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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 975-981

www.thepharmajournal.com
Received: 04-03-2023
Accepted: 12-04-2023

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

Shalini M, RM Hosamani and BG Vasanthi

Abstract
Superior lines of tomato *viz.,* PKM-1, IIVR-Sel-1, BL-342-1, CO-3, H-36 and SB-10 crossed with testers *viz.,* DARL-62, Bilahi-2, DARL-63, BT-120, Swarna Naveen, BT-1, LE-66, H-86 and Punjab Chhuhara in line x tester mating design to develop 54 hybrids to study average heterosis, heterobeltiosis and also economic heterosis for yield and yield attributing traits in tomato (*Solanum lycopersicum* L.). The experiment laid out in randomized block design, at Saidapur Farm, Division of Horticulture, University of Agricultural Sciences, Dharwad. Among the hybrids, two out of fifty four hybrids showed highest per se value in order of 'H-36 x BT-1' and 'H-36 x LE-66' expressed significantly positive average heterosis and heterobeltiosis while 'H-36 X BT-1' exhibited higher *per se* for total yield per plant and significant positive average heterosis, heterobeltiosis and also economic heterosis.

Keywords: Tomato, heterosis, line x tester and yield

Introduction
Tomato (*Solanum lycopersicum* L.) belonging to the family *solanaceae* stands unique among vegetables because of its high nutritive values and myriad uses. Tomato is consumed either fresh, cooked or processed into various products like juice, ketchup, sauce, puree, whole canned fruit and is the main constituent of 'pizzas'. It has medicinal value that pulp and juice are digestible, mild aperients a promoter of gastric secretion and blood purifier. In the present days it is gaining more medicinal importance because of the antioxidant property of ascorbic acid and lycopene content.

Tomato ranks third in priority after potato and onion in India but, ranks second after potato in the world. India ranks second in the world next to China in both area and production. In India, tomato is grown in an area of 0.84 million hectares with an annual production of 20.33 million tonnes (Anonymus, 2022) [2]. In Karnataka, it is grown in an area of 79.96 thousand ha with the production of 3.35 million tonnes with an average yield of 41.94 tonnes per ha.

Though, tomato a self-pollinated crop has a tremendous potential for heterosis breeding, an account of several advantages of hybrids over pure line varieties with response to marketable fruit yield and its component traits as well as resistance to biotic and abiotic stresses. That is why large number of commercial hybrids has been developed in the country in this crop. With increasing popularity of F_1 hybrids in tomato, it is imperative to obtain such hybrids with higher yields and its component characters. By keeping this objective in view the present investigation was under taken.

Materials and Methods
Present investigation was carried out at Saidapur Farm, Division of Horticulture, University of Agricultural sciences, Dharwad by involving inbred lines of fifteen divergent parents which were selected from 23 evaluated genotypes and crossed in line x tester mating design to produce fifty four hybrids. This involves six females (lines) *viz*., PKM-1, IIVR-Sel-1, BL-342-1, CO-3, H-36 and SB-10 and nine males (testers) *viz*., DARL-62, Bilahi-2, DARL-63, BT-120, Swarna Naveen, BT-1, LE-66, H-86 and Punjab Chhuhara available in AICVIP, UAS, Dharwad. The evaluation of hybrids along with their parents and commercial check (CC) Arka Abhijith for various traits were taken up through randomised block design with three replications. All recommended agronomic package of practices were carried out. Five random competitive plants per treatments were selected for recording the observations of yield and yield attributing characters.

The magnitude of heterosis was estimated in relation to mid parent (MP), better parent (BRP) and commercial check (cc) as percentage increase or decrease of F_1's over the respective mid parent value/better parent value/commercial check. Percent heterosis of F_1's over MP, BRP and CC was calculated using the methods of Turner (1953) [18] and Hayes *et al.* (1955) [8].

Results and Discussion

The *per se* performance of the parents, F_1's and commercial check, percent heterosis over mid parent (MP), better parent (BP), and commercial check (CC) for the characters studied are presented in Tables 1 to 3.

Table 1: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for Number of fruits per plant, Average fruit weight (g) and total yield per plant (kg)

Sl. No	F_1 hybrid	Number of fruits per plant			Average fruit weight (g)			Total yield per plant (kg)		
		MP	BP	CC	MP	BP	CC	MP	BP	CC
1	PKM1 X DARL-62	27.44**	14.20**	-11.10	13.16	5.75	-14.48	52.30**	28.51**	-13.54
2	PKM1 X Bilahi-2	6.24	-4.87	-25.82**	17.76*	13.10	-13.67	25.23*	8.24	-31.38**
3	PKM1 X DARL-63	46.85**	39.42**	-4.33	24.06**	13.76	-4.13	81.42**	58.44**	-1.85
4	PKM1 X BT-120	0.08	-7.97	-32.36**	41.46**	38.44**	-2.69	24.21*	5.06	-29.85**
5	PKM1 X Swarna Naveen	27.01**	6.83	-3.42	-8.29	-21.06**	-23.10*	13.51	-15.36*	-20.31*
6	PKM1 X BT-1	44.03**	33.06**	-3.20	11.07	9.44	-23.09*	46.84**	27.70*	-20.00
7	PKM1 X LE-66	17.96**	-8.24*	1.82	8.85	7.53	-24.43*	26.33**	-2.30	-17.23
8	PKM1 X H-86	71.54**	59.10**	-1.87	39.40**	36.36**	0.20	104.99**	86.23**	5.54
9	PKM1 X Punjab Chhuhara	19.24**	10.57	-20.21**	64.84**	33.99**	-5.83	99.74**	73.39**	-19.69*
10	IIVR-sel-1 X DARL-62	56.46**	43.46**	11.69*	-6.13	-12.14	-18.51	47.82**	44.66**	-2.77
11	IIVR-sel-1 X Bilahi-2	33.56***	22.38**	-4.57	-10.36	-18.30*	-24.22*	20.93*	20.06*	-22.77*
12	IIVR-sel-1 X DARL-63	49.16**	45.13**	-0.42	0.33	-4.25	-11.19	50.16**	47.29**	-5.23
13	IIVR-sel-1 X BT-120	49.75**	41.10**	3.63	12.15	-3.26	-10.26	51.88**	49.08**	-0.31
14	IIVR-sel-1 X Swarna Naveen	6.44	-8.57	-17.33	5.69	3.17	0.50	-8.28	-22.77**	-27.38**
15	IIVR-sel-1 X BT-1	37.80**	30.37**	-5.15	3.08	-10.55	-17.02	17.93	16.24	-25.23**
16	IIVR-sel-1 X LE-66	26.83**	0.51	11.54*	-0.40	-13.38	-19.66	28.84**	13.45	-4.00
17	IIVR-sel-1 X H-86	76.06**	59.54**	3.57	4.73	-6.15	-12.95	59.83**	50.16**	-3.38
18	IIVR-sel-1 X Punjab Chhuhara	44.77**	37.50**	-0.77	33.38**	-1.69	-8.81	96.87**	50.48**	-3.08
19	BL-342-1 X DARL-62	41.00**	13.61*	-11.54*	-3.94	-19.07**	-4.45	41.85**	34.60**	-9.54
20	BL-342-1 X Bilahi-2	16.43**	-6.23	-26.89**	1.00	-16.85**	-1.81	23.18*	20.19	-23.69*
21	BL-342-1 X DARL-63	47.45**	24.88**	-14.31*	-16.89**	-28.79**	-15.91	26.24**	24.67*	-22.77*
22	BL-342-1 X BT-120	35.65**	11.77*	-17.86**	-14.17*	-32.63**	-20.45*	10.07	4.75	-29.85**
23	BL-342-1 X Swarna Naveen	5.33	-19.59**	-27.31**	0.44	-8.35	8.22	-1.66	-19.28**	-24.00*
24	BL-342-1 X BT-1	35.16**	11.81*	-18.66**	-5.88	-25.75**	-12.32	24.10*	21.97*	-23.69*
25	BL-342-1 X LE-66	23.34**	-11.87**	-2.21	-16.74*	-34.19**	-22.30*	12.31	-3.76	-18.46*
26	BL-342-1 X H-86	80.06**	71.33**	-9.66	-10.57	-27.46**	-14.35	41.98**	37.52**	-16.92
27	BL-342-1 X Punjab Chhuhara	50.48**	24.89**	-9.88	-2.02	-32.76**	-20.61*	62.00**	26.66*	-23.38*
28	CO-3 X DARL-62	-16.43**	-23.50**	-28.31**	4.42	1.59	-17.85	-11.35	-16.64	-36.31**
29	CO-3 X Bilahi-2	20.24**	10.15*	3.21	-3.16	-3.26	-26.01*	16.72	6.85	-18.46*
30	CO-3 X DARL-63	5.10	-8.97*	-14.69*	4.81	-0.04	-15.75	11.49	0.94	-22.77*
31	CO-3 X BT-120	23.50**	10.18*	3.25	8.18	1.67	-22.22*	20.26*	12.75	-13.85
32	CO-3 X Swarna Naveen	1.36	-0.43	-6.68	3.11	-7.96	-10.35	4.75	-5.12	-10.77
33	CO-3 X BT-1	15.58**	2.66	-3.79	2.57	-2.97	-25.78*	3.91	-5.50	-27.69**
34	CO-3 X LE-66	2.61	-5.37	5.00	18.53*	12.40	-14.03	16.69*	11.03	-6.15
35	CO-3 X H-86	-8.20	-28.27**	-32.77**	6.58	4.49	-20.07	17.50	2.28	-21.85*
36	CO-3 X Punjab Chhuhara	-22.82**	-31.69**	-35.99**	17.33	-7.61	-29.33**	-12.16	-36.51**	-51.38**
37	H-36 X DARL-62	13.81**	5.57	-3.90	29.21**	28.56**	5.02	47.21**	35.82**	8.00
38	H-36 X Bilahi-2	2.68	-4.68	-13.24*	9.92	6.32	-13.15	13.12	1.68	-19.08*
39	H-36 X DARL-63	44.69**	26.88**	15.49**	-1.31	-2.82	-18.10	43.04**	27.19**	1.23
40	H-36 X BT-120	37.08**	23.87**	12.76*	29.53**	18.11*	-3.52	58.96**	46.26**	16.31
41	H-36 X Swarna Naveen	-6.81	-7.13*	-15.46**	-2.63	-10.49	-12.81	-9.45	-16.45*	-21.23*
42	H-36 X BT-1	48.23**	33.36**	21.39**	34.26**	23.19*	0.63	69.99**	51.80**	20.92*
43	H-36 X LE-66	17.75**	7.17	18.93**	18.00*	8.53	-11.34	31.79**	27.88**	8.31
44	H-36 X H-86	27.67**	0.81	-8.23	30.95**	24.37**	1.60	47.44**	26.16**	0.31
45	H-36 X Punjab Chhuhara	26.94**	13.79**	3.58	29.22**	-0.61	-18.80	55.05**	10.70	-12.00
46	SB-10 X DARL-62	49.17**	47.28**	14.68*	16.18	5.16	-14.96	56.72**	39.63**	-6.15
47	SB-10 X Bilahi-2	38.09**	36.24***	6.24	1.02	-6.13	-28.34**	24.56**	13.89	-27.69**
48	SB-10 X DARL-63	26.60**	20.54**	-8.52	15.62	2.76	-13.40	31.60**	21.69	-24.62**
49	SB-10 X BT-120	41.15**	38.93**	5.42	20.05*	18.48	-20.29	40.77**	25.77*	-16.00

50	SB-10 X Swarna Naveen	41.34**	29.99**	17.52**	7.83	-9.81	-12.14	40.18**	9.26	2.77
51	SB-10 X BT-1	54.00**	50.83**	14.45*	22.56*	20.14	-18.04	74.53**	60.66**	0.62
52	SB-10 X LE-66	21.78**	2.53	13.76*	11.16	8.69	-25.45*	32.29**	7.27	-9.23
53	SB-10 X H-86	78.02**	50.86**	14.58*	11.09	5.08	-22.78*	72.21**	66.12**	-5.85
54	SB-10 X Punjab Chhuhara	36.93**	33.57**	1.36	24.28*	3.85	-31.95**	69.47**	39.57**	-26.46**
	Arka Abhijith (CC)									
	S.Em+	2.26	2.61	2.61	3.58	4.14	4.14	0.19	0.22	0.22
	CD at 5%	5.40	7.21	7.21	8.56	11.44	11.44	0.45	0.61	0.61
	CD at 1%	7.11	9.50	9.50	11.26	15.06	15.06	0.59	0.80	0.80

*, **: Indicates significant at 5 and 1% level of probability respectively

Table 2: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for Number of clusters per plant, Number of flowers per cluster and Number of fruits per cluster

Sl. No	F_1 hybrid	Number of clusters per plant			Number of flowers per cluster			Number of fruits per cluster		
		MP	BP	CC	MP	BP	CC	MP	BP	CC
1	PKM1 X DARL-62	28.74	26.14	-21.12	1.69	-4.38	-8.57	6.47	-1.96	-7.47
2	PKM1 X Bilahi-2	23.43	11.99	-14.05	11.97*	4.58	1.52	6.36	-3.39	-6.02
3	PKM1 X DARL-63	0.06	-15.50	-23.27	13.48*	12.57*	-3.81	28.72**	22.35**	-2.89
4	PKM1 X BT-120	6.13	5.56	-33.27	-8.17	-12.15	-26.10**	-4.09	-7.43	-20.96*
5	PKM1 X Swarna Naveen	57.80**	57.87**	-1.32	22.48**	18.34**	-0.38	18.70**	11.11	1.20
6	PKM1 X BT-1	83.59**	79.01**	11.90	-26.83**	-36.10**	-27.81**	-13.21*	-23.70**	-20.00*
7	PKM1 X LE-66	47.90**	36.94*	0.54	5.15	-1.83	-4.76	1.96	-7.14	-10.12
8	PKM1 X H-86	39.10*	28.85	-5.51	-10.06	-10.17	-24.19**	41.40**	18.81*	-5.54
9	PKM1 X Punjab Chhuhara	33.02	21.14	-24.24	3.14	-4.15	-6.10	8.21	-7.38	-26.51**
10	IIVR-sel-1 X DARL-62	43.04*	35.98	-9.46	-37.46**	-41.70**	-44.19**	18.18**	4.85	-0.96
11	IIVR-sel-1 X Bilahi-2	39.69**	30.43	0.10	6.46	-1.31	-4.19	-9.48	-20.73**	-22.89*
12	IIVR-sel-1 X DARL-63	0.22	-13.16	-21.12	-8.27	-9.74	-22.86**	34.04**	32.64**	-3.13
13	IIVR-sel-1 X BT-120	46.86**	43.16*	-4.68	27.68**	23.01**	1.90	46.68**	36.12**	16.14
14	IIVR-sel-1 X Swarna Naveen	35.10*	31.00	-12.78	20.90**	17.79**	-2.48	39.92**	26.10**	14.94
15	IIVR-sel-1 X BT-1	35.86*	28.55	-14.44	-3.79	-16.56**	-5.71	-1.45	-16.33*	-12.29
16	IIVR-sel-1 X LE-66	19.72	14.13	-16.20	-8.05	-14.73**	-17.33*	13.62*	-0.25	-3.61
17	IIVR-sel-1 X H-86	23.64	17.92	-13.51	19.13**	18.15**	-0.38	66.14**	44.15**	5.54
18	IIVR-sel-1 X Punjab Chhuhara	38.79*	22.98	-18.15	-35.72**	-40.76**	-41.90**	57.25**	39.45**	1.93
19	BL-342-1 X DARL-62	27.40	23.41	-25.95	-17.41**	-26.36**	-29.52**	11.28	-2.21	-7.71
20	BL-342-1 X Bilahi-2	28.83	11.63	-14.34	-11.73*	-21.70**	-24.00**	28.03**	11.07	7.95
21	BL-342-1 X DARL-63	23.71	0.14	-9.02	14.96*	8.03	-7.81	38.69**	38.61**	-0.72
22	BL-342-1 X BT-120	26.42	19.42	-24.49	11.17	9.83	-15.62*	25.55**	15.33	-1.45
23	BL-342-1 X Swarna Naveen	30.68	24.14	-22.39	33.50**	30.61**	2.48	23.32**	10.05	0.24
24	BL-342-1 X BT-1	55.70**	51.64*	-10.00	-3.85	-19.99**	-9.52	5.56	-11.20	-6.99
25	BL-342-1 X LE-66	28.97	13.91	-16.39	-6.31	-16.88**	-19.43**	-1.81	-14.62*	-17.35
26	BL-342-1 X H-86	15.44	3.33	-25.22	-5.85	-10.92	-24.95**	46.51**	28.65**	-7.95
27	BL-342-1 X Punjab Chhuhara	29.01	23.42	-30.59	21.59**	7.26	5.14	71.89**	53.93**	10.12
28	CO-3 X DARL-62	2.26	-8.68	-30.34	-10.20*	-17.33**	-6.10	8.62	7.40	3.61
29	CO-3 X Bilahi-2	29.91*	29.48	-0.63	-3.25	-10.29*	1.90	12.47*	12.06	8.92
30	CO-3 X DARL-63	19.77	10.15	0.05	-4.60	-16.49**	-5.14	37.31**	19.55**	15.42
31	CO-3 X BT-120	30.68*	19.51	-8.88	-11.11*	-25.60**	-15.43*	7.81	1.58	-1.93
32	CO-3 X Swarna Naveen	33.50*	21.47	-7.37	5.95	-10.29*	1.71	11.39	8.24	4.58
33	CO-3 X BT-1	70.14**	51.28**	15.37	-15.46**	-15.60**	-4.19	-1.20	-5.06	-0.48
34	CO-3 X LE-66	47.65**	44.90**	10.49	-9.86*	-16.55**	-5.14	-1.66	-1.74	-5.06
35	CO-3 X H-86	-4.63	-6.50	-28.68	5.10	-8.44	4.00	29.60**	1.08	-2.41
36	CO-3 X Punjab Chhuhara	21.02	1.24	-22.78	-16.22**	-22.14**	-11.43	29.70**	2.83	-0.72
37	H-36 X DARL-62	42.00*	40.11*	-13.66	-6.91	-11.41*	-6.29	7.94	6.98	0.96
38	H-36 X Bilahi-2	26.52	14.07	-12.49	-12.30**	-15.92**	-11.05	-1.23	-3.55	-6.27
39	H-36 X DARL-63	48.10**	24.29	12.88	0.90	-8.89	-3.62	11.69	-1.04	-8.19
40	H-36 X BT-120	78.19**	75.93	11.22	3.76	-10.51*	-5.33	12.22	7.80	0.00
41	H-36 X Swarna Naveen	21.02	20.16	-24.88	-16.65**	-27.33**	-23.24**	-4.20	-5.03	-12.05
42	H-36 X BT-1	105.65**	101.85**	24.39	5.48	2.13	15.43*	18.47**	11.66	16.87
43	H-36 X LE-66	59.47**	46.62**	7.66	13.35**	8.59	14.86*	22.82**	20.27**	16.39
44	H-36 X H-86	41.94**	30.60	-4.24	14.43**	2.88	8.76	23.04**	-2.60	-9.64
45	H-36 X Punjab Chhuhara	78.32**	63.46**	0.73	-2.53	-6.13	-0.76	25.19**	0.78	-6.51
46	SB-10 X DARL-62	68.45**	55.27**	10.44	-10.22*	-12.18*	-12.19	-7.94	-8.26	-13.49

47	SB-10 X Bilahi-2	51.70**	46.18**	12.15	-14.40**	-15.61**	-15.62*	4.21	2.31	-0.48
48	SB-10 X DARL-63	-1.93	-12.55	-20.59	2.36	-5.14	-5.14	23.91**	9.25	2.41
49	SB-10 X BT-120	54.54**	45.94**	3.80	2.16	-9.77	-9.71	13.99*	8.91	2.17
50	SB-10 X Swarna Naveen	55.55**	46.13**	3.95	-3.09	-13.58*	-13.52	11.00	9.43	2.65
51	SB-10 X BT-1	70.24**	56.11**	11.07	-25.11**	-29.37**	-20.19**	0.36	-4.91	-0.48
52	SB-10 X LE-66	39.86**	37.65*	1.07	-1.35	-2.98	-2.86	12.78*	11.05	7.47
53	SB-10 X H-86	40.97**	38.80*	1.80	23.35**	13.65*	13.71	28.48**	1.29	-5.06
54	SB-10 X Punjab Chhuhara	44.17*	24.11	-11.71	-4.91	-5.90	-5.90	26.67**	1.54	-4.82
	Arka Abhijith (CC)									
	S.Em+	2.20	2.55	2.55	0.24	0.28	0.28	0.24	0.28	0.28

*, **: Indicates significant at 5 and 1% level of probability respectively

Table 3: Average heterosis (%), heterobeltiosis (%) and standard heterosis (%) for Number of fruits per plant, Average fruit weight (g) and total yield per plant (kg)

Sl. No	F_1 hybrid	Number of fruits per plant			Average fruit weight (g)			Total yield per plant (kg)		
		MP	BP	CC	MP	BP	CC	MP	BP	CC
1	PKM1 X DARL-62	27.44**	14.20**	-11.10	13.16	5.75	-14.48	52.30**	28.51**	-13.54
2	PKM1 X Bilahi-2	6.24	-4.87	-25.82**	17.76*	13.10	-13.67	25.23*	8.24	-31.38**
3	PKM1 X DARL-63	46.85**	39.42**	-4.33	24.06**	13.76	-4.13	81.42**	58.44**	-1.85
4	PKM1 X BT-120	0.08	-7.97	-32.36**	41.46**	38.44**	-2.69	24.21*	5.06	-29.85**
5	PKM1 X Swarna Naveen	27.01**	6.83	-3.42	-8.29	-21.06**	-23.10*	13.51	-15.36*	-20.31*
6	PKM1 X BT-1	44.03**	33.06**	-3.20	11.07	9.44	-23.09*	46.84**	27.70*	-20.00
7	PKM1 X LE-66	17.96**	-8.24*	1.82	8.85	7.53	-24.43*	26.33**	-2.30	-17.23
8	PKM1 X H-86	71.54**	59.10**	-1.87	39.40**	36.36**	0.20	104.99**	86.23**	5.54
9	PKM1 X Punjab Chhuhara	19.24**	10.57	-20.21**	64.84**	33.99**	-5.83	99.74**	73.39**	-19.69*
10	IIVR-sel-1 X DARL-62	56.46**	43.46**	11.69*	-6.13	-12.14	-18.51	47.82**	44.66**	-2.77
11	IIVR-sel-1 X Bilahi-2	33.56***	22.38**	-4.57	-10.36	-18.30*	-24.22*	20.93*	20.06*	-22.77*
12	IIVR-sel-1 X DARL-63	49.16**	45.13**	-0.42	0.33	-4.25	-11.19	50.16**	47.29**	-5.23
13	IIVR-sel-1 X BT-120	49.75**	41.10**	3.63	12.15	-3.26	-10.26	51.88**	49.08**	-0.31
14	IIVR-sel-1 X Swarna Naveen	6.44	-8.57	-17.33	5.69	3.17	0.50	-8.28	-22.77**	-27.38**
15	IIVR-sel-1 X BT-1	37.80**	30.37**	-5.15	3.08	-10.55	-17.02	17.93	16.24	-25.23**
16	IIVR-sel-1 X LE-66	26.83**	0.51	11.54*	-0.40	-13.38	-19.66	28.84**	13.45	-4.00
17	IIVR-sel-1 X H-86	76.06**	59.54**	3.57	4.73	-6.15	-12.95	59.83**	50.16**	-3.38
18	IIVR-sel-1 X Punjab Chhuhara	44.77**	37.50**	-0.77	33.38**	-1.69	-8.81	96.87**	50.48**	-3.08
19	BL-342-1 X DARL-62	41.00**	13.61*	-11.54*	-3.94	-19.07**	-4.45	41.85**	34.60**	-9.54
20	BL-342-1 X Bilahi-2	16.43**	-6.23	-26.89**	1.00	-16.85**	-1.81	23.18*	20.19	-23.69*
21	BL-342-1 X DARL-63	47.45**	24.88**	-14.31*	-16.89**	-28.79**	-15.91	26.24**	24.67*	-22.77*
22	BL-342-1 X BT-120	35.65**	11.77*	-17.86**	-14.17*	-32.63**	-20.45*	10.07	4.75	-29.85**
23	BL-342-1 X Swarna Naveen	5.33	-19.59**	-27.31**	0.44	-8.35	8.22	-1.66	-19.28**	-24.00*
24	BL-342-1 X BT-1	35.16**	11.81*	-18.66**	-5.88	-25.75**	-12.32	24.10*	21.97*	-23.69*
25	BL-342-1 X LE-66	23.34**	-11.87**	-2.21	-16.74*	-34.19**	-22.30*	12.31	-3.76	-18.46*
26	BL-342-1 X H-86	80.06**	71.33**	-9.66	-10.57	-27.46**	-14.35	41.98**	37.52**	-16.92
27	BL-342-1 X Punjab Chhuhara	50.48**	24.89**	-9.88	-2.02	-32.76**	-20.61*	62.00**	26.66*	-23.38*
28	CO-3 X DARL-62	-16.43**	-23.50**	-28.31**	4.42	1.59	-17.85	-11.35	-16.64	-36.31**
29	CO-3 X Bilahi-2	20.24**	10.15*	3.21	-3.16	-3.26	-26.01*	16.72	6.85	-18.46*
30	CO-3 X DARL-63	5.10	-8.97*	-14.69*	4.81	-0.04	-15.75	11.49	0.94	-22.77*
31	CO-3 X BT-120	23.50**	10.18*	3.25	8.18	1.67	-22.22*	20.26*	12.75	-13.85
32	CO-3 X Swarna Naveen	1.36	-0.43	-6.68	3.11	-7.96	-10.35	4.75	-5.12	-10.77
33	CO-3 X BT-1	15.58**	2.66	-3.79	2.57	-2.97	-25.78*	3.91	-5.50	-27.69**
34	CO-3 X LE-66	2.61	-5.37	5.00	18.53*	12.40	-14.03	16.69*	11.03	-6.15
35	CO-3 X H-86	-8.20	-28.27**	-32.77**	6.58	4.49	-20.07	17.50	2.28	-21.85*
36	CO-3 X Punjab Chhuhara	-22.82**	-31.69**	-35.99**	17.33	-7.61	-29.33**	-12.16	-36.51**	-51.38**
37	H-36 X DARL-62	13.81**	5.57	-3.90	29.21**	28.56**	5.02	47.21**	35.82**	8.00
38	H-36 X Bilahi-2	2.68	-4.68	-13.24*	9.92	6.32	-13.15	13.12	1.68	-19.08*
39	H-36 X DARL-63	44.69**	26.88**	15.49**	-1.31	-2.82	-18.10	43.04**	27.19**	1.23
40	H-36 X BT-120	37.08**	23.87**	12.76*	29.53**	18.11*	-3.52	58.96**	46.26**	16.31
41	H-36 X Swarna Naveen	-6.81	-7.13*	-15.46**	-2.63	-10.49	-12.81	-9.45	-16.45*	-21.23*
42	H-36 X BT-1	48.23**	33.36**	21.39**	34.26**	23.19*	0.63	69.99**	51.80**	20.92*
43	H-36 X LE-66	17.75**	7.17	18.93**	18.00*	8.53	-11.34	31.79**	27.88**	8.31
44	H-36 X H-86	27.67**	0.81	-8.23	30.95**	24.37**	1.60	47.44**	26.16**	0.31
45	H-36 X Punjab Chhuhara	26.94**	13.79**	3.58	29.22**	-0.61	-18.80	55.05**	10.70	-12.00

46	SB-10 X DARL-62	49.17**	47.28**	14.68*	16.18	5.16	-14.96	56.72**	39.63**	-6.15
47	SB-10 X Bilahi-2	38.09**	36.24***	6.24	1.02	-6.13	-28.34**	24.56**	13.89	-27.69**
48	SB-10 X DARL-63	26.60**	20.54**	-8.52	15.62	2.76	-13.40	31.60**	21.69	-24.62**
49	SB-10 X BT-120	41.15**	38.93**	5.42	20.05*	18.48	-20.29	40.77**	25.77*	-16.00
50	SB-10 X Swarna Naveen	41.34**	29.99**	17.52**	7.83	-9.81	-12.14	40.18**	9.26	2.77
51	SB-10 X BT-1	54.00**	50.83**	14.45*	22.56*	20.14	-18.04	74.53**	60.66**	0.62
52	SB-10 X LE-66	21.78**	2.53	13.76*	11.16	8.69	-25.45*	32.29**	7.27	-9.23
53	SB-10 X H-86	78.02**	50.86**	14.58*	11.09	5.08	-22.78*	72.21**	66.12**	-5.85
54	SB-10 X Punjab Chhuhara	36.93**	33.57**	1.36	24.28*	3.85	-31.95**	69.47**	39.57**	-26.46**
	Arka Abhijith (CC)									
	S.Em+	2.26	2.61	2.61	3.58	4.14	4.14	0.19	0.22	0.22
	CD at 5%	5.40	7.21	7.21	8.56	11.44	11.44	0.45	0.61	0.61
	CD at 1%	7.11	9.50	9.50	11.26	15.06	15.06	0.59	0.80	0.80

*, **: Indicates significant at 5 and 1% level of probability respectively

Plant height

Out of 54 F_1s, 8 showed significant positive heterosis, while 6 had significant negative heterosis for this trait. Heterosis in F_1s over their respective better parent ranged from -31.77 ('H-36' x 'Swarna Naveen') to 32.04 percent ('H-36' x 'LE-66'). Over the better parent four hybrids expressed significant positive heterosis while twenty three crosses exhibited significant negative heterosis indicating the presence of over dominance effect in these crosses. Twenty-seven crosses were showing positive heterosis over mid parent out of which only eight showed significant heterosis, indicating the presence of both additive and non-additive gene effects in these crosses for plant height. Singh and Asati (2011) [15], Yadav *et al.* (2013) [20] and Ahmed *et al.* (2011) [1] also reported positive significant heterosis for plant height in tomato.

Number of primary branches

The extent of heterosis over mid parent was -25.43 ('BL-342-1'x 'LE-66') to 49.54 percent ('PKM-1' x 'BT-1'). Out of 54 crosses, nine showed significant positive heterosis, while only one had significant negative heterosis. Heterosis over better parent ranged from -36.06 ('IIVR-Sel-1' x 'DARL-62') to 38.98 percent ('PKM-1' x 'BT-1'). The heterosis over commercial check varied from -48.30 to -36.46 percent. For number of branches per plant nineteen crosses showed positive heterosis over the commercial check, out of which none of them showed significant heterosis but three crosses showed significant negative heterosis over commercial check. Thirty four hybrids were showing negative heterosis over better parent and twenty one hybrids showing significantly negative heterosis over mid parent suggesting the importance of non-additive gene action of number of branches per plant. Shankar *et al.* (2013) [14], Solieman *et al.* (2013) [16] and Madhavi *et al.* (2013) [11] also observed similar results for above said growth parameter.

Days to 50 percent flowering

The heterosis over mid parent ranged from -17.70 ('CO-3' x 'Swarna Naveen') to 12.24 percent ('BL-342-1'x 'Bilahi-2'). Only one cross showed significant positive heterosis over mid parent, while three crosses exhibited significant negative heterosis. The cross 'PKM-1' x 'BT-120' showed significant positive heterosis of 18.84 percent over better parent while none of them showed significant heterosis over better parent. Thirty five crosses out of fifty four showed negative economic heterosis indicating early flowering in hybrids. While eighteen and thirty eight crosses showed negative heterosis over better parent and mid parent respectively. Similar results were observed by Shankar *et al.* (2013) [14] and Madhavi *et al.* (2013) [11].

Number of clusters per plant

Number of clusters per plant is one of the important yield component. All the crosses accept one ('SB-10' x 'DARL-63') exhibited positive heterosis over mid parent and forty nine crosses out of fifty four crosses showed positive heterobeltiosis. Thus indicating the predominance of non-additive gene effects for the said trait. Eighteen hybrids recorded positive economic heterosis. Similar trend was noticed by Duhan *et al.* (2005) [3] and Hannan, *et al.* (2007) [7].

Number of flowers per cluster

Out of 54 crosses, 12 crosses showed significant positive heterosis and 13 crosses exhibited significant negative heterosis. The range of better parent heterosis varied from -41.70 ('IIVR-Sel-1' x DARL-62) to 30.61 ('BL-342-1'x 'Swarna Naveen'). For number of flowers per cluster, only 2 crosses *viz.*, 'H-36' x 'BT-1'and 'H-36' x 'LE-66' showed significant positive heterosis over commercial check. Twelve and seven hybrids showed significant positive heterosis over mid and better parent respectively. Positive heterosis over better parent for this trait has also been reported by Pemba *et al.* (2014) [12], Enang *et al.* (2015) [4] and Hamisu *et al.* (2018) [6]

Number of Fruits per cluster

Heterosis over mid parent and better parent ranged from -13.21 and -23.70 ('PKM-1' x 'BT-1') to 71.89 and 53.93 percent ('BL-342-1'x 'Punjab Chhuhara') respectively. Significant positive and negative heterosis was noticed in twenty nine and single crosses respectively over mid parent. Whereas over commercial check four crosses registered significant negative heterosis. Number of fruits per cluster indicated the percent fruit set. Twelve hybrids showed significant positive heterobeltiosis. While forty four crosses showed positive average heterosis in which twenty nine were showing significant positive direction. These results are on line with Veena *et al.* (2017) [19], Raj *et al.* (2018) [13] and Hamisu *et al.* (2018) [6].

Number of Fruits per plant

With regard to heterosis over mid parent and better parent, the 'CO-3' x 'Punjab Chhuhara' and 'BL-342-1'x 'H-86' produced fruits ranging from -22.82 to 80.06 and -31.69 to 71.33 percent respectively. The maximum heterosis (21.39%) over commercial check was manifested by 'H-36' x 'BT-1'.

Except eleven crosses, all most all the crosses showed significant positive heterosis over mid parent while thirty one crosses showed significant positive heterosis over better parent for number of fruits per plant. Over commercial check eleven crosses showed significant positive heterosis indicating both additive and non-additive gene effect for the trait. Similar trend was noticed by Veena *et al.* (2017) [19], Kumar *et al.* (2017) [10], Gautam *et al.* (2018) [5], Raj *et al.* (2018) [13] and Hamisu *et al*. (2018) [6].

Average fruit weight (g)

The cross 'PKM-1' x 'BT-120' recorded the highest (38.44) heterobeltiosis and 'BL-342-1'x 'LE-66' recorded the lowest (34.19). Sixteen out of fifty four crosses expressed significant positive heterosis over mid parent and seven crosses exhibited significant positive heterosis over better parent. The studies corroborate with the findings of Shankar *et al.* (2013) [14], Solieman *et al.* (2013) [16], Triveni *et al.* (2017) [17] and Veena *et al.* (2017) [19].

Total yield per plant

Yield is a composite character, evidences suggest that heterosis of such a compound character is much regulated by the vigour expressed by its component character such as average fruit weight, clusters per plant and number of fruits per plant.

Except five and ten crosses out of fifty four hybrids manifested positive average heterosis and heterobeltiosis respectively in desired direction for total yield per plant. Commercial check had a yield potential of 3.25 kg. Heterosis over better parent and commercial check ranged from -36.51 to 86.23 percent and -51.38 to 20.92 respectively. Thirty-five crosses out of fifty four showed significant positive heterosis over mid parent value suggesting greater role of additively for this trait. Positive heterosis for fruit yield was reported earlier by Madhavi *et al.* (2013) [11], Kumar *et al.* (2018) [9], Raj *et al.* (2018) [13] and Hamisu *et al.* (2018) [6].

Conclusion

Among the hybrids, two out of fifty four hybrids showed highest per se value in order of 'H-36 x BT-1' and 'H-36 x LE-66' expressed significantly positive average heterosis and heterobeltiosis while 'H-36 x BT-1' showed heterosis over commercial check as well. Evidences suggest that yield was regulated by the hybrid vigour expressed by its component characters such as number of branches per plant, number of flowers per cluster, number of fruits per cluster and number of fruits per plant.

References

1. Ahmad S, Quamruzzaman AKM, Islam MR. Estimation of heterosis in tomato (*Solanum lycopersicum* L.). Bangladesh Journal of Agricultural Research. 2011;36(3):521-527.
2. Anonymous. Available at https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/jul/doc202271470601.pdf [Visited on 15 May, 2023]
3. Duhan D, Partap PS, Rana MK, Dahiya MS. Heterosis study for quality characters in a line x tester set of tomato. Haryana Journal of Horticulture Science. 2005;34:371-375.
4. Enang EM, Kadams AM, Simon SY, Louis SJ. Heterosis and general combining ability study on heat tolerant tomato (*Lycopersicon esculentum* Mill). International Journal of Horticulture. 2015;5(17):1-7.
5. Gautam N, Kumar M, Vikram A, Kumar S, Sharma S. Heterosis studies for yield and its components in tomato (*Solanum lycopersicum* L.) under North Western Himalayan Region, India. International Journal of Current Microbiology and Applied Sciences. 2018;7(02):1949-1957.
6. Hannan MM, Ahmed MB, Razvy MA, Karim R, Khatun M, Haydar A, *et al.* Heterosis and Correlation of Yield and Yield Components in Tomato (*Lycopersicon esulentum* Mill.). American-Eurasian Journal of Scientific Research. 2007;2(2):146-150.
7. Hamisu HS, Ado SG, Yeye MY, Usman IS, Mohammed SM, Usman A *et al*. Heterosis for fruit yield and heat tolerance traits in tomato (*Lycopersicon lycopersicum* Mill.) under field condition. Journal of Agricultural Studies. 2018;6(2):48-62.
8. Hayes HK, Immer IR, Smith DC. Methods of Plant Breeding. McGraw Hill Book Company, International Corporation, New York; c1955.
9. Kumar S, Singh V, Praveen KM, Kumar BA, Yadav PK. Evaluation of F1 hybrids along with parents for yield and related characteristics in tomato (*Solanum lycopersicum* Child). International Journal of Current Microbiology and Applied Sciences. 2017;6(9):2836-2845.
10. Kumar MS, Pal AK, Singh AK. Studies on heterosis andinbreeding depression for quality traits and yield in tomato (*Solanum lycopersicum* L.). International Journal of Current Microbiology and Applied Sciences. 2018;7(06):3682-3686.
11. Madhavi Y, Reddy RVSK, Thirupathi reddy M, Sudheer Kumar S, Bhave MHV. Exploitation of heterosis and combining ability for yield, quality and processing in tomato (*Solanum lycopersicum* L.). Ph.D. thesis, Dr.Y.S.R. Horticultural University, Andhra Pradesh; c2013.
12. Pemba S, Seth T, Shende VD, Pandiarana N, Mukherjee S, Chattopadhyay A. Heterosis, dominance estimate and genetic control of yield and post-harvest quality traits of tomato. Journal of Applied and Natural Science. 2014;6(2):625-632.
13. Raj T, Bhardwaj ML, Pal S, Kumari S, Dogra RK. Performance of tomato (*Solanum lycopersicum* L.) hybrids for yield and its contributing traits under mid-hill conditions of Himachal Pradesh. International Journal of Bio-resource and Stress Management. 2018;9(2):282-286.
14. Singh AK, Asati BS. Combining ability and heterosis studies in tomato under bacterial wilt condition. Bangladesh Journal of Agricultural Research. 2011;36:313-318.
15. Shankar A, Reddy RVSK, Prathap M, Sujatha M. Combining ability and gene action studies for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.). Helix. 2013;6:431-435.
16. Solieman THI, El-Gabry MAH, Abido AI. Heterosis, potence ratio and correlation of some important characters in tomato (*Solanum lycopersicum* L.). Scientia Horticulture. 2013;150:25-30.
17. Triveni D, Saidaiah P, Reddy KR, Pandravada SR. Mean performance of the parents and hybrids for yield and

yield contributing traits in tomato. International Journal of Current Microbiology and Applied Sciences. 2017;6(11):613-619.
18. Turner JM. A study of heterosis in upland cotton. II. Combining ability and inbreeding effects. Agronomy Journal. 1953;43:487-490.
19. Veena AM, Paliwal A, Pant SC, Mishra RC, Kumar V, Bahuguna P. Hybridization studies in tomato (*Solanum lycopersicum* L.). International Journal of Pure and Applied Bioscience. 2017;5(6):64-70.
20. Yadav SK, Singh BK, Baranwal DK, Solankey SS. Genetic study of heterosis for yield and quality components in tomato (*Solanum lycopersicum* L.). African Journal of Agricultural Research. 2013;8(44): 5585-5591.