abhinav	30.88	90.25	148.79	96.28	11.77	34.20	81.58	2.78	4.94	4.64

Table 2: Mean performance of parents, their hybrids and standard check for different traits in tomato.

Parents	Number of locules per fruit	TSS (°Brix)	Alcoholic insoluble solids (%)	Titrable acidity (%)	Fruit pH	Ascorbic acid (mg/100g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Lycopene content (mg/100g)	Viscosity (cSt)
AVTO-2	3.09	4.92	1.12	0.89	3.20	23.69	3.19	1.13	4.32	4.68	157.90
AVTO-3	3.66	3.67	1.37	0.61	4.31	25.01	3.01	1.17	4.18	2.55	257.08
AVTO-4	4.63	3.71	1.26	0.48	3.16	23.23	4.14	0.73	4.86	3.25	104.36
AVTO-7	4.09	4.13	1.17	0.44	3.72	26.99	4.58	1.30	5.88	3.93	178.13
AT-4	3.64	3.96	1.05	1.03	4.20	20.07	4.26	0.30	4.56	3.51	107.26
JTL-12-12	3.58	3.45	1.30	0.62	4.17	26.06	4.32	0.86	5.18	4.04	152.57
JT-3	3.43	3.24	1.07	0.56	3.16	23.71	3.35	1.68	5.03	2.79	94.70
Hybrids											
AVTO-2 x AVTO-3	2.80	4.25	1.19	0.59	3.86	27.99	3.17	1.24	4.41	2.27	112.71
AVTO-2 x AVTO-4	4.08	4.65	1.25	0.83	3.03	32.84	3.11	1.39	4.51	2.93	110.47
AVTO-2 x AVTO-7	3.22	4.86	1.20	0.72	3.89	29.49	3.80	1.07	4.87	2.16	237.63
AVTO-2 x AT-4	2.67	4.85	1.15	0.70	3.87	33.92	4.08	1.54	5.61	4.60	258.30
AVTO-2 x JTL-12-12	3.31	4.61	1.18	0.80	3.13	28.69	4.16	1.39	5.54	5.49	136.53
AVTO-2 x JT-3	3.48	4.91	1.40	0.84	3.43	29.63	3.20	0.73	3.93	3.37	146.61
AVTO-3 x AVTO-4	4.63	4.54	1.13	0.86	3.76	26.03	2.23	1.11	3.34	5.13	113.80
AVTO-3 x AVTO-7	3.52	3.93	1.15	0.88	3.92	33.12	3.23	2.03	5.26	3.50	118.81
AVTO-3 x AT-4	3.19	4.55	1.17	0.65	3.84	31.44	3.34	1.01	4.35	5.38	138.11
AVTO-3 x JTL-12-12	2.77	3.63	1.23	0.90	4.24	27.87	3.48	2.13	5.61	3.59	150.23
AVTO-3 x JT-3	3.22	4.62	1.37	0.73	4.11	33.46	3.14	1.27	4.41	2.73	213.73
AVTO-4 x AVTO-7	3.44	4.69	1.40	0.58	3.50	24.51	4.01	1.10	5.11	5.68	266.94
AVTO-4 x AT-4	4.17	4.57	1.22	0.71	2.81	27.31	4.15	1.01	5.13	6.01	177.66
AVTO-4 x JTL-12-12	2.81	3.81	1.44	0.57	3.66	29.98	2.92	0.97	3.89	4.79	201.13
AVTO-4 x JT-3	3.67	4.35	1.21	0.56	4.16	30.52	4.63	1.32	5.95	3.90	155.82
AVTO-7 x AT-4	3.52	4.52	1.19	0.63	2.96	31.64	3.04	1.12	4.15	4.60	146.99
AVTO-7 x JTL-12-12	3.02	4.76	1.36	0.69	4.23	28.42	4.20	1.85	6.05	4.03	165.58
AVTO-7 x JT-3	4.38	4.47	1.35	0.54	3.70	27.34	3.22	1.41	4.63	4.95	178.91
AT-4 x JTL-12-12	3.96	4.56	1.45	0.71	4.03	30.87	2.85	1.13	3.99	3.66	260.63
AT-4 x JT-3	4.83	2.63	1.26	0.52	3.96	28.03	3.51	1.18	4.69	2.84	263.42
JTL-12-12 x JT-3	4.18	3.98	1.36	0.70	3.68	29.06	4.18	1.51	5.69	4.61	98.10
Standard check											
Abhinav	3.04	4.64	1.38	0.66	3.85	30.41	4.62	0.82	5.44	4.68	211.37

Table 2: Magnitude of standard heterosis for different traits in tomato.

Hybrids	Days to 50 % flowering	Days to first picking	Days to last picking	Plant height (cm)	Number of branches per plant	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (kg)	Fruit polar diameter (cm)	Fruit equatorial diameter (cm)	Number of locules per fruit
AVTO-2 x AVTO-3	-3.52	2.08	-3.60	-6.33	-7.65	1.75	2.18	4.19	-3.91	1.87	-8.00
AVTO-2 x AVTO-4	15.60*	5.30	7.49	-1.27	4.82	9.16	-19.41**	-11.62	-15.52*	-18.98*	34.32*
AVTO-2 x AVTO-7	1.26	1.50	-1.01	-3.87	-5.38	-0.49	-13.01*	-13.17	-16.46*	4.24	6.03
AVTO-2 x AT-4	-1.64	-2.82	2.98	0.01	12.18	32.75**	0.93	34.73**	-2.29	-1.94	-12.28
AVTO-2 x JTL-12-12	5.92	-4.66	-0.29	-3.89	-6.80	-1.46	-6.21	-7.66	5.40	-15.31*	8.88
AVTO-2 x JT-3	8.82	4.82	7.01	-0.92	-8.78	-1.56	-30.19**	-31.38**	-12.42	1.87	14.47
AVTO-3 x AVTO-4	-4.05	-0.32	4.19	6.80	11.05	27.49**	-4.61	21.44*	-11.54	-14.95*	52.30**
AVTO-3 x AVTO-7	19.98*	5.69	0.90	-3.65	-5.10	-2.44	-26.16**	-28.02*	-10.80	-15.53*	15.79
AVTO-3 x AT-4	-3.43	13.56**	4.23	5.72	8.22	13.94	3.65	18.20	16.60*	1.58	4.93
AVTO-3 x JTL-12-12	14.44	3.84	6.42	-0.32	-11.33	-19.30*	-8.13	-25.51*	-0.40	-5.18	-8.88
AVTO-3 x JT-3	16.98*	-2.68	-0.05	-2.65	-9.07	-24.85**	-6.39	-29.58**	3.10	6.18	5.92
AVTO-4 x AVTO-7	-1.93	-3.66	7.24	9.76	-12.75*	-3.31	6.51	2.99	5.80	3.09	13.05
AVTO-4 x AT-4	12.07	5.94	1.95	2.63	2.83	5.65	0.40	6.11	-4.72	-3.16	37.06**
AVTO-4 x JTL-12-12	-4.61	-0.88	-0.05	-0.98	-4.25	-1.75	15.01*	13.05	5.80	7.26	-7.68
AVTO-4 x JT-3	22.04**	7.50*	-1.51	1.07	9.92	0.49	-7.80	-7.66	-6.14	15.31*	20.72
AVTO-7 x AT-4	-1.42	-0.53	-2.22	11.11	-1.42	-6.63	-2.22	-8.62	-26.65**	-18.69*	15.79
AVTO-7 x JTL-12-12	21.73**	-1.67	-1.07	8.48	3.68	4.00	-1.52	2.87	3.24	5.03	-0.55
AVTO-7 x JT-3	12.29	7.12*	-0.05	16.21*	20.40**	1.56	10.03	11.74	-12.48	2.59	44.08**
AT-4 x JTL-12-12	-0.74	-5.47	-5.52	4.05	0.85	-1.66	-2.06	-3.59	-11.27	-7.48	30.15*
AT-4 x JT-3	6.16	4.65	-0.04	-2.83	-13.31*	3.70	-12.32	-8.98	-1.82	4.03	58.99**
JTL-12-12 x JT-3	31.52**	10.37**	-0.82	7.64	3.97	-7.50	23.87**	15.09	0.74	11.21	37.61**
S. Ed. (±)	2.24	2.98	5.68	6.64	0.71	2.51	5.23	0.30	0.38	0.33	0.42
C.D. @ 5%	4.49	5.98	11.38	13.31	1.43	5.02	10.49	0.59	0.76	0.67	0.83
C.D. @ 1%	5.98	7.96	15.15	17.72	1.91	6.69	13.97	0.79	1.01	0.89	1.11

References

1. Angadi A, Dharmatti PR. Heterosis for processing quality traits in tomato (*Solanum lycopersicum* L.). Res. J Agric. Sci. 2012; 3(5):1028-1230.
2. Bai Y, Lindhout P. Domestication and breeding of tomatoes: what have we gained and what can we gain in the future! Ann. Bot. 2007; 100:1085-1094.
3. Bhakti Panchal. Genetic studies for productivity and its related traits in tomato (*Solanum lycopersicum* L.). M.Sc. Thesis submitted to Navsari Agricultural University, Navsari, 2015.
4. Bharathkumar MV, Sadashiva AT, Kumar S, Thontadarya RN. Heterosis for fruit quality parameters in tomato (*Solanum lycopersicum* L.). Indian Ecological Soc: International Conference, 2016, 319-320.
5. Bhatt RP, Biswas VR, Kumar N. Heterosis, combining ability and genetics for vitamin C, TSS and yield in tomato at 1700 m altitude. J Agr. Sci. 2001; 137:71-75.
6. Choudhary B. Vegetables. National Book Trust of India, New Delhi, 1965.
7. Dasi S, Mandal B, Hazra P. Study of Brinjal (*Solanum melongena* L.) for yield attributing traits. J Crop Weed. 2009; 5:25-30.
8. Fernie AR, Tadmor Y, Zamir D. Natural genetic variation for improving crop quality. Cur. Opin. Pl. Biotechnol. 2006; 9:196-202.
9. Hayes HK, Immer IR, Smith DC. Methods of plant breeding. McGraw Hill, New York, 1956.
10. Hedrick UP, Booth N. Mendelian characters in tomato. Proc. Amer. Soc. Hort. Sci. 1907; 5:19-23.
11. Jadav NK, Patel SY, Malviya AV, Chaudhari AA, Chaudhari BB. Heterosis study for yield, quality and its component traits of tomato (*Solanum lycopersicum* L.). Advances Life Sci. 2016; 5(18):7246-7271.
12. Jaiprakashnarayan RP, Mallesh SB, Patil MG, Kushal. Development of F_1 hybrids resistance to bacterial wilt incidence in tomato (*Solanum lycopersicum* L.). Ele. J Pl. Br. 2016; 7(4):911-918.
13. Josna Jose, Patel AI, Patel HB. Heterosis studies for yield and yield attributing traits in tomato (*Solanum lycopersicum* L.). Advances Life Sci. 2016; 5(3):908-913.
14. Kanthaswamy V, Koder MM, Thamburaj S. A study of generation means analysis in tomato. South Indian Hort. 1995; 43:25-29.
15. Khan A, Jindal SK. Exploiting yield potential in tomato (*Solanum lycopersicum* L.) through heterosis breeding. Pl. Gene & Trait. 2016; 7(8):1-7.
16. Krishna Patel. Study of heterosis, combining ability and stability for yield and quality traits in tomato (*Solanum lycopersicum* L.). Ph.D. Thesis submitted to Navsari Agricultural University, Navsari, 2017.
17. Kumar C, Singh SP. Heterosis and inbreeding depression to identify superior F_1 hybrids in tomato (*Solanum lycopersicum* L.) for the yield and its contributing traits. J Appl. & Nat. Sci. 2016; 8(1):290-296.
18. Kumar RL, Sridevi O, Kage V, Solimath PM, Madalageri D, Natikar P. Heterosis studies in chilli (*Capsicum annum* L.). Intl. J Hort. 2014; 4:40-43.
19. Kumari S, Sharma M. Exploitation of heterosis for yield and its contributing traits in tomato, *Solanum lycopersicum* L. Int. J Farm Sci. 2011; 1(2):45-55.
20. Kumar P, Paliwal A, Pant SC, Bahuguna P, Abrol G. Heterosis studies in tomato (*Lycopersicon esculentum* Mill.) for yield and yield attributing traits for further implications in crop improvement. J Bio. Innov 2016; 5(6):959-972.
21. Marbhal SK, Ranpise SA, Kshirsagar DB. Heterosis study in cherry tomato for quantitative traits. Int. Res. J Multi. Studies. 2016; 2(2):1-4.
22. Renuka DM, Sadashiva AT. Heterosis for growth, yield and quality traits in cherry tomato (*Solanum

lycopersicum var. *cerasiforme*). Pl. Archives, 2016; 16(2):654-658.
23. Rick CM. The tomato. Scientific American, 1978; 239:76-87.
24. Riggs TJ. Breeding F_1 hybrid varieties of vegetables. J Hort. Sci. 1988; 63:369-382.
25. Sankhla PM. Heterosis and combining ability analysis for productivity and its related traits in tomato. M.Sc. Thesis submitted to Navsari Agricultural University, Navsari, 2015.
26. Savale SV, Patel AI, Sante PR. Study of heterosis over environments in tomato (*Solanum lycopersicum* L.). Int. J Chem. Stu. 2017; 5(3):284-289.
27. Shull GH. Duplicate genes for capsule form in Bursa bursa pastoris. Zeitscher. Induct. Abstamm. U. Verebungsl. 1914; 12:97-149.
28. Solieman THI, El-Gabry MAH, Abido AI. Heterosis for yield and quality characters in tomato. Crop res. 2013; 29:285-287.
29. Vilas CA. Studies on heterosis and combining ability in tomato (*Solanum lycopersicum* L.). Ph.D. Thesis submitted to Haryana Agricultural University, Hisar, 2015.
30. Virupannavar H, Dharmatti PR, Kumar KH, Y Sogalad, A. Estimation of heterosis for bacterial wilt resistance in tomato. Asian J Hort. 2010; 5(1):40-43.
31. Wellington R. Influence of crossing in increasing the yield of tomato. Bull. N. Y. Ag, 1912.