Nature and Magnitude of heterosis against earliness and yield characters in tomato (*Solanum lycopersicum* L.) using leaf curl resistant mutant

Abstracts

Aim: To select the sutaible parent and their hybrids for desirable characters especially earliness and yield related characters.

Study Design: The experiment was laid out in Randomized Block Design with three replications..

Place and Duration of Study: The experimental site was at ICAR-Indian Institute of Vegetable Research, Varanasi situated approximately 20 km south-west of Varanasi at the bank of Ganga River and exists between 82.52^{o}E longitude and 25.10^{o}N latitude at an elevation of 128.93 m from mean sea level (MSL). The selected piece of land was homogenous in fertility status and uniform in textural build up. The experiment was conducted during late kharif season 0f 2015 and 2016 and summer seasons of 2017.

Methodology: To assess the performance of 14 tomato genotypes, including the advanced breeding line H-88-78-2, a mutant resistant to leaf curl with altered inflorescence and ripening, and the susceptible Punjab Chhuhara variety, and to determine the heterosis of their crosses for various traits related to earlyness and yield. Currently under investigation Eleven cultivars were the female parents, while three testers were the male parents (lines). Using the line-and-line tester method, crosses were produced. As a result, 33 tomato hybrids were produced. heterosis estimates over the better parent, the mid parent, and the standard/check (Arka Rakshak).

Results: On the basis of both season performances, the maximum significant heterosis exhibited by cross P7 × P13 for earliness characters like days to first flower, days to 50% flower and days to first ripening over mid, better and commercial check whereas, P10 × P14 showed the maximum heterosis per cent for number of leaves before truss. The result also indicated that maximum yield per plant in the above mentioned hybrids was attributed by maximum number of fruits per plant.

Conclusion: on the basis of both sasons performance it is concluded that the tomato mutant (P13) × cultivated hybrids were found to low and negative heterosis for charcters related to earliness and high and positive heterosis for yield related traits. Therefore, earliness and yield can more accurately be estimated by the days to first ripening and number of fruits per plant, and it would be possible to achieve yield improvement with early crop by manipulating this particular traits. Hence, breeders should concentrate mainly on days to first ripening and fruit number in their efforts to obtain high and early yield.

Key words: tomato, earliness, yield, heterosis

Introduction

Tomato (Solanum lycopersicum L) belonging to family Solanaceae is one of the most popular and widely grown vegetable in the world ranking second in importance to potato in many countries. It is a major vegetable crop that has achieved tremendous popularity over the last century and grown in practically every country of the world in outdoor fields, green houses and net houses. The tomato fruits which acidic tastes much more like a vegetable are eaten raw or cooked and very versatile in the kitchen. Tomato in large quantities is used to produce soup, juice ketchup, puree, paste and powder. Tomato is being cultivated in most of the countries of the world ranks second after potato with global production of over the 182.30 million MT from an area of 4.85 million hectare (FAOSTAT. 2017). The United States, China, Turkey and Italy are major producers of tomato. Tomatoes take a vital part in increasing the income of vegetable growers as well as our country's economy. India is only second to China as a tomato grower, with production and productivity of 20.70 MT and 25.98 t/ha, respectively, accounting for 11.35 percent of worldwide tomato production (FAOSTAT, 2018).The four major vegetable crops i.e. potato (28.9%), tomato (11.3%), onion (10.3%) and brinjal (8.1%) have a say 58.6% of total vegetable production of our country. Tomato is widely cultivated across different states in the country. The states of Andhra Pradesh, Madhya Pradesh, Karnataka, Orissa, Maharashtra, Bihar, West Bengal and Gujarat contribute more than 65% of the total national production. Despite the fact that the area and output of tomato in our nation have steadily risen, the productivity (25.98 t/ha) remains low when compared to the worldwide average (37.6 t/ha) (FAOSTAT, 2018).

Heterosis is a universal phenomenon and it occurs both in self and cross Pollinated crops. It is defined as the increased vigour of F1 over the mean parents or over the better parent or over the standard check (Peter and Rai, 2006). Estimates of heterosis may help in deciding whether the hybrids are of economic value and worth exploiting. Exploitation of hybrid vigour or heterosis is a quick and convenient approach of combining desirable characters and hence assumed greater significance in the production of hybrids. Heterosis breeding provides an opportunity for improvement in productivity, earliness and yield attributing characters in crop plant.

Materials and methods

The experimental site was at ICAR-Indian Institute of Vegetable Research, Varanasi situated approximately 20 km south-west of Varanasi at the bank of Ganga River and exists between 82.52^{o}E longitude and 25.10^{o}N latitude at an elevation of 128.93 m from mean sea level (MSL). The selected piece of land was homogenous in fertility status and uniform in textural build up. The soil of experimental field was the sandy loam in texture and sufficiently well drained.

Chemically the soil was neutral in reaction with low organic carbon, deficient in nitrogen and medium in phosphorus and potash contents. Fourteen tomato genotypes consisting germplasm, advance breeding lines with one leaf curl susceptible variety Punjab Chhuhara received from IIVR, Varanasi. The advance breeding line H-88-78-2 which is a leaf curl resistant mutant with altered inflorescence and ripening was used in present investigation. Eleven cultivars i.e. 2103-1-2 (P1), VRT 2103-1-4 (P2), 2103 -1-8 (P3), 2103-3-6 (P4) and 2103-6-1 (P5), VRT 2102-13-3 (P6) EC- 538411 (P7), EC- 538441 (P8), Punjab Chhuhara (P9), Punjab Barkha Bahar -1 (P10), Punjab Barkha Bahar -2 (P11) used as lines (female parents) and three testers viz., D-2-2-3 (P12) and leaf curl resistant mutant VRT 88-78-2 (P13), and CLN-8-6-1 (P14) were used as male parents. Thirty days old seedlings of each season were transplanted in RBD with three replications separately in a plot size of 4.50 x 1.20 m at spacing of 60 x 45 cm. A standard package of practices was adopted to raise good crop.

The mature buds for emasculation were chosen from the female lines and emasculated carefully using forceps during the evening hours. Next morning pollen collected from the male parent's flower on and manual pollination on emasculated buds was done without causing any damage to the stigma. The pollinated buds were covered with cotton and labeled using crossing tags. The mature red ripe crossed fruits (F1's) were collected, seed extracted, dried in shade, packed in envelope and stored to evaluate in next season.

Thirty three F1s with their 14 parents and check (hybrid from public sectors) were raised in nursery during rainy, winter and summer seasons, 2016-2017 and about four weak days old seedlings were transplanted in a well prepared plot size of 4.5 x 1.2 m at spacing of 60 x 45 cm in RBD for field experiment, while 20 plants were maintained in field for data observations and pots for artificial screening in net house, respectively. Good agronomical practices were applied timely to take better crop. Data of ten randomly selected plants of each genotypes and its crosses in each replication was recorded for different traits related to earliness and yield viz. Days to first flowering, days to 50 percent flowering, number ofleaf before truss, number of fruits per plant, average ten fruit weight (g), fruit yield per plant (kg), yield (q/ha) and averaged replication wise mean data was used for statistical analysis. The analysis of variance (ANOVA) for RCBD was estimated crosswise according to Panse and Sukhtame (1989) and ANOVA for line × tester analysis was done according to Kempthorne (1957) and Singh and Chaudhary (1985). Heterosis over better parent (heterobeltiosis) and standard/check (Arka Rakshak) were estimated (Table 1 & 2). Significance of heterosis is tested with the help of standard error using't' test.

Result and Discussion

Magnitude of heterosis for different horticultural traits related to earliness in tomato

There were significant differences among the parents, lines, testers, line vs. tester, line × tester and parent vs. hybrid for all the horticultural traits related to earliness *viz*.,days to first flower, days to 50% flowering, Number of leaves before truss, and days to first ripening. The summary of range of mean values of parents; F1 hybrids and heterosis percentage are given in Table 1. The mean values of parents for days to first flower ranged from 28.00 (P7) to 37.33 (P13) and 24.67 (P2) to 42.00 (P13) for season I and season II, respectively. Among crosses mean ranged from 20.00 (P2 × P13) to 32 (P1 × P13) in season I and 20.33 (P4 × P13) to 28.67 (P3 × P14) in season II. Out of 33 F1 hybrids, a total of 17 and 22 crosses showed significant negative heterosis over mid parent, better parent, respectively and none over commercial check. In the second season similar trend showed by the hybrids and a total of 20, 25 and 29 crosses exhibited negative heterosis over mid parent, better parent and commercial check (Arka Rakshak) respectively. In both season Cross P7 × P13 exhibited maximum negative heterosis per cent i.e. -38.78.-40.28 over mid parent, -46.33, -50.00, better parent and -17.81, -33.68 % over commercial check (commercial check) in both first and second season, respectively.

Table 1: Range of mean values of parents, F_1 hybrids and heterosis (%) over mid, better and commercial check earliness characters in tomato

Parameter	Days to first flowering		Days to 50% flowering		No. of leaf before truss		Days to first ripening	
	SI	SII	SI	SII	SI	SII	SI	SII
1. Range of mean values								
Parents	28.00-37.33	24.67-42.00	33.67-43.00	27.67-45.67	8.27-13.13	5.93-11.80	78.00-113.00	62.00-84.67
F1	20.00-32.00	20.33-28.67	27.67-44.33	24.67-34.00	8.93-11.47	5.73-8.07	75.67-113.00	58.33-75.33
2. Range of heterosis Percentage								
MP	-38.78-0.53	-40.28-3.9	-28.85-12.24	-34.19-1.11	-19.79-13.49	-33.33-17.28	-22.19 5.84	-17.73-1.53
BP	-46.43-0.00	-50.00 2.56	-35.66-5.36	-43.80 1.11-	-31.98 10.81	-45.76-9.8	-30.09 3.82	-28.74-1.02
CC	-17.81-31.51	-35.79 -9.47	-13.54-38.54	-29.52--2.86	-2.9 24.64	-19.63-13.08	-11.67-31.91	-17.06-7.11
3. Number of desirable significant heterotic crosses over								
MP	17	20	13	21	6	16	14	24
BP	22	25	18	26	13	18	21	27
CC	0	29	0	28	0	3	1	24
4. top Three parents								
	P7 (28.00)	P2 (24.67)	P7 (33.67)	P2 (27.67)	P8 (8.27)	P11 (5.93)	P7 (78.00)	P7 (62.00)
	P5 (28.67)	P8 (25.00)	P6 (35.67)	P8 (28.00)	P7 (8.80)	P7 (6.80)	P6 (88.67)	P14 (65.00)

	P4, P9 (30.33)	P12 (25.33)	P=3 (36.00)	P4, P12 (30.00)	P3 (9.00)	P8 (6.87)	P10 (90.33)	P2, P6 (65.67)
5. Three top F1s with heterosis Percentage								
MP	P7×P13 (-38.78)	P7×P13 (-34.19)	P8×P13 (-28.85)	P7×P13 (-40.28)	P10×P13 (-19.76)	P4×P13 (-33.33)	P8×P13 (-22.19)	P7×P13 (-17.73)
	P8×P14 (-36.19)	P11×P13 (-33.90)	P7×P13 (-27.83)	P11×P13 (-36.79)	P5×P13 (-18.48)	P1×P13 (-28.28)	P7×P13 (-17.28)	P4×P13 (-15.10)
	P8×P13 (-30.30)	P10×P13 (-31.45)	P8×P14 (-23.65)	P10×P13 (-30.63)	P11×P12 (-13.49)	P8×P13 (-25.71)	P11×P13 (-16.46)	P8×P13 (-14.54)
BP	P7×P13 (-46.43)	P7×P13 (-43.80)	P7×P13 (-35.66)	P7×P13 (-50.00)	P10×P13 (-31.98)	P4×P13 (-45.76)	P7×P13 (-30.09)	P7×P13 (-28.74)
	P8×P14 (-38.53)	P11×P13 (-43.07)	P8×P13 (-30.23)	P11×P13 (-46.83)	P5×P13 (-29.44)	P1×P13 (-41.24)	P8×P13 (-28.61)	P8×P13 (-23.62)
	P7×P12 (-31.58)	P10×P13 (-37.96)	P8×P14 (-25.81)	P10×P13 (-38.89)	P7×P13 (-39.60)	P8×P13 (-41.24)	P11×P13 (-22.12)	P4×P13 (-23.62)
CC	P7×P13 (-17.81)	P7×P12 (-29.52)	P7×P13 (-13.54)	P4×P14 (-35.79)	-	P8×P14 (-19.63)	P7×P14 (-11.67)	P8×P14 (-17.06)
		P7×P13 (-29.52)		P7×P13 (-33.68)	-	P4×P12 (-18.69)		P7×P13 (-14.22)
				P8×P12 (-33.68)	-			P7×P12 (-11.85)
6. Best F_1 hybrid	P7× P13	P7× P13	P7×P13	P7× P13	P10×P13	P4× P13	P8× P13	P8× P13

With respect to days to 50% flowering, parental mean ranged from 33.67 (P7) to 43.00 (P13) during the first season whereas, in the second season parental mean ranged from 27.67 (P2) to 45.67 (P13). Among the crosses it ranged from 27.67 (P7 × P13) to 44.33 (P3 × P13) in the first season and from 24.67 (P7 × P12 and P8 × P12) to 34.33 (P5 × P13) in the second season. The range of heterosis varied from -28.85 (P8 × P13) to 12.24 % (P3 × P13) over mid parent, -35.66 (P7 × P13) to 5.36 % (P2 × P12) over better parent and -13.54 (P7 × P13) to 38.54 per cent (P3 × P13) over commercial check in the first season and in the second season range from -34.19 (P7 × P13) to 1.11 per cent (P4 × P12) over mid parent -28.74 (P7 × P13) to 1.11 percent (P4 × P12) over better parent and -29.52 (P4 × P14) to -2.86 % (P5 × P13) over commercial check. The desirable negative heterosis showed by 13 and 18, 0 and 21, 26 and 28 crosses over mid, better, and commercial check in first and second season, respectively.

The mean values of parents for number of leaves before truss ranged from 8.27 (P8) to 13.13 (P13) and 5.93 (P11) to 11.80 (P13) for season I and season II, respectively. Among crosses mean ranged from 8.93 (P8 × P14) to 11.47 (P4 × P13) in season I and 5.73 (P8 × P14) to 8.07 (P3 × P12) in season II. Among the 33 F1 hybrids, heterosis ranged from -19.76 (P10 × P13) to 11.26 (P11 × P14) over mid, -31.98 (P10 × P13) to 10.81 (P11 × P12) over better and -2.9 (P10 × P13) to 24.64 (P4 × P13) over commercial check. A total of 5, 13

and none cross showed significant negative heterosis over mid parent, better parent and commercial check, respectively in the first season. In the second season similar trend showed by the hybrids and heterosis ranged from -33.33 (P4 × P13) to 17.28 (P11 × P14) over mid, -44.76 (P4 × P13) to8.49 (P8 × P12) over better and -19.63 (P8 × P14) to13.08 (P3 × P12) over commercial check. A total of 16, 18 and 3 crosses exhibited negative heterosis over mid parent, better parent and commercial check, respectively. In the first season Cross P10 × P13 exhibited maximum heterosis per cent i.e. -19.76 over mid parent, P10 × P13 (-31.98) over better parent. However, in second season P4 × P13 (-33.33, -45.76) showed the maximum heterosis over mid and better parent while P8 × P14 (-19.63) over commercial check.

For the days to first ripening, parental mean ranged from 78.0 (P7) to 133.00 (P13) during the first season whereas in the second season parental mean ranged from 62 (P7) to 84.67 (P13). Among the crosses it ranged from 20 (P7 × P13) to 30 (P1 × P13) in the first season and from 20.33 (P4 × P14) to 28.67 (P3 × P14 and P5 × P13) in the second season.

The range of heterosis varied from -22.19 (P8 × P13) to 5.84 percent (P 2 × P12) over mid parent, -30.09 (P 7 × P13) to 3.82 per cent (P2 × P12) over better parent and -11.67 (P7 × P14) to 31.91% (P3 × P13) over commercial check and 14, 21, 1 cross showed desired negative heterosis in the first session while, in the second session the negative significant heterosis showed by 24, 27 and 24 crosses over mid, better and commercial check, respectively. The heterosis per cent ranged from -17.73 (P7 × P13) to 1.53 (P2 × P14) over mid parent -28.74 (P7 × P13) to 1.02% (P2 × P14) over better parent and -17.06 (P8 × P14) to 0 % (P1 × P13) over commercial check. Different heterosis (%) , i.e., relative heterosis, heterobeltiosis and standard heterosis for character related to earliness were estimated by the several researcher globally and found desirable significnt heterotic hybrids in desirable direction which were published in Indurani and Veraragavatham (2012), Shankar *et al*. (2013), Chauhan *et al*. 2014; Kumar *et al.,* 2016; Rehana *et al*. 2019 and Ghadage *et al*. (2019).

Nature and Magnitude of heterosis for yield related attributes in Tomato

There were significant differences among the parents, lines, testers, line vs. tester, line × tester and parent vs. hybrid for all the traits related to yield *viz.*,number of fruits per plant, fruit weight (gm), fruit yield per plant and fruit yield per plot (kg). The summary of range of mean values of parents; F1 hybrids and heterosis percentage are given in table 2. In the first season the mean values of parents for number of fruits per plant ranged from 8.13 (P13) to

34.53 (P12) and crosses mean ranged from 20.13 (P4 × P13) to 44.43 (P3 × P12). Out of 33 F1 hybrids, a total of 22, 10 and 6 crosses showed significant positive heterosis over mid parent, better parent and commercial check, respectively.

In the second season similar trend showed by the parent and their crosses mean ranged from 2.67 (P13) to 30.99 (P8) and 10.87 (P1 × P13) to 39.04 (P3 × P14), respectively. Among the tested hybrids, a total of 29, 19 and 3 crosses exhibited significant positive heterosis over mid parent, better parent and commercial check, respectively. In both season Cross P7 × P13 exhibited maximum heterosis per cent i.e. 134.97, 619.89 over mid parent and 71.78, 592.04, over better parent, respectively while, cross P3 × P12 (35.61) and cross P8 × P14 (18.45) showed the maximum significant positive heterosis over commercial check, in first and second season, respectively.

In respect to ten fruit weight (g), parental mean ranged from 493.61 (P9) to 1842.0 (P13) and among the crosses it ranged from 616.42 (P8 × P13) to 1204.17 (P6 × P13) The range of heterosis varied from -47.52 (P8 × P13) to 29.51 per cent (P9 × P12) over mid parent, -66.54 (P 8 × P13) to 10.20 per cent (P10 × P14) over better parent and -12.80 (P8 × P13) to 70.35 per cent (P6 × P13) over commercial check during the first season. Whereas, in the second season parental mean ranged from 318.0 (P8) to 1063.17 (P13) and their crosses mean ranged from 438.83 (P8 × P14) to 833.44 (P1 × P13). Heterosis range varied from -29.00 (P7 × P13) to 6.57 per cent (P2 × P14) over mid parent -51.35 (P7 × P13) to 05.88 per cent (P10 × P12) over better parent and -32.95 (P8 × P14) to 27.35 per cent (P1 × P13) over commercial check (commercial check).

In the first season for yield per plant (kg), the parental mean differed from 0.88 (P9) to 2.77 (P10) and their crosses mean ranged from 2.01 (P4 × P12) to 3.56 (P10 × P14). The range of heterosis varied from -20.29 (P4 × P12) to 121.04 % (P9 × P13) over mid parent, -23.09 (P 4 × P12) to 75.11 % (P9 × P13) over better parent and -13.11 (P4 × P12) to 53.89 % (P10 × P14) over commercial check.

In the second season, parental mean ranged from 0.15 (P9) to 1.39 (P11). Among the crosses it ranged in the first season and from 0.88 (P4 × P12) to 2.42 (P10 × P14) in the second season. The heterosis ranged from -14.24 (P4 × P12) to 587.69 % (P9 × P13) over mid parent -15.61 (P4 × P12) to 425.88% (P9 × P13) over better parent and -59.10 (P4 × P12) to 12.04. The minimum parental mean for yield per plot (kg) was recorded in P9 (16.60, 2.84) whereas, the maximum parental mean was recorded in P10 (49.73, 25.84) in the both season, respectively. Among the crosses it ranged from 37.74 (P4 × P12) to 68.47 (P10 × P14) in the first season and from 15.91 (P3 × P13) to 45.22 (P10 × P14 and P5 × P13) in the

second season. The range of heterosis varied from -47.52 (P8 × P13) to 46.17 % (P6 × P13) over mid parent, -66.54 (P 8 × P13) to 34.27 % (P6 × P14) over better parent and -12.80 (P8 × P13) to 51.68 % (P10 × P13) over commercial check in the first session whereas, in the second season it ranged from -29.00 (P7 × P13) to 111.85 % (P4 × P13) over mid parent -51.35 (P7 × P13) to 61.05 % (P5 × P14) over better parent and -59.67 (P3 × P13) to 26.74 % (P11 × P13) over commercial check.

In tomato, number of fruits per plant and average 10 fruit weight are the direct component of yield. In the first season cross P9 × P13, P8 × P13 and P11 × P13 exhibited maximum heterosis over mid parent, cross P3 × P14, P9 × P14 and P8 × P13 over better Parent and cross P3 × P12, P7 × P12 and P8 × P12 over commercial check for number of fruits per plant. For the average, ten fruit weight cross P9 × P12, P10 × P14 and P11 × P14 over better parent and cross P6 × P13, P5 × P3 and P4 × P13 over commercial check. The maximum positive heterosis for yield per plant exhibited by cross P9 × P13, P11 × P13 and P7 × P13 over mid parent , P9 × P13, P7 × P13 and P8 × P13 over better parent and cross P10 × P14, P10 × P13 and P11 × P12 over commercial check while, for yield per plot, cross P6 × P13, P1 × P13 and P3 × P14 over mid parent, P6 × P14, P3 × P14 and P6 × P12 over better parent and cross P10 × P13, P11 × P13 and P10 × P14 over commercial check.

Similarly, In the second season cross P9 × P13, P9 × P14 and P9 × P12 showed maximum heterosis percentage over mid parent, cross P9 × P13, P9 × P14 and P10 × P14 over better parent and cross P8 × P14, P10 × P14 and P9 × P14 for number of fruits per plant, for average ten fruit weight cross P2 × P14, P8 × P14 P4 × P12 and P10 × P12 over mid parent and over the commercial check cross P1 × P13, P7 × P13, P3 × P13, P9 × P13, P2 × P13 and P8 × P13 showed the maximum heterotic per cent for average ten fruits weight. For total yield per plant F1 hybrids P9 × P13, P9 × P14 and P8 × P13 over mid and better parent and P10 × P14 over commercial check while, crosses P4 × P13, P5 × P13 and P5 × P14 over mid, P5 × P13, P5 × P14 and P6 × P12 over better and cross P11 × P13, P10 × P13 and P9 × P13 over commercial check.

The above result also indicated that maximum yield per plant in the above mentioned hybrids was attributed by maximum number of fruits per plant. Therefore, mutant (P13) with cultivated hybrids were found to have maximum heterosis for yield related traits various workers in tomato reported high and positive heterosis over better parents for yield traits Chattopadhaya *et al.* (2012); Indurani and Veraragavatham (2012), Shankar *et al*. (2013), Kumar *et al.,* 2016; Rehana *et al*. 2019 and Ghadage *et al*. (2019)

Table 2: Range of mean values of Parents, F_1 hybrids and heterosis (%) over mid, better and commercial check for earliness characters in tomato

Parameter	No of fruits/plant		Ten Fruits weight (g)		Yield/plant (kg)		Yield/plot (kg)	
	SI	SII	SI	SII	SI	SII	SI	SII
1. Range of mean values								
Parents	8.13-34.53	2.67-30.99	493.61-1842.00	616.42-1204.17	0.88-2.77	0.15-1.39	16.60-49.73	2.84-25.84
F_1	20.13-44.43	10.87-39.04	616.42-1204.17	438.83-833.44	2.01-3.56	0.88-2.42	37.74-68.47	15.91-45.22
2. Range of heterosis (%)								
MP	-25.90-134.97	-19.28-619.86	-47.52-29.51	-27.37-6.57	-20.29-121.04	-14.24-587.69	-47.52-46.17	-29.00-111.83
BP	-34.20-71.78	-22.89-592.04	-66.54-10.20	-40.95-3.51	-23.09-75.11	-15.61-28.66	-66.54-34.27	-51.35-61.05
CC	-35.56-35.61	-97.03-18.45	-12.80-70.35	-4.08-27.35	-13.11-53.89	-59.10-12.04	-15.84-47.83	-61.74-26.74
3. Number of desirable significant heterotic crosses over								
MP	22	29	3	4	24	15	15	14
BP	10	19	1	0	15	28	8	9
CC	6	3	23	19	15	22	16	4
4. Top three parents								
	P12 (34.53)	P8 (30.99)	P13 (1842.00)	P13 (1063.17)	P10 (2.77)	P11 (1.39)	P10 (49.73)	P11 (25.84)
	P10 (31.73)	P11 (20.91)	P6 (1058.33)	P1 (937.78)	P4 (2.61)	P10 (1.27)	P2 (49.07)	P10 (23.89)
	P2 (31.53)	P10 (19.25)	P5 (908.28)	P6 (802.78)	P6 (2.58)	P6 (1.21)	P4 (48.27)	P6 (23.02)
5. Best three hybrids with their heterosis								
MP	P9×P13 (134.97)	P9×P13 (619.86)	P9×P12 (29.51)	P2×P14 (6.57)	P9×P13 (121.04)	P9×P13 (587.69)	P6×P13 (46.17)	P4×P13 (111.83)
	P8×P13 (111.58)	P9×P14 (403.48)	P10×P14 (14.59)	P8×P14 (6.57)	11×P13 (73.36)	P9×P14 (289.54)	P1×P13 (43.69)	P5×P13 (107.45)
	P11×P13 (70.78)	P9×P12 (229.97)	P11×P14 (11.39)	P10×P12 (6.30)	P7×P13 (71.93)	P9×P13 (215.76)	P3×P14 (43.18)	P5×P14 (74.09)
BP	P9×P13 (71.78)	P9×P13 (592.04)	P10×P14 (10.20)	-	P9×P13 (75.11)	P9×P13 (425.88)	P6×P14 (34.27)	P5×P14 (61.05)
	P3×P14 (43.84)	P9×P14 (211.57)			P7×P13 (69.70)	P10×P12 (126.07)	P3×P14 (34.18)	P5×P13 (42.26)
	P8×P13 (34.06)	P10×P14 (100.07)			P8×P13 (62.20)	P8×P13 (99.66)	P6×P12 (34.02)	P6×P14 (40.08)
CC	P3×P12 (35.61)	P8×P14 (18.45)	P6×P13 (70.35)	P7×P13 (27.35)	P10×P14 (53.89)	P10×P14 (12.04)	P10×P13 (51.68)	P11×P13 (26.74)
	P7×P12 (33.37)	P10×P14 (16.87)	P5×P13 (69.99)	P1×P13 (27.35)	P10×P13 (52.45)		P11×P13 (48.60)	P10×P13 (14.01)
	P8×P12 (30.21)	P9×P14 (14.95)	P4×P13 (54.04)	P9×P13 (25.21)	P11×P12 (44.67)		P10×P14 (47.83)	P9×P13 (13.58)
6. Best F_1 hybrid	P9×P13	P9×P14	P10×P14	P7×P13	P10×P14	P9×P13	P10×P13	P5×P13

Conclusion

On the basis of both season performances, it is concluded that the maximum significant heterosis exhibited by cross P7 × P13 for earliness characters like days to first flower, days to 50% flower and days to first ripening over mid, better and commercial check whereas, P10 × P14 showed the maximum heterosis per cent for number of leaves before truss. In tomato, number of fruits per plant and average ten fruit weight are the direct component of yield. The result also indicated that maximum yield per plant in the above mentioned hybrids was attributed by maximum number of fruits per plant. Therefore, tomat mutant (P13) × cultivated hybrids were found to high and positive heterosis for yield related traits. Therefore, earliness and yield can more accurately be estimated by the days to first ripening and number of fruits per plant, and it would be possible to achieve yield improvement with early crop by manipulating this particular traits. Hence, breeders should concentrate mainly on days to first ripening and fruit number in their efforts to obtain high and early yield.

Referenses:

Chauhan, V.B.S., Kumar, R., Behera, T.K. and Yadav, R.K. (2014).Studies on heterosis for yield and its attributing traits in tomato (*Solanumlycopersicum* L.).Intern.Journ.of Agricul. Environ.an d Biotech., 7 (1): 95-100.

Chattopadhyay, A. and Paul, A. 2012.Studies on Heterosis for yield and its Attributing Traits in Tomato (*Solanumlycopersicum* L.).Int. J. of Agric. Env. Biotech, 5(4): 405-410.

FAOSTAT, (2017).Food and Agriculture organization of the United Nations Statistical Databases.http://faostat.fao.org/.

FAOSTAT, (2018).Food and Agriculture organization of the United Nations Statistical Databases.http://faostat.fao.org/.

Ghadage, N.C., G.U. Kulkarni, H.R. Meta and Raju Shyadambi. 2019. Heterosis Studies for Fruit Yield and its Components in Tomato (*Solanumlycopersicum* L.). Int.J.Curr.Microbiol.App.Sci. 8(07): 1011-1020.

Indurani, C and Veeraragavathatham, D. (2012). Combining ability and gene action for yield and processing qualities in F_1 tomato (*Lycopersicon esculentum* Mill.) hybrids. Int. J. of Plant Breed. Agric. and Biol. Sci., 5(1): 1-9.

Kempthorne, O (1957). An introduction to genetic statistics.John Wiley and sons.Inc. New York.

Kumar, P., Paliwal, A., Pant, S.C., Bahuguna, P. and Abrol, G. (2016). Heterosis studies in tomato (Lycopersicon esculentum Mill.) for yield and yield attributing traits for further implications in crop improvement. Journal of Bio Innovation 5:959 -72.

Shankar, A., Reddy, R.V.S.K., Sujata, M. and Pratap, M. (2013). Genetic variability studies in F1 generation of tomato (*Solanum lycopersicon* L.) JOSR J. Agric. Vet. Sci. 4(5): 31-34.

Singh, R.K. and Chaudhary, B.D. (1987).Biometrical Methods in Quantitative Genetic Analysis.Kalyani Publishers, New Delhi, Ludhiana, India, 318.