Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(6): 270-275
Received: 13-09-2020
Accepted: 22-10-2020

Santosh Kumari
Department of Vegetable Science, College of Horticulture & Forestry, Neri, Hamirpur (Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh, India

Arushi Khanna
Agriculture Finance Officer, Central Bank of India, Gurgaon, Haryana, India

BS Dogra
Department of Vegetable Science, College of Horticulture & Forestry, Neri, Hamirpur (Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh, India

Corresponding Author:
Santosh Kumari
Department of Vegetable Science, College of Horticulture & Forestry, Neri, Hamirpur (Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh, India

Heterotic expression for yield and its components in tomato (*Solanum lycopersiucm* L.)

Santosh Kumari, Arushi Khanna and BS Dogra

Abstract
Tomato is member of nightshade family, fruits are consumed as a vegetable and is beneficial to human health. Heterosis breeding is a tool used for improvement in tomato and developing good quality, uniform, high yielding hybrids having resistance/tolerance to disease and insect pest. It reduces the risk of heart diseases and cancer. Five diverse tomato genotypes were crossed in a diallel fashion (excluding reciprocals) during 2015-16 and in the next year i.e. 2016-17, ten crosses along with five parents and one standard check (Naveen 2000+) were evaluated in Randomized Complete Block Design with three replications. Analysis of variance depicted remarkable differences for different characters studied. Results revealed that maximum fruits per plant were recorded in the genotype Solan Lalima (26.81) followed by BT Best (24.67) and BT-10-12 (21.93) and among cross combinations, maximum numbers for the trait were recorded in Solan Lalima x BT Best (31.43) followed by Solan Lalima x BT-10-12 (22.86) and UHF-519 x EC-2798 (26.73). Solan Lalima x BT Best (17.22 %), UHF-519 x EC-2798 (10.16 %) and UHF-519 x BT-10-12 (4.21 %) were found best heterotic cross combinations over better parent. Highest average fruit weight was recorded in parent UHF-519 (74.17 g) followed by EC-2798 (73.07 g) and Solan Lalima (68.67 g) and six cross combinations showed significant heterosis over the better parent among which BT-10-12 x BT Best (17.32 %) showed the highest heterosis followed by UHF-519 x EC-2798 (12.27 %) and UHF-519 x BT Best (8.76 %). UHF-519 x EC-2798 (4.74 %) and UHF-519 x BT Best (1.47 %) showed significant positive heterosis over standard check. Maximum yield (kg/plant) was recorded in the genotypes Solan Lalima (1.64 kg), EC-2798 (1.57 kg) and BT Best (1.39 kg) and among cross combinations, UHF-519 x EC-2798 (2.03 kg) recorded maximum yield followed by Solan Lalima x BT Best (1.89 kg) and Solan Lalima x BT-10-12 (1.87 kg). Six cross combinations revealed highest positive heterobeltiosis being maximum in UHF-519 x EC-2798 (28.78 %). Cross combinations viz., UHF-519 x EC-2798 (15.77 %), Solan Lalima x BT Best (7.99 %), Solan Lalima x BT-10-12 (7.02 %) and Solan Lalima x EC-2798 (6.39 %) exhibited significant positive heterosis over standard check.

Keywords: Heterosis, tomato, fruit yield and fruit weight

Introduction
Tomato is one of the most important commercial vegetable crop grown throughout the world, ranking second in importance after potato. It belongs to family Solanaceae. It is a self-pollinated crop and diploid chromosome number is 24. The crop is native to Peru, Ecuador, Bolivia, region of Andes and South America. It is a day neutral plant grown in warm season, tolerant to heat and draught stress. Tomato is mainly consumed as salad, cooked or processed into a variety of products such as ketchup, soup, powder, juice, paste and puree. It is good source of lycopene, β – carotene, vitamin A, vitamin C and minerals like calcium, phosphorus and iron. It is grown as the spring summer and autumn winter crop in many parts of the country. Mid-hills of the state supplies fresh tomatoes to the Northern markets of country during rainy and autumn seasons. As tomato is a self-pollinating crop, further comparative ease in emasculation, high percentage of fruit setting and good number of seeds per fruit also facilitates exploitation of heterosis in tomato on large scale. Though both the productivity and production potential of tomato due to growing of F_1 hybrid have improved, still there is a scope to increase this and bring to the level of agriculturally advanced countries. Several new cultivars have been developed over years to meet the diverse needs and varied situations and climates under which tomato is grown. With the passage of time, already existing varieties have become susceptible to many biotic and abiotic stresses and the quality of seeds and their availability sometimes is not assured. Therefore, to meet the ever-increasing demand for this vegetable in fresh market and processing industries, it is imperative to develop such hybrids having a complex of valuable attributes *viz.*, earliness, uniformity, good quality, high yield, resistance to diseases and adaptability to wider environment conditions. Heterosis breeding is a tool for the genetic improvement in tomato and for exploiting hybrid vigour. Basically for development of F_1 hybrids, the selection of parents to be involved in crosses is of paramount

importance. Many biometrical procedures have been developed to obtain information on combining ability. Diallel crossing technique is one among them which is widely used to work out combining ability of parents and cross in hybrid production. Diallel sets of F1 crosses between collections of tomato lines are usually used for obtaining a preliminary impression of the genetic variation for characters of economic importance.

Materials and Methods

The Experimental Farm of the Department of Vegetable Science is situated at altitude of 1270 meters from sea level, lying between latitude of 30.51 º N and longitude of 77.11 º E. The experimental area falls under the mid hills of the state. The climate of Experimental Farm is generally characterized as sub humid, sub-temperate with cool winters. December and January were the coldest months, while April and May were the hottest. The soil structure of the experimental farm is loam to clay loam with pH ranging from 6.8-7.0. Five diverse purelines of tomato viz. Solan Lalima, UHF-519, EC-2798, BT-10-12 and BT Best were selected on the basis of fruit shape, size and colour and were crossed in a diallel fashion (excluding reciprocals) to obtain ten cross combinations. The seedlings were transplanted in April 2016 to attempt crosses and to generate F_1's. The seeds of crosses were harvested during 2016. F_1 seeds along with the parents and check were planted in kharif 2017 for evaluation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The seedlings were raised in February 2017 and were transplanted in March 2017 in a plot size of 2.7 m X 1.8 m at spacing 90 cm X 30 cm accommodating eighteen plants. The standard cultural practices recommended in the Package of Practices of Vegetable Crops were followed for a healthy crop stand. Besides the application of Farm Yard Manure @ 20 t/ha, chemical fertilizers were applied as per the recommendation of package of practice *i.e* 100 kg N, 75 kg P_2O_5 and 50 kg K_2O/ha. One third dose of N and full doses of P_2O_5 and K_2O were applied at the time of field preparations. Remaining two-third dose of N was top dressed in equal amounts after 30 and 45 days of transplanting. Other intercultural operations were carried out as per the package of practice. Data was recorded for characters viz., plant height, 50% flowering, marketable maturity, fruit weight ,fruit per cluster, fruits per plant, locules per fruit, fruit yield (per plant) and per ha, fruit shape index, pericarp thickness, harvest duration and TSS.

Results and Discussion

Analysis of variance conducted, showed significant dissimilarities between different parents as well as cross combinations. The mean performance of five parents along with ten F_1s have been given out in Table 1 and the magnitude of heterosis have been presented character wise in Table 2. Number of days to 50 percent flowering is an important horticultural trait, as it helps to determine the maturity of the crop, the hybrids which are early are preferred over pure line varieties of tomato. Among parents, minimum days to 50 % flowering were recorded by BT-10-12 (36.00 days) and maximum were recorded in BT Best (38.67 days). Among cross combinations, the minimum days to 50 % flowering were recorded in Solan Lalima x EC-2798 (34.67 days), which was statistically at par with UHF-519 x BT-10-12 (35.00 days), UHF-519 x EC-2798 (35.67 days) and UHF-519 x BT Best (35.67 days). Cross combinations Solan Lalima x EC-2798 (-7.10 %), UHF-519 x BT Best (-6.96 %) and UHF-519 x EC-2798 (-4.46 %) showed significant negative heterosis over better parent. Heterosis over standard check ranged from -7.96 % (Solan Lalima x EC-2798) to 4.42 % (Solan Lalima x BT Best). Among ten cross combinations, seven crosses showed significant negative heterosis over standard check Naveen 2000+. Significant negative heterosis over better parent was reported by (Sekhar *et al.,* 2010) [25], (Islam *et al.,* 2012) [13], (Chattopadhaya and Paul 2012) [5], (Patwary *et al.*, 2013) [20] and (Dagade *et al.*, 2015) [7] for days to 50 % flowering. Among parents, minimum days to marketable maturity were recorded in BT-10-12 (72.67 days) which was statistically at par with EC-2798 (73.33 days). Among cross combinations, minimum days to marketable maturity were recorded in Solan Lalima x EC-2798 (68.67 days) which was statistically at par with UHF-519 x EC-2798 (69.00 days). Among cross combinations, heterobeltiosis ranged from -6.40 % (Solan Lalima x EC-2798) to 6.31 % (Solan Lalima x BT Best). Solan Lalima x EC-2798 (-6.40 %), UHF-519 x BT Best (-6.19 %), UHF-519 x EC-2798 (-5.91 %) and UHF-519 x BT-10-12 (-4.12 %) showed significant negative heterosis over better parent. Heterosis over standard check ranged from -6.36 % (Solan Lalima x EC-2798) to 7.27 % (Solan Lalima x BT Best). Negative heterosis for marketable maturity over better parent and standard check has been reported by (Hannan *et al.*, 2007) [11], (Sharma and Thakur, 2008) [26], (Chauhan *et al*., 2014) [6] and (Kumar and Singh, 2016) [14]. Negative heterosis over better parent for the trait has also been noted by (Rehana *et al*., 2019) [24]. Maximum plant height was recorded in EC-2798 (135.00 cm), whereas minimum in BT Best (123.00 cm) among the parental lines. Among cross combinations, maximum plant height was recorded in BT-10-12 x BT Best (142.40 cm), while minimum in EC-2798 X BT-10-12 (101.70 cm). Heterosis over better parent ranged from -24.67 % (EC-2798 x BT-10-12) to 7.88 % (BT-10-12 x BT Best). Four cross combinations *viz*., BT-10-12 x BT Best (7.88 %), Solan Lalima x BT Best (6.80 %), Solan Lalima x UHF-519 (2.85 %) and UHF-519 x BT Best (2.40 %) exhibited significant positive heterosis over better parent. Heterosis over standard check ranged from -17.98 % (EC-2798 x BT-10-12) to 14.84 % (BT-10-12 x BT Best). Six cross combinations showed significant positive heterosis over standard check Naveen 2000+. Similar results over better parent for plant height has also been reported by (Baishya *et al.,* 2001) [4], (Sharma and Thakur, 2008) [26], (Kumari *et al.*, 2010) [17], (Sekhar *et al.,* 2010) [25], (Singh *et al.,* 2012) [27], (Hussein, 2014) [12], (Kumar *et al.*, 2016) [15] and (Rehana *et al.*, 2019) [24]. Mean fruits per cluster among parents were found maximum in BT-10-12 (4.88) while minimum in UHF-519 (3.90). Among cross combinations, maximum fruits per cluster were recorded in Solan Lalima x BT Best (5.80) and was statistically at par with Solan Lalima x EC-2798 (5.48) and EC-2798 x BT Best (5.50) and minimum in UHF-519 x EC-2798 (4.34) and EC-2798 x BT-10-12 (4.34). Heterosis over better parent ranged from -11.13 % (EC-2798 x BT-10-12) to 21.00 % (Solan Lalima x BT Best), whereas over standard check Naveen 2000+ ranged from -11.43 % (UHF-519 x EC-2798 and EC-2798 x BT-10-12) to 18.37 % (Solan Lalima x BT Best). Cross combinations Solan Lalima x BT Best (21.00 %, 18.37 %), EC-2798 x BT Best (16.03 %, 12.24 %), Solan Lalima x EC-2798 (14.39 %, 11.90 %), Solan Lalima x BT-10-12 (11.40 %, 11.02 %) and UHF-519 x BT-10-12 (10.38 %, 10.00 %) revealed significant positive heterosis over better parent and standard check respectively. (Rao *et al.,* 2007) [23], (Sharma and Thakur, 2008) [26], (Gul *et*

al., 2010) [9], (Singh *et al.*, 2012) [27], (Patwary *et al.*, 2013) [20], (Hussein, 2014) [12], (Chauhan *et al.*, 2014) [6], (Kumar *et al.*, 2016) [16] and (Rehana *et al*., 2019) [24] revealed significant positive heterosis over better parent for fruits per cluster in tomato. Data recorded on fruits per plant revealed that among parents, maximum numbers were recorded in Solan Lalima (26.81), whereas minimum in UHF-519 (19.00). Among the cross combinations, maximum fruits per plant were recorded in Solan Lalima x BT Best (31.43), whereas minimum in Solan Lalima x UHF-519 (18.47). Heterosis over the better parent ranged from -31.13 % (Solan Lalima x UHF-519) to 17.22 % (Solan Lalima x BT Best). Cross combinations Solan Lalima x BT Best (17.22 %), UHF-519 x EC-2798 (10.16 %) and UHF-519 x BT-10-12 (4.21 %) exhibited significant positive heterosis over better parent. Heterosis over standard check ranged from -24.74 % (Solan Lalima x UHF-519) to 28.09 % (Solan Lalima x BT Best). Four cross combinations *viz*., Solan Lalima x BT Best (28.09 %), Solan Lalima x BT-10-12 (10.76 %), UHF-519 x EC-2798 (8.95 %) and Solan Lalima x EC-2798 (4.61 %) showed significant positive heterosis over standard check Naveen 2000+. Significant positive heterosis over better parent and check was proposed by (Baishya *et al.*, 2001) [4], (Premalakshme *et al.*, 2005) [21], (Hannan *et al.*, 2007) [11], (Gaikwad and Cheema, 2010) [8], (Kumari *et al*., 2010) [17], (Chauhan *et al.*, 2014) [6] and (Kumar and Singh, 2016) [14] for number of fruits per plant in tomato. Significant positive heterosis over better parent has also been reported by (Tamta and Singh, 2017) [28] and (Rehana *et al*., 2019) [24] for the trait.

Fruit weight is an important characteristic, as it directly affects the yield of the plant. Parent UHF-519 (74.17 g) recorded maximum fruit weight and was statistically at par with EC-2798 (73.07 g). Among cross combinations, maximum fruit weight was recorded by UHF-519 x EC-2798 (83.27 g). Heterobeltiosis effect for average fruit weight ranged from -6.57 % (EC-2798 x BT Best) to 17.32 % (BT-10-12 x BT Best). Six cross combinations showed significant positive heterobeltiosis over better parent. Out of 10 cross combinations, two crosses *viz*., UHF-519 x EC-2798 (4.74 %) and UHF-519 x BT Best (1.47 %) recorded significant positive heterosis over standard check Naveen 2000+. (Baishya *et al.*, 2001) [4], (Premalakshme *et al*., 2005) [21], (Hannan *et al.*, 2007) [11], (Sharma and Thakur, 2008) [26], (Kumari *et al.*, 2010) [17], (Agarwal *et al.*, 2014) [1], (Chauhan *et al.*, 2014) [6], (Kumar and Singh, 2016) [16], (Tamta and Singh, 2017) [28] and (Rehana *et al*., 2019) [24] observed similar results over better parent for the trait. The data recorded for fruit yield per plant revealed that among parents, maximum fruit yield per plant was recorded by Solan Lalima (1.64 kg). Among cross combinations, the maximum yield per plant was recorded in UHF-519 x EC-2798 (2.03 kg). Heterosis over the better parent ranged from -32.62 % (Solan Lalima x UHF-519) to 28.78 % (UHF-519 x EC-2798). Six cross combinations *viz*., UHF-519 x EC-2798 (28.78 %), UHF-519 x BT-10-12 (26.49 %), UHF-519 x BT Best (23.28 %), Solan Lalima x BT Best (15.26 %), Solan Lalima x BT-10-12 (14.22 %) and Solan Lalima x EC-2798 (13.55 %) showed significant positive heterosis over better parent. Heterosis over the standard check ranged from -36.87 % (Solan Lalima x UHF-519) to 15.77 % (UHF-519 x EC-2798). Four cross combinations *viz*., UHF-519 x EC-2798 (15.77 %), Solan Lalima x BT Best (7.99 %), Solan Lalima x BT-10-12 (7.02 %) and Solan Lalima x EC-2798 (6.39 %) showed significant positive heterosis over standard check Naveen 2000+. Significant positive heterosis over better parent for fruit yield per plant was proposed by (Baishya *et al.*, 2001) [4], (Rao *et al*., 2007) [23], (Kumari *et al*., 2010) [17], (Amaefula *et al*., 2014) [3], (Hussein, 2014) [12] (Aisyah *et al*., 2016) [2], (Kumar *et al*.,2016) [16], (Tamta and Singh, 2017) [28] and (Rehana *et al*., 2019) [24]. Similar findings over standard check were noted by (Agarwal *et al.*, 2014) [1], (Kumar *et al*., 2016) [16] and (Kumar and Singh, 2016) [14] for the trait.

Data recorded for fruit yield per hectare depicted that among parents, maximum fruit yield per ha was recorded in Solan Lalima (485.83 q) and among cross combinations, maximum yield per ha was recorded by UHF-519 x EC-2798 (600.28 q). Heterosis over the better parent ranged from -32.62 % (Solan Lalima x UHF-519) to 28.78 % (UHF-519 x EC-2798). Six cross combinations *viz*., UHF-519 x EC-2798 (28.78 %), UHF-519 x BT-10-12 (26.49 %), UHF-519 x BT Best (23.28 %), Solan Lalima x BT Best (15.26 %), Solan Lalima x BT-10-12 (14.22 %) and Solan Lalima x EC-2798 (13.55 %) showed significant positive heterosis over better parent. Four cross combinations *viz*., UHF-519 x EC-2798 (15.77 %), Solan Lalima x BT Best (7.99 %), Solan Lalima x BT-10-12 (7.02 %) and Solan Lalima x EC-2798 (6.39 %) showed significant positive heterosis over standard check Naveen 2000+. Fruit shape index is defined as the ratio of polar diameter to the equatorial diameter of the fruit. For processing, elliptical shapes are given preference, while spherical shapes are preferred for fresh purposes.Maximum fruit shape index was recorded in BT Best (0.89) and was statistically at par with UHF-519 (0.88), EC-2798 (0.87) and BT-10-12 (0.87) among parents and among cross combinations, maximum fruit shape index was observed in UHF-519 x EC-2798 (0.90), UHF-519 x BT-10-12 (0.90) and EC-2798 x BT-10-12 (0.90) and was statistically at par with UHF-519 x BT Best (0.89) and BT-10-12 x BT Best (0.89). Heterosis studies revealed that maximum heterobeltiosis was recorded in EC-2798 x BT-10-12 (3.45 %). Two cross combinations *viz.*, UHF-519 x EC-2798 (2.80 %) and EC-2798 x BT-10-12 (3.45 %) showed significant positive heterosis over better parent. Heterosis over standard check ranged from -18.36 % (Solan Lalima x BT-10-12) to -11.02 % (UHF-519 x EC-2798). Similar results over better parent for fruit shape index was also observed by Hussien (2014) [12].

Data recorded on locules per fruit depicted that among the parents, the minimum numbers were observed in BT-10-12 (2.55). Former one was statistically at par with BT Best (2.59) and Solan Lalima (2.67). Among cross combinations, the lowest value for number of locules was recorded in BT-10-12 x BT Best (2.07) which were statistically at par with EC-2798 x BT Best (2.13), Solan Lalima x BT-10-12 (2.20) and Solan Lalima x BT Best (2.27). Cross combinations BT-10-12 x BT Best (-18.85 %), EC-2798 x BT Best (-17.53 %), Solan Lalima x BT-10-12 (-13.61 %) and Solan Lalima x BT Best (-12.37 %) revealed significant negative heterosis over better parent. Cross combinations BT-10-12 x BT Best (-20.51 %), EC-2798 x BT Best (-17.95 %), Solan Lalima x BT-10-12 (-15.38 %) and Solan Lalima x BT Best (-12.82 %) showed significant negative heterosis over standard check. Significant negative heterosis over better parent was noted by (Sekhar *et al.*, 2010) [25], (Patwary *et al.*, 2013) [20], (Dagade *et al.*, 2015) [7], (Pandiarana *et al.*, 2015) [19], (Aisyah *et al.*, 2016) [2] and (Raj *et al.*, 2018) [22] for the character under study.

Pericarp thickness is one of the important trait as fruits having high pericarp thickness can withstand shipping and remain firm for more number of days as compared to thin fleshed fruits. Among parents, maximum pericarp thickness was recorded in BT Best (6.34 mm) and was statistically at par

with BT-10-12 (6.24 mm) and among cross combinations, maximum pericarp thickness was recorded in Solan Lalima x BT-10-12 (6.10 mm). Heterobeltiosis ranged from -24.21 % (EC-2798 x BT-10-12) to 16.46 % (UHF-519 x EC-2798). Heterosis over standard check ranged from Solan Lalima x EC-2798 (-22.16 %) to Solan Lalima x BT-10-12 (14.09 %). Four cross combinations *viz*., Solan Lalima x BT-10-12 (14.09 %), UHF-519 x BT-10-12 (9.04 %), UHF-519 x BT Best (5.61 %) and BT-10-12 x BT Best (3.62 %) revealed significant positive heterosis over standard check Naveen 2000+. (Gaikwad and Cheema 2010) [8], (Kumar and Paliwal, 2012) [15], (Dagade *et al.*, 2015) [7], (Pandiarana *et al*., 2015) [19], (Kumar and Paliwal, 2016) [15] and (Raj *et al.*, 2018) [22] observed significant positive heterosis over better parent for the trait. (Sharma and Thakur, 2008) [26] also noted significant heterosis over standard check. Total soluble solids content is an important trait for processing, as it influences the flavour and consistency of the final product. Data recorded for total soluble solids depicted that among parents, maximum total soluble solids were recorded in BT-10-12 (5.08 ºB) and was statistically at par with Solan Lalima (4.83 ºB). Among cross combinations, maximum value for the trait was recorded in Solan Lalima x EC-2798 (5.61 ºB) and was statistically at par with UHF-519 x EC-2798 (5.40 ºB) and UHF-519 x BT-10-12 (5.39 ºB). Five cross combinations showed significant positive heterobeltiosis. Heterosis over standard check ranged from EC-2798 x BT Best (-17.02 %) to Solan Lalima x EC-2798 (28.47 %). Significant positive heterosis over better parent has been observed by (Sharma and Thakur, 2008) [26], (Islam *et al.*, 2012) [13], (Kumar and Paliwal, 2016) [15], (Nosser, 2012) [18], (Gul *et al.*, 2013) [10], (Pandiarana *et al.*, 2015) [19], (Kumar and Paliwal, 2016) [15] and (Raj *et al.*, 2018) [22] for the trait. Among parents, longest harvest duration was recorded in Solan Lalima (40.00 days) and among cross combinations, maximum harvest duration was recorded in Solan Lalima x BT Best (43.00 days) which was statistically at par with UHF-519 x EC-2798 (42.33 days). Four cross combinations *viz.*, UHF-519 x EC-2798 (18.69 %), UHF-519 x BT-10-12 (9.26 %), Solan Lalima x BT Best (7.50 %) and UHF-519 x BT Best (6.25 %) showed significant positive heterosis over better parent. Three cross combinations *viz*., Solan Lalima x BT Best (10.26 %), UHF-519 x EC-2798 (8.55 %) and Solan Lalima x BT-10-12 (5.98 %) exhibited significant positive heterosis over standard check Naveen 2000+. Similar significant results over better parent were observed by (Sharma and Thakur, 2008) [26] and (Gaikwad and Cheema, 2010) [8] and over standard check by (Sharma and Thakur, 2008) [26] for harvest duration.

Table 1: Mean performance of parents and crosses for different characters in tomato

Parents	Days to the 50% flowering	Days to marketable maturity	Plant height (cm)	Number of fruit per cluster	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (kg)	Fruit shape index	Number of locules per fruit	Pericarp thickness (mm)	Total Soluble Solids (ºB)	Harvest duration (days)
Solan Lalima	37.33	74.00	126.40	4.79	26.81	68.67	1.64	0.86	2.67	5.19	4.83	40.00
UHF-519	38.33	76.67	125.00	3.90	19.00	74.17	1.21	0.88	3.33	4.02	4.18	35.33
EC-2798	37.33	73.33	135.00	4.10	24.27	73.07	1.57	0.87	2.96	4.69	4.18	35.67
BT-10-12	36.00	72.67	132.00	4.88	21.93	66.20	1.26	0.87	2.55	6.24	5.08	36.00
BT Best	38.67	75.33	123.00	4.74	24.67	64.33	1.39	0.89	2.59	6.34	4.42	37.33
Crosses												
Solan Lalima X UHF-519	37.67	75.33	130.00	4.50	18.47	70.67	1.10	0.86	2.63	4.93	4.87	36.67
Solan Lalima X EC-2798	34.67	68.67	105.55	5.48	25.67	80.33	1.86	0.84	2.48	4.16	5.61	40.33
Solan Lalima X BT-10-12	36.33	72.60	133.00	5.44	27.18	76.27	1.87	0.83	2.20	6.10	4.43	41.33
Solan Lalima X BT Best	39.33	78.67	135.00	5.80	31.43	66.50	1.89	0.87	2.27	4.89	5.19	43.00
UHF-519 X EC-2798	35.67	69.00	127.30	4.34	26.73	83.27	2.03	0.90	3.30	5.46	5.40	42.33
UHF-519 X BT-10-12	35.00	69.67	118.60	5.39	22.86	78.23	1.59	0.90	3.03	5.83	5.39	39.33
UHF-519 X BT Best	35.67	70.67	128.00	4.40	23.67	80.67	1.71	0.89	2.80	5.65	4.72	39.67
EC-2798 X BT-10-12	36.33	72.00	101.70	4.34	19.00	71.83	1.16	0.90	2.55	4.73	4.01	37.33
EC-2798 X BT Best	37.00	73.67	122.60	5.50	21.33	68.27	1.26	0.87	2.13	4.89	3.62	38.67
BT-10-12 X BT Best	36.00	73.00	142.40	5.20	19.83	77.67	1.34	0.89	2.07	5.54	4.78	36.33
Naveen 2000 + **(Check)**	37.67	73.33	124.00	4.90	24.54	79.50	1.75	1.02	2.60	5.35	4.37	39.00
Population Mean	36.81	73.04	126.74	4.86	23.59	73.73	1.54	0.88	2.64	5.25	4.69	38.65
SE(m)±	0.44	0.28	0.43	0.12	0.26	0.39	0.02	0.01	0.10	0.06	0.09	0.52
$CD_{0.05}$	1.28	0.81	1.24	0.34	0.70	1.14	0.06	0.02	0.29	0.18	0.27	1.15

* Significant at 5% level of significance

Table 2: Heterosis over better parent and check for different characters in tomato

Parents	Days to the 50% flowering		Days to marketable maturity		Plant height (cm)		Number of fruit per cluster		Number of fruits per plant		Average fruit weight (g)	
	Better parent	Check	Better parent	Check	Better parent	Check	Better parent	Check	Better parent	Check	Better parent	Check
Solan Lalima X UHF-519	0.90	0.00	1.80*	2.73*	2.85*	4.84*	-6.12	-8.16*	-31.13*	-24.74*	-4.72*	-11.11*
Solan Lalima X EC-	-7.10*	-7.96*	-6.40*	-6.36*	-21.80*	-	14.39*	11.90*	-4.28*	4.61*	9.94*	1.04

2798						14.88*						
Solan Lalima X BT-10-12	0.93	-3.54*	-0.09	-1.00	0.76	7.26*	11.40*	11.02*	1.36	10.76*	11.07*	-4.07*
Solan Lalima X BT Best	5.36*	4.42*	6.31*	7.27*	6.80*	8.87*	21.00*	18.37*	17.22*	28.09*	-3.16*	-16.35*
UHF-519 X EC-2798	-4.46*	-5.31*	-5.91*	-5.91*	-5.70*	2.66*	5.85	-11.43*	10.16*	8.95*	12.27*	4.74*
UHF-519 X BT-10-12	-2.78	-7.08*	-4.12*	-5.00*	-10.15*	-4.35*	10.38*	10.00*	4.21*	-6.85*	5.48*	-1.59*
UHF-519 X BT Best	-6.96*	-5.31*	-6.19*	-3.64*	2.40*	3.23*	-7.17	-10.20*	-4.05*	-3.55*	8.76*	1.47*
EC-2798 X BT-10-12	0.93	-3.54*	-0.92	-1.82*	-24.67*	-17.98*	-11.13*	-11.43*	-13.37*	-22.56*	-1.69*	-9.64*
EC-2798 X BT Best	-0.89	-1.77	0.45	0.45	-9.19*	-1.13*	16.03*	12.24*	-13.53*	-13.07*	-6.57*	-14.13*
BT-10-12 X BT Best	0.00	-4.42*	0.46	-0.45	7.88*	14.84*	6.48	6.12	-19.61*	-19.18*	17.32*	-2.31*

Table 2: continued...

Parents	Fruit yield per plant (kg)		Fruit shape index		Number of locules per fruit		Pericarp thickness (mm)		Total Soluble Solids (ºB)		Harvest duration (days)	
	Better parent	Check	Better parent	Check	Better parent	Check	Better parent	Check	Better parent	Check	Better parent	Check
Solan Lalima X UHF-519	-32.62*	-36.87*	-1.90	-15.08*	-1.25	1.28	-5.10*	-7.86*	0.70	11.45*	-8.30*	-5.98*
Solan Lalima X EC-2798	13.55*	6.39*	-3.80*	-17.38*	-6.88	-4.49	-19.80*	-22.16*	16.10*	28.47*	0.80	3.42
Solan Lalima X BT-10-12	14.22*	7.02*	-4.21*	-18.36*	-13.61*	-15.38*	-2.19	14.09*	-12.79*	1.53	3.33	5.98*
Solan Lalima X BT Best	15.26*	7.99*	-1.88	-14.43*	-12.37*	-12.82*	-22.92*	-8.54*	7.45*	18.93*	7.50*	10.26*
UHF-519 X EC-2798	28.78*	15.77*	2.80*	-11.76*	11.49*	26.92*	16.46*	2.16	29.29*	23.66*	18.69*	8.55*
UHF-519 X BT-10-12	26.49*	-9.24*	1.89	-11.76*	19.11*	16.67*	-6.52*	9.04*	6.10*	23.51*	9.26*	0.85
UHF-519 X BT Best	23.28*	-2.31	-1.32	-12.74*	8.25	7.69	-11.00*	5.61*	6.79*	8.02*	6.25*	1.71
EC-2798 X BT-10-12	-25.96*	-33.44*	3.45*	-11.76*	0.26	-1.79	-24.21*	-11.60*	-21.11*	-8.17*	3.70	-4.27*
EC-2798 X BT Best	-9.41*	-28.22*	-1.43	-14.43*	-17.53*	-17.95*	-22.92*	-8.54*	-17.96*	-17.02*	3.57	-0.85
BT-10-12 X BT Best	-3.36*	-23.42*	0.34	-12.74*	-18.85*	-20.51*	-12.68*	3.62*	-6.03*	9.39*	-2.68	-6.84*

Conclusion

On the basis of heterosis studies, cross combinations UHF-519 x EC-2798, Solan Lalima x BT Best and Solan Lalima x BT-10-12 were found promising for most of horticultural traits. UHF-519 x EC-2798, Solan Lalima x BT Best and Solan Lalima x BT-10-12 were possessing significant positive heterosis for almost all the traits including yield over standard check

Acknowledgements

Special thanks to Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP for providing facilities for conducting this study.

References

1. Agarwal A, Arya DN, Ranjan R, Ahmed Z. Heterosis, combining ability and gene action for yield and quality traits in tomato (*Solanum lycopersicum* L.). Helix 2014; 2:511-15.
2. Aisyah SI, Wahyuni S, Syukur M, Witono JR. Estimation of combining ability and heterosis effect for yield and yield components in tomato (*Solanum lycopersicum* L.) at lowland. Ekin Journal of Crop Breeding and Genetics 2016;2:23-29.
3. Amaefula C, Agbo CU, Nwofia GE. Hybrid vigour and genetic control of some quantitative traits of tomato (*Solanum lycopersicum* L.). Open Journal of Genetics 2014;4:30-39.
4. Baishya KC, Syamai MM, Singh KP. Heterotic studies in tomato (*Lycopersicon esculentum* M.). Vegetable Science 2001;28:168-69.
5. Chattopadhyay A, Paul A. Studies on heterosis in tomato (*Solanum lycopersicum* L.). International Journal of Bio-resource and Stress Management 2012;3:278-83.
6. Chauhan VB, Kumar R, Behera TK, Yadav RK. Studies on heterosis for yield and its attributing traits in tomato (*Solanum lycopersicum* L.). International Journal of Agriculture, Environment & Biotechnology 2014;7:95-100.
7. Dagade SB, Barad AV, Dhaduk LK, Hariprasanna K. Heterosis and inbreeding depression for fruit yield and related characters in tomato (*Lycopersicon esculentum* Mill.). International Journal of Research in Biosciences 2015;4:21-28.
8. Gaikwad AK, Cheema DS. Studies on heterosis using heat tolerant lines in tomato. Journal of Research Punjab Agricultural University 2010;47:53-57.
9. Gul R, Rahman H, Khalil IH, Shah SM, Ghafoor A. Heterosis for flower and fruit traits in tomato (*Solanum lycopersicum* L.). African Journal of Biotechnology 2010;9:4144-51.
10. Gul R, Rahman H, Tahir M, Naeem M, Ghafoor A. Estimates of heterosis for morphological and flavour attributes in tomato. International Journal of Vegetable Science 2013;19:256-62.
11. Hannan MM, Ahmed MB, Razvy MA, Karim R, Khatun M, Haydar A, Hossain M et al. Heterosis and correlation of yield and yield components in tomato (*Solanum lycopersicum* L.). American Eurasian Journal of Scientific Research 2007;2:146-50.
12. Hussien AH. Combining ability, heterosis and path coefficient analysis for yield and its components in tomato. Egypt Journal of Plant Breeding 2014;18:737-53.
13. Islam MR, Ahmed S, Rahman MM. Heterosis and qualitative attributes in winter tomato (*Solanum lycopersicum* L.) hybrids. Bangladesh Journal of Agricultural Research 2012;37:39-48.

14. 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. Journal of Applied and Natural Science 2016;8:290-96.
15. Kumar P, Paliwal A. Heterosis breeding for quality improvement in tomato (*Lycopersicon esculentum* Mill.) for cultivation in mid hills of Uttarakhand. International Journal of New Technology and Research 2016;2:75-78.
16. Kumar P, Paliwal A, Pant SC, Bahuguna P, Abrol G. Heterosis studies in tomato (*Lycopersicum esculentum* Mill.) for yield and yield attributing traits for further implications in crop improvement. Journal of Bio Innovation 2016;5:959-72.
17. Kumari N, Srivastava JP, Singh B, Deokaran. Heterotic expression for yield and its component in tomato (*Solanum lycopersicum* L.). Annals of Horticulture 2010;3:98-101.
18. Nosser MA. Heterosis and inbreeding depression in tomato. Egyptian Journal of Plant Breeding 2012;16:1-17.
19. Pandiarana N, Chattopadhyay A, Seth T, Shende VD, Dutta S, Hazra P. Heterobeltiosis, potence ratio and genetic control of processing quality and disease severity traits in tomato. New Zealand Journal of Crop and Horticultural Sciences 2015, 282-93.
20. Patwary MMA, Rahman MM, Ahmad S, Miah MAK, Barua H. Study of heterosis in heat tolerant tomato (*Solanum lycopersicum*) during summer. Bangladesh Journal of Agricultural Research 2013;38:531-44.
21. Premalakshme V, Thangaraj T, Veeraragavathatham D, Arumugam T. Heterosis and combining ability in tomato (*Solanum lycopersicum* L.). Vegetable Science 2005;32:47-50.
22. Raj Tanvi, Bhardwaj Madan Lal, Pal Sahib. Estimation of heterosis for quality traits in tomato (*Solanum lycopersicum* L.) Journal of Pharmacognosy and Phytochemistry 2018;7(1):2401-2404.
23. Rao ES, Munshi AD, Singh B, Kumar R. Studies on heterosis and combining ability for yield and resistance to early blight in tomato. Indian Journal of Horticulture 2007;64:331-34.
24. Rehana S, Ullah MZ, Zeba N, Narzis N, Husna A, Siddique AB. Estimation of heterosis for yield and yield attributing traits in tomato crossed with line and tester method. Progressive Agriculture 2019;30(2):179-185.
25. Sekhar L, Prakash BG, Salimath PM, Hiremath CP, Sridevi O, Patil AA. Implications of heterosis and combining ability among productive single cross hybrids in tomato. Electronic Journal of Plant Breeding 2010; 1:706-11.
26. Sharma D, Thakur MC. Evaluation of diallel progenies for yield and its contributing traits in tomato under mid hill conditions. Indian Journal of Horticulture 2008; 65:297-301.
27. Singh NB, Wani SH, Haribhushan A, Nongtomban R. Heterosis studies for yield and its components in tomato (*Solanum lycopersicum* L.) under valley conditions of Manipur. Vegetos 2012;25:257-65.
28. Tamta Savita, Singh JP. Heterosis in Tomato for Growth and Yield Traits. International Journal of Vegetable Science doi:org/10.1080/19315260.2017.1407857