International Journal of Environment and Climate Change

Volume 12, Issue 12, Page 178-186, 2022; Article no.IJECC.93678
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Studies on Heterosis Employing Leaf Curl Resistant Mutant for Several Horticultural Traits Related to Earliness and Yield in Tomato (*Solanum lycopersicum* L.)

Rajneesh Srivastava [a*], V. M. Prasad [b] and Kamlesh Meena [a]

[a] Krishi Vigyan Kendra (ICAR-IIVR), Malhana, Deoria, Uttar Pradesh, India.
[b] Department of Horticulture, NAI, SHUATS, Prayagraj, Uttar Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i121451

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/93678

Original Research Article

Received: 07/09/2022
Accepted: 14/11/2022
Published: 17/11/2022

ABSTRACT

Aim: Determine the degree of heterosis for the yield and earliness component qualities in order to generate hybrids for early and high yield through heterosis breeding.
Study Design: The experiment was laid out in Randomized Block Design with three replications.
Place and Duration of Study: The experiment was conducted at the ICAR-Indian Institute of Vegetable Research in Varanasi, which is located about 20 kilometres to the southwest of the city on the Ganga River's bank at an elevation of 128.93 metres above mean sea level and lies between 82.52 degrees east and 25.10 degrees north (MSL). The experiment was carried out in late Kharif in 2015 and 2016, as well as in the summer of 2017.
Methodology: In total 33 crosses were developed using 14 tomato genotypes, including the tomato

**Corresponding author: E-mail: rajneeshkvk@gmail.com;*

leaf curl virus susceptible variety Punjab Chhuhara and the advanced breeding line H-88-78-2, a mutant resistant to leaf curl with altered inflorescence and ripening, in order to evaluate the heterosis for earliness and yield attributes. Three cultivars were the male parents (testers), while eleven cultivars were the female parents (line). As a result, 33 tomato hybrids were developed adopting the line tester method. Each line in this design is paired with one of the "t" testers using a random sample of "l" lines. Over the better parent, the mid parent, and the standard/check (Arka Rakshak) heterosis was estimated according to Singh and Chaudhary (1979).

Results: Based on results from both seasons, the cross P7×P13 showed the highest significant negative heterosis per cent for earliest traits like days to first flower (-46.43, -43.80), days to 50% flowering (-35.66, -50.00), and days to first ripening (-30.09, -28.74) over superior parent in first and second seasons, respectively. The hybrid P9×P13 displayed the highest significant heterosis per cent for the features linked to yield in the first and second seasons, for the number of fruits per plant (71.78, 592.04) and yield per plant (75.11, 425.88). The outcome showed that minimum days of first blooming and first ripening are indicative of earliness, and the maximum yield per plant was associated with the highest possible number of fruits per plant.

Conclusion: Based on the results of both seasons, it was determined that the tomato mutant (P13) generated hybrids had low and negative heterosis for qualities associated to earliness and high and positive heterosis for traits related to yield. As a result, the number of fruits per plant and the number of days before the first fruit ripens are better measures of output and earliness. By altering this particular attribute, it would be possible to improve productivity with early crops. Breeders should therefore concentrate largely on the number of fruits and the days to first ripening in order to achieve a high and early yield.

Keywords: Tomato; earliness; yield; heterosis.

1. INTRODUCTION

The tomato, or *Solanum lycopersicum* L, is a member of the Solanaceae family and is one of the most extensively consumed and cultivated vegetables in the world, coming in second to potatoes in many nations. It is a significant vegetable crop that has grown in almost every country in the world in open fields, greenhouses, and net houses. It has gained remarkable popularity over the past century. The tomato fruits, which have an acidic flavour more akin to a vegetable and are quite adaptable in the kitchen, can be eaten raw or cooked. Large amounts of tomato are used to make soup, juice, ketchup, puree, paste, and powder. With a global production of more than 182.30 million MT from an area of 4.85 million hectares, tomatoes are grown in the majority of the world's nations and come in second place behind potatoes [1]. Major tomato producers include China, Turkey, Italy, the United States, and China. Potato (28.9%), tomato (11.3%), onion (10.3%), and brinjal (8.1%) are the four primary vegetable crops, and together they account for 58.6% of the nation's total vegetable production. Throughout the nation's several states, tomato cultivation is very common. More than 65% of the nation's production is produced in the states of Andhra Pradesh, Madhya Pradesh, Karnataka, Orissa, Maharashtra, Bihar, West Bengal, and Gujarat. Although tomato production and area have increased consistently in our country, the productivity (25.98 t/ha) is still low compared to the global average (37.6 t/ha) [2].

Heterosis is a global phenomena that affects crops that are both self-pollinated and cross-pollinated. It is described as the enhanced vigour of F1 compared to the superior parent, mean parents, or standard check (Peter and Rai, 2006). Determine whether the hybrids have economic potential and should be exploited using heterosis estimates. Because using hybrid vigour or heterosis is a quick and practical way to combine desirable traits, it has gained more significance in the creation of hybrids. Through earliness and yield-attributing traits in tomato, heterosis breeding offers a chance to increase output. The goal of the current study is to quantify the degree of heterosis for the yield and earliness component qualities.

2. MATERIALS AND METHODS

The experiment was conducted at the ICAR-Indian Institute of Vegetable Research in Varanasi, which is located about 20 kilometres to the southwest of the city on the Ganga River's bank at an elevation of 128.93 metres above

mean sea level and lies between 82.52 degrees east and 25.10 degrees north (MSL). The chosen plot of land had a consistent texture and a homogenous fertility state. The experimental field's soil had a sandy loam texture and was adequately well drained. The soil's chemical composition was neutral, with low levels of organic carbon, low levels of nitrogen, and medium levels of phosphate and potash. From IIVR, Varanasi, acquired 14 tomato genotypes made up of germplasm, advanced breeding lines, and the susceptible variety Punjab Chhuhara for leaf curl. In the current study, an advanced breeding line called H-88-78-2 was employed. This mutant has changed inflorescence and ripening and is resistant to leaf curl. Eleven cultivars were used as lines (female parents), including the following: 2103-1-2 (P1), VRT 2103-1-4 (P2), 2103-1-8 (P3), 2103-3-6 (P4), and 2103-6-1 (P5); Punjab Chhuhara (P9); Punjab Barkha Bahar -1 (P10); and Punjab Barkha Bahar -2 (P11); and three testers, D-2-2-3 (P12), leaf curl resistant mutant VRT88-78-2 (P13), and CLN-8-6-1 (P14) were used as male parents. Each season's 30 day-old seedlings were transplanted in RBD in three different replications on a 4.50 × 1.20 m plot with a 60 x 45 cm spacing. To raise a good crop, a standardised set of procedures was used.

During the twilight hours, forceps were used to carefully emasculate the mature buds from the female lines. The following morning, hand pollination of emasculated buds was carried out without harming the stigma by collecting pollen from the male parent's flower. Cotton was used to cover the pollinated buds, and crossing tags were used to identify them. The mature red ripe crossed fruits (F1s) were gathered, the seeds were removed, they were dried in the shade, they were packaged in an envelope, and they were saved to be evaluated the following season.

Thirty three F1s, along with their 14 parents and the commercial ceck (Arka Rakhak), were raised in the nursery during the late Kharif, and summer seasons of 2016–2017. When the seedlings were about four weak days old, they were transplanted in a well–prepared plot measuring 4.5 x 1.2 m with a spacing of 60 x 45 cm in RBD for a field experiment. 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 per cent flowering, number of leaves before truss, number of fruits per plant, average ten fruit weight (g), fruit yield per plant (kg), yield per plot (kg) 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 [3] and ANOVA for line × tester analysis was done according to and Singh and Chaudhary [4].

3. RESULT AND DISCUSSION

3.1 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 the range of parents; F1 hybrids mean values and heterosis per centage 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, and 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.

In terms of days to 50% flowering, the parental mean during the first season ranged from 33.67 (P7) to 43.00 (P13). 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 while 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 per cent (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, a 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 per cent (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 several researchers globally and found desirable heterotic hybrids in adesirable direction which were published in Indurani and Veraragavatham [5], Shankar et al. [6], Chauhan et al. [7]; Kumar et al. [8]; Rehana et al. [9]and Ghadage et al. [10].

3.2 Heterosis for Different Horticultural Traits Related to Yield 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). Table 2 summarises the range of parental mean, F1 hybrids mean values, and the percentage of heterosis. 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 hybrids 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.

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 Per centage								
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 Per centage								
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	P7×P13	P7×P13	P7×P13	P10×P13	P4×P13	P7×P13	P7×P13

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
	(-46.43)	(-43.80)	(-35.66)	(-50.00)	(-31.98)	(-45.76)	(-30.09)	(-28.74)
	P8×P14	P11×P13	P8×P13	P11×P13	P5×P13	P1×P13	P8×P13	P8×P13
	(-38.53)	(-43.07)	(-30.23)	(-46.83)	(-29.44)	(-41.24)	(-28.61)	(-23.62)
	P7×P12	P10×P13	P8×P14	P10×P13	P7×P13	P8×P13	P11×P13	P4×P13
	(-31.58)	(-37.96)	(-25.81)	(-38.89)	(-39.60)	(-41.24)	(-22.12)	(-23.62)
CC	P7×P13	P7×P12	P7×P13	P4×P14	-	P8×P14	P7×P14	P8×P14
	(-17.81)	(-29.52)	(-13.54)	(-35.79)		(-19.63)	(-11.67)	(-17.06)
		P7×P13		P7×P13	-	P4×P12		P7×P13
		(-29.52)		(-33.68)		(-18.69)		(-14.22)
				P8×P12	-			P7×P12
				(-33.68)				(-11.85)
6. Best F_1 hybrid	P7× P13	P7× P13	P7×P13	P7× P13	P10×P13	P4× 13	P8× P13	P8× 13

Table 2. Range of mean values of Parents, F1 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

Parameter	No of fruits/plant		Ten Fruits weight (g)		Yield/plant (kg)		Yield/plot (kg)	
	SI	**SII**	**SI**	**SII**	**SI**	**SII**	**SI**	**SII**
BP	10	19	1	0	15	28	8	9
CC	6	3	23	19	15	22	16	4
4. Top three parents								
	P12	P8	P13	P13	P10	P11	P10	P11
	(34.53)	(30.99)	(1842.00)	(1063.17)	(2.77)	(1.39)	(49.73)	(25.84)
	P10	P11	P6	P1	P4	P10	P2	P10
	(31.73)	(20.91)	(1058.33)	(937.78)	(2.61)	(1.27)	(49.07)	(23.89)
	P2	P10	P5	P6	P6	P6	P4	P6
	(31.53)	(19.25)	(908.28)	(802.78)	(2.58)	(1.21)	(48.27)	(23.02)
5. Best three hybrids with their heterosis								
MP	P9×P13	P9×P13	P9×P12	P2×P14	P9×P13	P9×P13	P6×P13	P4×P13
	(134.97)	(619.86)	(29.51)	(6.57)	(121.04)	(587.69)	(46.17)	(111.83)
	P8×P13	P9×P14	P10×P14	P8×P14	11×P13	P9×P14	P1×P13	P5×P13
	(111.58)	(403.48)	(14.59)	(6.57)	(73.36)	(289.54)	(43.69)	(107.45)
	P11×P13	P9×P12	P11×P14	P10×P12	P7×P13	P9×P13	P3×P14	P5×P14
	(70.78)	(229.97)	(11.39)	(6.30)	(71.93)	(215.76)	(43.18)	(74.09)
BP	P9×P13	P9×P13	P10×P14	-	P9×P13	P9×P13	P9×P16	P9×P13
	(71.78)	(592.04)	(10.20)		(75.11)	(425.88)	(34.27)	(61.05)
	P3×P14	P9×P14			P7×P13	P10×P12	P3×P14	P5×P13
	(43.84)	(211.57)			(69.70)	(126.07)	(34.18)	(42.26)
	P8×P13	P10×P14			P8×P13	P8×P13	P6×P12	P6×P14
	(34.06)	(100.07)			(62.20)	(99.66)	(34.02)	(40.08)
CC	P3×P12	P8×P14	P6×P13	P7×P13	P10×P14	P10×P14	P10×P13	P11×P13
	(35.61)	(18.45)	(70.35)	(27.35)	(53.89)	(12.04)	(51.68)	(26.74)
	P7×P12	P10×P14	P5×P13	P1×P13	P10×P13		P11×P13	P10×P13
	(33.37)	(16.87)	(69.99)	(27.35)	(52.45)		(48.60)	(14.01)
	P8×P12	P9×P14	P4×P13	P9×P13	P11×P12		P10×P14	P9×P13
	(30.21)	(14.95)	(54.04)	(25.21)	(44.67)		(47.83)	(13.58)
6. Best F_1 hybrid	P9×P13	P9×P14	P10×P14	P7×P13	P10×P14	P9×P13	P10×P13	P5×P13

Concerning to ten fruit weights (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) to10.20 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 hybrid, 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 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 an average fruit weights are the direct components 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 per cent 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 × P14P4 × P12 and P10 × P12 over mid parent and 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. In respect of 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 aforementioned outcome also showed that the maximum number of fruits per plant in the aforementioned hybrids was responsible for the hybrids' highest yield per plant. As a result, it was discovered that mutant (P13) with developed hybrids had the highest heterosis for attributes relevant to yield. Indurani and Veraragavatham [5]; Chattopadhaya et al. [11]; Shankar et al. [6]; Kumar et al., [8]; Rehana et al. [9]; Ghadage et al. [10] and Mishra et al. (2021) reported significant and favourable heterosis over superior parents for yield traits in tomato.

4. CONCLUSION

According to results from both seasons, cross P7 with P13 showed the most significant heterosis for early characters like days to first flower, days to 50% flower, and days to first ripening over mid, better, and commercial check, whereas P10 with P14 showed the most significant heterosis per cent for several leaves before truss. In tomatoes, the direct component of yield is the number of fruits per plant and the average weight of fruits. The outcome also showed that the largest number of fruits per plant in the aforementioned hybrids was responsible for the hybrids' maximum yield per plant. As a result, it was discovered that tomato mutant (P13) cultivated hybrids had high and favourable heterosis for attributes related to yield.. Therefore, the days until the first fruit ripens and the number of fruits per plant are better indicators of earliness and production, and by modifying this particular attribute, it would be feasible to increase yield with early crops. Therefore, in order to get a high and early production, breeders should focus primarily on the days to first ripening and fruit number.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAOSTAT. Food and Agriculture organization of the United Nations Statistical Databases; 2017. Available: http://faostat.fao.org/
2. FAOSTAT. Food and Agriculture organization of the United Nations Statistical Databases; 2018. Available: http://faostat.fao.org/
3. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers, ICAR Publication. 1967;381.
4. Singh RK. Chaudhary BD. Biometrical Methods in Quantitative Genetic Analysis.Kalyani Publishers, New Delhi, Ludhiana, India. 1987:318.
5. Indurani C, Veeraragavathatham D. 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. 2012;5(1):1-9.
6. Shankar A, Reddy RVSK, Sujata M, Pratap M. Genetic variability studies in F1 generation of tomato (*Solanum lycopersicon* L.) JOSR J. Agric. Vet. Sci. 2013;4(5): 31-34.
7. Chauhan VBS, Kumar R, Behera TK, Yadav RK. Studies on heterosis for yield and its attributing traits in tomato (*Solanumlycopersicum* L.).Intern. Journ. of Agricul. Environ. and Biotech. 2014;7(1): 95-100.
8. 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. Journal of Bio Innovation. 2016;5: 959 -72.
9. Rehana S, Ullah, Mohammad Z, Zeba N, Narzis N, Husna A, Siddique A. Estimation of heterosis for yield and yield attributing traits in tomato crossed with line and tester method. Progressive Agriculture. 2019;30: 179-185.
10. Ghadage NC, Kulkarni GU, Meta HR, Shyadambi R. Heterosis Studies for Fruit Yield and its Components in Tomato (*Solanumlycopersicum* L.). Int. J. Curr. Microbiol. App. Sci. 2019;8(07):1011-1020.
11. Chattopadhyay, A. and Paul, A..Studies on Heterosis for yield and its Attributing Traits in Tomato (*Solanum lycopersicum* L.). Int. J. of Agric. Env. Biotech. 2012;5(4): 405-410.
12. Mishra A, Nandi A, Thriveni V, Das S, Mohanty IC, Pattanayak SK. Heterosis in tomato (*Solanum lycopersicum*) hybrids for growth, yield and quality traits. Pharma Innovation 2021;10(6):220-229.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/93678