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Exploitation of Heterosis for Yield and Yield Components In Tomato (*Solanum lycopersicum* L.)

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ABSTRACT
A study was conducted in tomato using a line × tester mating design evolved thirty crosses with 10 genotypes as female parents (lines) and 3 genotypes as male parents (testers). Ten lines (female parents), three testers (male parents) and thirty F_1 hybrids were evaluated for growth, yield and quality contributing traits. The maximum positive heterosis and heterobeltiosis for fruit yield per hectare were observed in PT-09-06 × PT- 3 and PT-2009-02 × PT- 3, respectively Whereas, PT-09-06 × PT-3 and PT-2009-02 × PT-3 were promising hybrids for fruit yield per plant. Maximum heterosis was observed in S-06-1 × Roma for number of fruits per plant. PT-20 × Punjab Chhuhara was the best hybrid among early types Whereas, PT-11 × PT-3 was the most promising cross combination for day to first harvest.
Keywords: Heterosis, heterobeltiosis, quantity traits and tomato.

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INTRODUCTION

Tomato (*Solanumlycopersicum* L.) is native of Peru Ecuador Bolivia Region of Andes, South America (Rick, 1969). It is self-pollinated crop but a certain extent of cross pollination may take place. Tomato is a warm loving crop so easily tolerate heat and drought stress. In India, total tomato area and production was about 0.80 million hectare and 19.69 million tonnes, respectively during 2017 [1-3]. Tomato is mainly consumed as salad, cooked or processed into several products like ketchup, juice, puree, sauce and whole canned fruit. Tomato is a rich source of antioxidants (mainly lycopene and β- carotene), Vitamin A, Vitamin C and minerals like Ca, P, and Fe in diet [5].F_1 hybrid breeding is prominent among the methods used in the crop improvement of vegetable crops. Hybrids offer opportunities for improvement in productivity, earliness, uniformity and quality and for the rapid deployment of dominant genes for resistance to diseases and insect pests [7].The present experiment was carried out to identify best combiner parents and best cross combination for developing promising hybrids for yield and its contributing traits using Line **×** Tester mating design.

MATERIALS AND METHODS

The present investigation was carried out during spring –summer season of 2012 and 2013 at Vegetable Research Centre (VRC) of the G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Pantnagar is located at an altitude of 243.84 meters above mean sea level and at 29^0 N latitude and 79.3^0 E longitudes. Climate of Pantnagar is humid subtropical with maximum temperature ranging from 21^0 C to 41^0 C minimum ranging from 8.8^0 C to 27.1^0 C in summer. Soil type of the area is predominantly clay-loam. Genetically divers 10 lines (PT-41,S-06-1,PT-2009-02,PT-11,PT-19,S-816,PT-20,PT-0906,PT-1 and PT-11) were crossed with three testers (PT-3, Roma and Punjab Chhuhara) in line × tester mating. The most desirable tester is one which provides maximum information about the performance of a line in cross combinations under different environmental conditions. The criteria for selecting tester are broad genetic base, wider adaptability and poor in the trait for which line are to be evaluated.
The resultant 33 F_1 was evaluated along with their parents. The experiment was laid out in a Randomized Block design (RBD) with three replications with inter and intra row spacing 50 cm. Five competitive plants were randomly selected for recording the observations on different characters such as fruit yield

per plant (kg), average fruit weight (g), number of fruits per plant, fruit yield per hectare (t/ha), days to first harvest, and days to last harvest. Data collected during the two growing season for above characters were pooled and analysis of variance and combining ability analysis were done as suggested by Panse and Sukhatme [6] and kempthorne [3], respectively

RESULTS AND DISCUSSION

The mean performance of parents and hybrids and the estimate of relative heterosis and heterobeltiosis are presented in Table 1 and 2.

Fruit yield per plant (kg)

Relative heterosis and heterobeltiosis were observed for fruit yield per plant ranged from −13.69 to 137.90 % and −25.96 to 105.85 %, respectively. The maximum positive heterosis over mid-parents and better parents for fruit yield per plant were recorded in PT-09-06 × PT-3 (137.90 %) and PT-2009-02 × PT-3 (105.85 %), respectively. Fruit yield per plant is important trait and give prime importance in tomato breeding. Out of thirty cross combinations, 27 hybrids showed significant relative heterosis and heterobeltiosis. PT-09-06 × PT-3 and PT-2009-02 × PT-3 were promising hybrid for fruit yield per plant with respect of heterosis and heterobeltiosis, respectively. This observation was also recorded by Asati *et al*., [2], Tiwari and Lal [11].

Average fruit weight (g)

Average fruit weight ranged from −46.39 to 53.27 % and 47.33 to 44.99 % for relative heterosis heterobeltiosis, respectively. The maximum positive heterosis over mid parents for average fruit weight was recorded in PT-2009-02 × PT-3 (53.27 %) and the maximum negative heterosis over mid parents recorded in S-816 × Punjab Chhuhara (46.39 %). The highest positive value for heterobeltiosis for average fruit weight was observed in PT-2009-02 × PT-3 (44.99 %) and highest negative value observed in S-816 × Punjab Chhuhara (47.33 %). Average fruit weight directly affects the total fruit yield, so this character is very important during breeding fruit yield is concerned. PT-2009-02 × PT-3 and S-816 × Punjab Chhuhara were observed most promising hybrids with respect of relative heterosis and heterobeltiosis, respectively. The positive heterosis for average fruit weight in tomato was also reported by Kumar et.al., [3], Singh and Asati [8] and Kumar and Sharma [4].

Number of fruits per plant

Relative heterosis and heterobeltiosis were observed for number of fruits per plant ranged from -0.90 to 156.02 % and -9.85 to 148.65 %, respectively. The maximum positive heterosis over mid parents and better parents for number of fruits per plant were recorded in PT-09-06 × Punjab Chhuhara, 156.02 % and 148.65 %, respectively. The cross combination S-06-1 × Roma was observed minimum heterosis (-0.90 %) and heterobeltiosis (-9.85 %). The number of fruit directly affects the total fruit yield per plant; therefore this character is very important for fruit yield. The most promising cross combination was PT-09-06 × Punjab Chhuhara for relative heterosis and heterobeltiosis. Similar observation recorded also by Asati *et.al*., [2], Saleem *et.al*., [8], Kumari and Sharma [5].

Fruit yield per hectare

The heterosis over mid-parents ranged from -13.90 to 138.56 %, whereas heterobeltiosis over better parents ranged from -25.64 to 107.34 % for fruit yield per hectare (t/ha.). The maximum positive heterosis over mid-parents and better parents for fruit yield per hectare were recorded in PT-09-06 × PT-3 (138.56 %) and PT-2009-02 × PT-3 (107.34 %), respectively. The minimum negative heterosis over mid-parents and better parents for fruit yield per hectare (t/ha) were recorded in PT-41 × Punjab Chhuhara (-13.90 %) and S-06-1 × Roma (-25.64 %), respectively. Fruit yield per hectare is the ultimate and most important trait. Among the all crosses, 27 hybrids cross combinations exhibited significant heterosis over mid-parents and over better parents. Similar finding was also observed by Kumari and Sharma [5], Singh and Asati [9].

Days to first harvest

The heterosis over mid-parents ranged from -8.75 to 3.01 %, whereas heterobeltiosis over better parents ranged from -10.51 to 2.36 % for days to first harvest or earliness. The minimum negative heterosis over mid-parent and better parents for days to first harvest in tomato were recorded in PT-11 × PT-3, -8.75 % and -10.51 %, respectively. The maximum positive heterosis over mid-parents and better parents for days to first harvest were recorded in PT-09-06 × Punjab Chhuhara, 3.01 % and 2.36 %, respectively. Out of thirty cross combinations, fifteen cross combinations showed significant negative heterosis and only two cross combinations, PT-19 × Punjab Chhuhara (2.89 %) and PT-09-06 × Punjab Chhuhara (3.01 %) showed significant positive relative heterosis for days to first harvest. Significant negative heterosis over better parents was observed in 18 hybrids, whereas as positive heterosis observed but not significant for days to first harvest. For the development of early fruiting genotype, negative heterosis is desirable for

days to first harvest. PT-11 × PT-3 was the most promising cross combination for both relative heterosis and heterobeltiosis. Heterosis for earliness was also reported by Singh and Nandpuri [10], Asati *et.al*., [2].

Days to last harvest

The minimum negative relative heterosis over mid-parents and heterobeltiosis over better parents for days to last harvest were recorded in PT-20 × Punjab Chhuhara, -8.29 % and -8.93 %, respectively. The maximum positive relative heterosis over mid-parents and heterobeltiosis over better parents for days to last harvest were recorded in PT-11 × Roma (3.87 %) and PT-19 × Roma (2.20 %), respectively. Heterosis for days to last harvest, 11 hybrids were showed significant negative heterosis and only cross combination PT-11 × Roma (3.87 %) showed significant positive relative heterosis. Significant negative heterosis over better parents was observed in 15 hybrids, whereas as positive heterosis not observed in any cross combination. PT-20 × Punjab Chhuhara was the best hybrid among early types respect of relative heterosis and heterobeltiosis. Desirable heterosis for days to maturity were also observed by Singh and Nandpuri [10] and Saleem *et.al*., [8].

Table 1. Mean performance of genotypes and F_1 hybrids and extent of heterosis in tomato for fruit yield/ plant, average fruit weight and number offruits/plant

Genotypes	Fruit yield/plant (kg)			Average fruit weight (g)			Number of fruits/plant		
	Mean	MPH	BPH	Mean	MPH	BPH	Mean	MPH	BPH
Parents									
PT-41	0.69	–	–	32.84	–	–	21.01	–	–
S-06-1	0.53	–	–	32	–	–	16.56	–	–
PT-2009-02	0.55	–	–	38.32	–	–	14.35	–	–
PT-11	0.41	–	–	33.09	–	–	12.39	–	–
PT-19	0.68	–	–	33.68	–	–	20.19	–	–
S-816	0.63	–	–	37.21	–	–	16.93	–	–
PT-20	0.58	–	–	46.04	–	–	12.59	–	–
PT-09-06	0.46	–	–	25.06	–	–	18.33	–	–
PT-1	0.54	–	–	30.75	–	–	17.55	–	–
PT-12	0.5	–	–	25.84	–	–	19.33	–	–
PT-3	0.68	–	–	34.18	–	–	19.89	–	–
Roma	0.78	–	–	38.59	–	–	20.21	–	–
Punjab Chhuhara	0.75	–	–	38.56	–	–	19.45	–	–
F1 Hybrids									
PT-41 x PT-3	0.73	6.80**	6.28*	35.35	5.49**	3.41	20.65	0.98	−1.71
PT-41 x Roma	0.79	7.24**	0.85	29.78	−16.60**	−22.82**	26.52	28.68**	26.23**
PT x Punjab Chhuhara	0.62	−13.69**	−16.96**	29.2	−18.20**	−24.27**	21.22	4.9	1.02
S-06-1 x PT-3	0.62	2.2	−9.27**	26.68	−19.37**	−21.94**	23.23	27.46**	16.79**
S-06-1 x Roma	0.58	−11.68**	−25.96**	31.83	−9.81**	−17.52**	18.22	−0.90	−9.85**
S-06-1 x Punjab Chhuhara	0.61	−4.44	−18.30**	30.6	−13.26**	−20.64**	19.93	10.66**	2.43
PT-2009-02 x PT-3	1.41	128.11**	105.85**	55.56	53.27**	44.99**	25.37	48.20**	27.55**
PT-2009-02 x Roma	1.48	122.50**	89.36**	55.97	45.54**	45.03**	26.44	53.02**	30.83**
PT-2009-02 x Punjab Chhuhara	1.33	105.14**	78.13**	37.5	−2.45	−2.75	35.46	109.82**	82.28**
PT-11 x PT-3	0.84	53.66**	22.93**	25.68	−23.65**	−24.87**	32.71	102.66**	64.45**
PT-11 x Roma	0.88	47.49**	12.34**	24.66	−31.19**	−36.10**	35.68	118.90**	76.55**
PT-11 x Punjab Chhuhara	0.9	55.62**	20.54**	30.01	−16.22**	−22.16**	29.99	88.36**	54.16**
PT-19 x PT-3	1.06	55.88**	55.12**	44.65	31.59**	30.63**	23.74	18.46**	17.58**
PT-19 x Roma	1.13	54.34**	43.83**	40.54	12.18**	5.04**	27.87	37.97**	37.90**
PT-19 x Punjab Chhuhara	1.28	79.86**	71.43**	54.05	49.64**	40.17**	23.68	19.47**	17.29**
S-816 x PT-3	0.63	−4.06	−7.80**	25.34	−29.01**	−31.90**	24.86	35.02**	24.99**
S-816 x Roma	0.65	-8.02**	−17.02**	30.82	−18.69**	−20.14**	21.08	13.51**	4.3
S-816 x Punjab Chhuhara	0.61	-11.38**	−18.30**	20.31	−46.39**	−47.33**	30.03	65.06**	54.37**

PT-20 x PT-3	0.88	38.95**	28.78**	39.7	−1.03	−13.78**	22.17	36.51**	11.46**
PT-20 x Roma	0.86	25.85**	9.79**	45.07	6.51**	−2.11	19.08	16.34**	−5.59
PT-20 x Punjab Chhuhara	0.93	39.85**	24.55**	35.61	−15.82**	−22.65**	26.11	62.97**	34.22**
PT-09-06 x PT-3	1.36	137.90**	99.02**	31.71	7.05	−7.23**	42.86	124.24**	115.47**
PT-09-06 x Roma	1.29	106.97**	64.26**	31.09	−2.31	−19.44**	41.59	115.79**	105.77**
PT-09-06 x Punjab Chhuhara	1.22	102.76**	63.84**	25.22	−20.72**	−34.60**	48.37	156.02**	148.65**
PT-1 x PT-3	0.68	11.17**	−0.49	36.42	12.19**	6.56**	18.67	−0.29	−6.15
PT-1 x Roma	0.7	6.30**	−10.21**	26.05	−24.86**	−32.50**	26.86	42.29**	32.94**
PT-1 x Punjab Chhuhara	0.72	11.92**	−3.57	23.76	−31.45**	−38.39**	30.28	63.66**	55.67**
PT-12 x PT-3	0.87	48.02**	27.80**	30.69	2.25	−10.22**	28.34	44.52**	42.48**
PT-12 x Roma	0.98	53.13**	25.11**	39.72	23.30**	2.93	24.67	24.79**	22.07**
PT-12 x Punjab Chhuhara	0.96	54.42**	28.57**	40.54	25.90**	5.13**	23.68	22.11**	21.73**

*Significant at 5%**significant at 1%

Table 2.Mean performance of genotypes and F_1 hybrids and extent of heterosis in tomato for fruit yield (t/ha), days to first harvest and days to last harvest

Genotypes	Fruit yield(t/ha)			Days to first harvest			Days to last harvest		
	Mean	MPH	BPH	Mean	MPH	BPH	Mean	MPH	BPH
Parents									
PT-41	27.6	–	–	109.35	–	–	134.89	–	–
S-06-1	21.2	–	–	106.43	–	–	130.09	–	–
PT-2009-02	22	–	–	107.86	–	–	138.69	–	–
PT-11	16.4	–	–	109.99	–	–	130.51	–	–
PT-19	27.2	–	–	106.04	–	–	126.31	–	–
S-816	25.2	–	–	101.66	–	–	124.52	–	–
PT-20	23.2	–	–	106.89	–	–	135.21	–	–
PT-09-06	18.4	–	–	103.36	–	–	122.02	–	–
PT-1	21.6	–	–	101.86	–	–	120.35	–	–
PT-12	20	–	–	106.47	–	–	136.01	–	–
PT-3	27.2	–	–	105.74	–	–	130.59	–	–
Roma	31.2	–	–	107.27	–	–	126.11	–	–
Punjab Chhuhara	30	–	–	104.67	–	–	133.32	–	–
Hybrids									
PT-41 x PT-3	29.2	6.54**	5.77*	102.5	−4.69**	−6.26**	130.96	−1.34	−2.91
PT-41 x Roma	31.6	7.48**	1.28	105.6	−2.50*	−3.43*	133.05	1.96	−1.36
PT x Punjab Chhuhara	24.8	−13.90**	−17.34**	101.52	−5.13**	−7.16**	129.8	−3.21*	−3.78*
S-06-1 x PT-3	24.8	2.49	−8.82**	102.98	−2.93*	−3.24*	129.24	−0.84	−1.03
S-06-1 x Roma	23.2	−11.45**	−25.64**	105.65	−1.12	−1.51	126.17	−1.51	−3.01
S-06-1 x Punjab Chhuhara	24.4	−4.69	−18.68**	106.99	1.36	0.52	130.57	−0.86	−2.06
PT-2009-02 x PT-3	56.4	129.27**	107.34**	101.56	−4.90**	−5.84**	127.74	−5.12**	−7.90**
PT-2009-02 x Roma	59.2	122.56**	89.74**	104.43	−2.91*	−3.17*	126.74	−4.28**	−8.62**
PT-2009-02 x Punjab Chhuhara	53.2	104.60**	77.31**	101.14	−4.82**	−6.23**	130.93	−3.73**	−5.60**
PT-11 x PT-3	33.6	54.10**	23.51**	98.43	−8.75**	−10.51**	123.62	−5.31**	−5.34**
PT-11 x Roma	35.2	47.90**	12.83**	101.85	−6.24**	−7.40**	133.27	3.87**	2.11
PT-11 x Punjab Chhuhara	36	55.14**	19.98**	99.25	−7.53**	−9.76**	129.67	−1.70	−2.74
PT-19 x PT-3	42.4	55.88**	55.86**	101.72	−3.94**	−4.07**	128.89	0.34	−1.30
PT-19 x Roma	45.2	54.80**	44.87**	105.13	−1.43	−1.99	128.99	2.2	2.12
PT-19 x Punjab Chhuhara	51.2	79.02**	70.65**	108.4	2.89*	2.23	125.09	−3.64*	−6.18**
S-816 x PT-3	25.2	−3.82	−7.36**	101.91	−1.73	−3.62*	129.6	1.6	−0.76
S-816 x Roma	26	−7.79**	16.66**	104.99	0.5	−2.13	128.42	2.48	1.83

S-816 x Punjab Chhuhara	24.4	−11.60**	−18.68**	102.44	−0.70	−2.13	126.34	−2.00	−5.24**
PT-20 x PT-3	35.2	39.66**	29.38**	107.35	0.97	0.43	133.05	0.11	−1.60
PT-20 x Roma	34.4	26.47**	10.26**	105.15	−1.80	−1.98	127.15	−2.69	−5.96**
PT-20 x Punjab Chhuhara	37.2	39.84**	23.99**	103.55	−2.11	−3.13*	123.14	−8.29**	−8.93**
PT-09-06 x PT-3	54.4	138.56**	99.98**	103.3	−1.19	−2.30	129.82	2.79	−0.59
PT-09-06 x Roma	51.6	108.05**	65.35**	103.2	−2.01	−3.80**	126.6	2.04	0.38
PT-09-06 x Punjab Chhuhara	48.8	101.63**	62.65**	107.15	3.01*	2.36	123.04	−3.63*	−7.71**
PT-1 x PT-3	27.2	11.48**	−0.01	97.51	−6.05**	−7.78**	123.66	−1.44	−5.30**
PT-1 x Roma	28	6.07*	−10.26**	98.79	−5.53**	−7.91**	120.21	−2.45	−4.68**
PT-1 x Punjab Chhuhara	28.8	11.63**	−4.01	102.29	−0.94	−2.28	122.21	−3.65*	−8.34**
PT-12 x PT-3	34.8	47.44**	27.93**	103.15	−2.78*	−3.12*	127.4	−4.42**	−6.33**
PT-12 x Roma	39.2	53.12**	25.64**	102.02	−4.54**	−4.90**	125.65	−4.13**	−7.62**
PT-12 x Punjab Chhuhara	38.4	53.59**	28.00**	101.79	−3.58**	−4.40**	134.28	−0.28	−1.27

*Significant at 5%**significant at 1%

CONCLUSION

In conclusion, the present investigation suggests that study resulted into identification of hybrid for tomato fruit quantity. The maximum positive heterosis and heterobeltiosis for fruit yield per hectare were observed in PT-09-06 × PT- 3 and PT-2009-02 × PT- 3, respectively. The hybrid PT-09-06 × PT-3 and PT-2009-02 × PT-3 were promising hybrids for fruit yield per plant.

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