Electronic Journal of Plant Breeding, 7(4): 911-918 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00124.1

Research Article

Development of F_1 hybrids resistance to bacterial wilt incidence in tomato (*Solanum lycopersicum* L.)

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(Received: 16 April 2016; Accepted: 28 Oct 2016)

Abstract
Maximum heterosis over standard parent in desirable direction was 102.80 per cent (TP44 x TP40) for equatorial diameter of fruit, 67.30 per cent (TP44x TP40) for average fruit weight, 22.70 per cent (TP24 x TP40) for number of fruits per plant and 70.56 per cent (TP5 x TP29) for total yield per plant. A total of 15 crosses exhibited negative and significant heterosis over better parent for bacterial wilt incidence .The cross TP50 x TP25 for equatorial diameter of fruit; TP45x TP25 for average fruit weight; TP24 x TP40 for bacterial wilt, number of fruits per plant and total yield per plant were identified as good specific combiners. The parents TP45 and TP44 for equatorial diameter of fruit; TP5, TP24 and TP27 for bacterial wilt; TP45 and TP44 for average fruit weight; TP27 and TP24 for number of fruits per plant and TP44 for total yield per plant were identified as good general combiners. Non additive gene action was predominant for plant height at 90 DAT, days to 50 per cent flowering, equatorial diameter of fruit, bacterial wilt, average fruit weight and total yield per plant.

Key words
Bacterial wilt, combining ability, heterosis, yield traits and tomato

Introduction

Tomato (*Solanum lycopersicum* L.), belonging to the family Solanaceae occupies an area of 8.82 lakh hectares (9.4% of total vegetable area) with an annual production of 187.36 lakh metric tonnes (11.50 % of the total vegetable production) accounting to an average productivity of 21.2 tonnes per hectare. The Indian national average yield is 21.2 tonnes per hectare compared to the world average of 33.9 tonnes per hectare. The highest tomato average yield to the extent of 88.00 tonnes per hectare had been recorded in USA (NHB, 2015). At present, in the countries like Spain, Netherlands, Denmark, France, Australia, United Kingdom and USA, more than 90 per cent of area under tomato is covered with F_1 hybrids, whereas it is just 38.65 per cent in India (Chadha, 2015). Low productivity in India is attributed to lack of high yielding varieties or hybrids and presence of serious pests and diseases. Of all the diseases, the occurrence of bacterial wilt in tomato is a major constraint in cultivation of tomato during rainy season in India. Bacterial wilt is caused by a soil borne bacterial pathogen, *Ralstonia solanacearum* (Smith). The loss in yield due to bacterial wilt upto an extent of 90.62 per cent was reported by Ramkishun, 1987. Host plant resistance is an important disease control strategy and environmentally safe, with low running costs. Therefore, breeding tomato cultivars possessing inbuilt resistance is an appropriate approach for disease management. One of the methods to achieve quantum jump in yield and resistance to bacterial wilt is heterosis breeding. Heterosis breeding has contributed tremendously for increased productivity and production of vegetable crops. In addition heterosis breeding makes possible the attainment of a given breeding task in the shortest, more precise and surest way by combining the valuable dominant genes of both the parents. The hybrid seed production in tomato is very much economical as hundreds of seeds per cross are obtained and seed requirement per unit area for commercial production is lesser. Hence, an attempt has been made in the present investigation for development of F_1 hybrids resistant to bacterial wilt disease in tomato.

Materials and methods

The materials for the present study comprised of 14 lines as female parents with 3 testers as male parents and these were crossed in all possible combinations to obtain 42 F_1 hybrids. The parental genotypes and 42 F_1 hybrids were grown in randomized block design with three replications and other agronomic practices were followed as per package of practices given by University of Horticultural Sciences, Bagalkot (Anon., 2013). The traditional sick plots maintained for screening bacterial wilt resistant were used for experimental study. It occurs normally after the flowering period and can cause considerable yield losses by sudden wilting and death of whole plant. *R. solanacearum* is known to survive in soil upto 45 cm depth and hence it can be transmitted by infected plant material, irrigation water, soil and farm implements, Bacterial wilt incidence is the number of plants infected out of the total number of plants that were planted and the observations were recorded at every two weeks interval after

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transplanting. The values obtained were expressed in per cent wilt incidence. The per cent wilt incidence values were converted to arcsine values to obtain normal distribution and analysis was done for arcsine values. Data were recorded in thirty randomly selected plants in each F_1s and parents for different parameters. The observations were subjected to line x tester analysis. In practical plant breeding, superiority of the F_1 over mid parent is of little value, since it does not offer any advantage. However, the commercial usefulness of a hybrid would primarily depend on its performance in comparison to the best existing commercial variety or hybrids. Hence, heterosis over better parent and the standard parent was worked out in the present investigation for identification of superior hybrids. The genotype TP25 was selected as the standard parent, since it is the commercial popular variety widely grown in Southern Karnataka. The systematic study in relation to general and specific combining ability is necessary to assess the genetic potentialities of the parents in hybrid combinations (Griffing, 1956). Line x tester (l x t) method developed by Kempthorne (1957) has been used in the present study for estimating combining ability (GCA and SCA) and other genetic parameters.

Results and discussion

The maximum heterosis was observed in the cross TP48 x TP40 (31.70 %) over better parent and in the cross TP50 x TP25 (31.02 %) over the standard parent. Out of 42 crosses, 27 crosses over better parent and 30 crosses over standard parent exhibited positive and significant heterosis for the plant height at 90 DAT. Among 14 lines, five lines had positive and significant *gca* effects and the highest positively significant *gca* effects was observed in the line TP24 (7.53) followed by TP50 (5.33) and TP59 (4.86). Among three testers, TP29 (2.71) and TP25 (1.40) exhibited significant *gca* effects. Among 42 crosses, 9 crosses recorded significant positive *sca* effects and the highest *sca* was observed in TP45 X TP25 (9.75) followed by TP50 x TP25 (9.49) and TP1 x TP40 (9.43). The GCA: SCA ratio is high (1:7.19) reveals the predominance of non additive gene action contribution for expression of heterosis as evidenced by Dharmatti *et al.* (2000).

Days to 50 per cent flowering is an indication of earliness and negative value for the trait is desirable. The maximum negative and significant heterosis was exhibited by the cross TP19 x TP25 over better parent (-37.12 %) and in cross TP46 x TP29 over the standard parent (-42.60 %). Out of 42 crosses, 27 crosses over better parent and 42 crosses over standard parent exhibited significant heterosis in the desirable direction. The parents TP46 (-2.12) followed by TP50 (-1.41) and TP25 (-1.25) exhibited maximum negative and significant *gca* effects and the crosses TP46 x TP29 (-3.76), TP19 x TP25 (-3.20), TP24 x TP40 (-3.14) and TP15 x TP29 (-1.83) exhibited maximum significant *sca* effects in the negative direction. The GCA: SCA ratio is 1:4.176 indicates the predominance of non additive gene action for the cause of heterosis as observed by Dhaliwal *et al*. (2000).

Magnitude of heterosis over better parent and standard parent was significant in both the directions for bacterial wilt incidence. The cross TP24 x TP40 exhibited significant maximum heterosis in the desirable direction (negative) over better parent (-99.04 %). The 18 crosses exhibited non significant (desirable) heterosis over the standard parent (TP29) in the needful direction and 15 crosses exhibited negative and significant heterosis over better parent for bacterial wilt incidence. Among 15 lines, six lines exhibited significant *gca* effects in the desirable (negative) direction and maximum negative and significant *gca* effects was observed in TP5, TP24 and TP27 (-32.31) followed by TP45 (-30.71). Among testers TP40 (-3.92) expressed negative and significant *gca* effects. Out of 42 crosses, 7 exhibited significant *sca* effects in the desirable direction and maximum *sca* effects in the desirable direction was exhibited by TP50 x TP29 (-17.50) followed by TP44 x TP40 (-17.30) and TP44 x TP29 (-14.76). The GCA: SCA ratio is also high (1:32.15) indicates the predominance of non additive gene action contributing for heterosis as evidenced by Grimault (1995), Louw (1985), and Vidavsky *et al.* (1998).

The maximum positive and significant heterobeltiosis was recorded in the cross TP45 x TP40 (30.21 %) followed by the cross TP19 x TP40 (28.82 %) and TP26 x TP40 (17.51 %). The cross TP44 x TP40 (102.80 %) exhibited maximum positive and significant heterosis over the standard parent followed by the cross TP45 x TP40 (97.20 %) and TP5 x TP29 (88.41 %). Out of 42 crosses, 14 crosses over better parent and 39 crosses over standard parent exhibited positive and significant heterosis for equatorial diameter of fruit. Five lines showed positively significant *gca* effects and four lines had negatively significant *gca* effects. Lines *viz.*, TP45 (0.41) followed by TP44 (0.32) and TP50 and testers *viz.*, TP40 (0.60) and TP29 (0.42) expressed maximum positive and significant *gca* effects. A total of 10 crosses showed positively significant *sca* effects and maximum positive *sca* effects were exhibited by TP50 x TP25 (0.67) followed by TP44 x TP40 (0.56) and TP15 x TP25 (0.54). The GCA: SCA ratio is also high (1:24.26) indicates the predominance of non additive gene action contributing for heterosis as evidenced by Kaur *et al.* (2002).

The maximum positive and significant heterobeltiosis was exhibited by the cross TP45 x TP25 (39.70%) followed by TP5 x TP29 (36.02 %) and TP45 x TP40 (27.09 %). Maximum positive and significant heterosis over the standard parent was exhibited by the cross TP44 x TP40 (67.30 %) followed by TP5 x TP29 (56.28 %) and TP1 x TP29 (59.41 %). Out of 42 crosses, 14 over better parent and 25 crosses over standard parent recorded positive and significant heterosis for average fruit weight. Among lines, thirteen showed significant *gca* effects and the line TP45 (18.71) showed maximum positive *gca* effects followed by TP44 (13.62) and TP5 (12.10). Testers, *viz*., TP44 (10.97) and TP29 (9.15) exhibited positively significant *gca* effects. 14 crosses expressed positively significant *sca* effects and the maximum was observed in TP45 x TP25 (24.89) followed by TP1 x TP29 (24.75) and TP15 x TP40 (23.50). The GCA: SCA ratio is 1:22.31 indicates higher influence of non additive gene action for heterosis as evidenced by Padma *et al.* (2002).

The maximum positive and significant heterobeltiosis was exhibited by the cross TP24 x TP40 (51.18 %) followed by TP59 x TP29 (46.62 %) and TP27 x TP40 (42.17 %). The maximum positive and significant heterosis over the standard parent was observed in cross TP24 x TP40 (22.76 %) followed by the cross TP27 x TP29 (21.02 %) and TP27 x TP40 (20.58 %). Out of 42 crosses, 12 over better parent and 5 over standard parent recorded positive and significant heterosis for number of fruits per plant. The lines TP27 (9.18) followed by TP24 (3.75) and the tester TP25 (3.58) expressed positively significant *gca* effects. Among the crosses, positively significant *sca* effects was observed in seven crosses and the cross TP24 x TP40 (13.51) exhibited maximum positive *sca* effects followed by TP50 x TP25 (9.30) and TP46 x TP25 (8.60). The GCA: SCA ratio is almost equal (1:1.06) indicates the involvement of both additive and non additive gene action which can be improved by simple selection and recurrent selection method of breeding. Similar findings were also also reported by Bhatt *et al.* (2001) and Kulkarni (1999).

Maximum positive and significant heterobeltiosis was exhibited by the cross TP1 x TP29 (96.15 %) followed by TP1 x TP29 (98.15 %), TP24 x TP40 (86.16 %) and TP5 x TP29 (81.39 %). The cross TP5 x TP29 exhibited maximum positive and significant heterosis over the standard parent (70.56 %) followed by TP1 x TP29 (69.74 %) and TP24 x TP40 (67.57 %). Majority of the crosses exhibited positive and significant heterosis over better parent (31 crosses) and standard parent (25 crosses) for total yield per plant. Four lines, *viz*., TP5 (0.52), TP44 (0.26), TP59 (0.25) and TP45 (0.21) and the testers, *viz*., TP40 (0.21) and TP29 (0.16) exhibited positively significant *gca* effects. 12 crosses exhibited positive and significant *sca* effects and the highest positive *sca* effects was observed in the cross TP24 x TP40 (1.10) followed by TP46 x TP25 (1.01), TP1 x TP29 (0.96), TP45 x TP25 (0.93), TP51 x TP25 (0.93) and TP50 x TP25 (0.80). The GCA: SCA ratio for total yield (1:2.46) indicates little dominance of non additive gene action and involvement of additive gene action reveals that heterosis breeding can exploited for improvement of yield in heterotic hybrids and at the same time, transgressive segregants can be obtained by following reciprocal recurrent selection method of breeding. Similar findings were also reported by Padma *et al.* (20002) and Bhatt *et al.* (2001).

Conclusion

Non additive gene action was predominant for plant height at 90 DAT, days to 50 per cent flowering, equatorial diameter of fruit, bacterial wilt and average fruit weight can be exploited by heterosis breeding. Both additive and non additive gene action was noticed for number of fruits and total yield per plant that can be improved by simple selection and recurrent selection method of breeding.

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DOI: 10.5958/0975-928X.2016.00124.1

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Electronic Journal of Plant Breeding, 7(4): 911-918 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00124.1

Table 1. Heterosis (%) over better parent and standard parent for growth, earliness and in tomato hybrids

Sl. No.	Cross	Plant height at 90 DAT (cm)		Days to 50 per cent flowering		Per cent bacterial wilt incidence	
		BP	SP	BP	SP	BP	SP
1.	TP1 x TP40	1.26	3.06	-6.65	-20.92**	-0.98	1113.91**
2.	TP1 x TP29	11.56**	13.55**	-7.49	-23.38**	2.61	1157.89**
3.	TP1 x TP25	-1.42	0.33	-25.56**	-25.56**	-3.27	1085.84**
4.	TP5 x TP40	6.72	4.66	-3.60	-18.33**	-91.32**	-0.00
5.	TP5 x TP29	13.99**	11.78**	-5.71	-21.91**	-91.32**	-0.00
6.	TP5 x TP25	12.19**	12.19**	-25.72**	-25.72**	-91.32**	-0.00
7.	TP15x TP40	-8.43*	-5.14	-11.81**	-15.96**	11.58	1185.96**
8.	TP15 x TP29	-0.10	3.49	-22.73**	-26.37**	6.37	1125.90**
9.	TP15 x TP25	5.87	9.68*	-19.47**	-19.47**	2.89	1085.84**
10.	TP19 x TP40	5.99	7.09	-7.56	-14.55**	-8.64	1085.84**
11.	TP19 x TP29	-8.86*	-7.91*	-12.59**	-19.20**	-3.09	1157.89**
12.	TP19 x TP25	11.13**	12.29**	-37.12**	-37.12**	-4.01	1145.90**
13.	TP24 x TP40	16.19**	29.02**	-18.78**	-29.43**	-99.04**	-89.38
14.	TP24 x TP29	10.76**	22.98**	-8.15	-20.19**	-82.84**	89.38
15.	TP24 x TP25	-0.60	10.37**	-22.16**	-22.16**	-91.63**	-0.00
16.	TP26 x TP40	18.63**	11.79**	-9.47*	-23.30**	-10.72	999.81**
17.	TP26 x TP29	11.92**	5.46	-7.89	-23.71**	-3.74	1085.84**
18.	TP26 x TP25	4.69	4.69	-31.77**	-31.77**	-0.49	1125.90**
19.	TP27 x TP40	18.59**	19.41**	-12.72**	-26.06**	-92.22**	-0.00
20.	TP27 x TP29	10.68**	11.44**	-4.70	-21.07**	-92.22**	-0.00
21.	TP27 x TP25	6.77	7.50	-30.16**	-30.16**	-92.22**	-0.00
22.	TP44 x TP40	28.22**	27.60**	-6.29	-19.09**	-81.30**	89.38
23.	TP44 x TP29	10.30**	9.26*	-9.96*	-22.25**	-72.47**	178.76
24.	TP44 x TP25	11.45**	11.45**	-32.01**	-32.01**	14.02	1185.96**
25.	TP45 x TP40	4.13	10.83**	-12.58**	-25.94**	-0.00	-0.00
26.	TP45 x TP29	-11.04**	-5.32	-10.73*	-26.07**	-0.00	-0.00
27.	TP45x TP25	15.03**	22.43**	-29.68**	-29.68**	-83.21**	89.38
28.	TP46 x TP40	16.91**	13.71**	-3.45	-18.20**	89.38	89.38
29.	TP46 x TP29	12.70**	9.61*	-30.70**	-42.60	89.38	89.38
30.	TP46 x TP25	17.28**	17.28**	-32.17**	-32.17**	-91.13**	-0.00
31.	TP48 x TP40	31.70**	25.72**	-6.81	-21.05**	33.15*	921.18**
32.	TP48 x TP29	17.46**	12.13**	-14.96**	-29.57**	43.40**	999.81**
33.	TP48 x TP25	11.15**	11.15**	-26.59**	-26.59**	-9.15	924.66**
34.	TP50 x TP40	22.29**	12.37**	-9.04*	-22.94**	-83.49**	89.38
35.	TP50 x TP29	21.92**	11.21**	-18.09**	-32.16**	-91.28**	-0.00
36.	TP50 x TP25	31.02**	31.02**	-31.40**	-31.40**	-5.75	981.24**
37.	TP51 x TP40	22.05**	12.15**	1.44	-14.06**	16.18	999.81**
38.	TP51 x TP29	29.73**	18.34**	0.61	-16.68**	18.92	10.25.78**
39.	TP51 x TP25	9.53**	9.53*	-21.35**	-21.35**	-2.49	999.81**
40.	TP59 x TP40	6.67	16.26**	-3.10	-17.91**	-13.12	921.18**
41.	TP59 x TP29	-2.36	6.42	-5.49	-21.73**	0.89	1085.84**
42.	TP59 x TP25	19.50**	30.26**	-31.67**	-31.67**	15.54	1258.01**
	S.Em±	**3.312**	**3.312**	**1.279**	**1.279**	**5.51**	**5.51**
	C.D. at 5%	**9.18**	**9.18**	**3.456**	**3.456**	**15.29**	**15.29**
	C.D. at 1%	**12.08**	**12.08**	**4.667**	**4.667**	**20.12**	**20.12**

* and ** indicate significance of values at p=0.05 and p=0.01, respectively.
BP – Heterosis over better parent, SP – Heterosis over standard parent (TP25)

Electronic Journal of Plant Breeding, 7(4): 911-918 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00124.1

Table 2. Heterosis (%) over better parent and standard parent for yield traits in tomato hybrids

Sl. No.	Cross	Equatorial diameter of fruit (cm)		Average fruit weight (g)		No. of fruits/ plant		Total yield/ plant (kg)	
		BP	SP	BP	SP	BP	SP	BP	SP
1.	TP1 x TP40	-0.80	80.75**	-9.60**	17.80**	2.89	-30.56**	6.99	8.01
2.	TP1 x TP29	1.19	84.37**	22.33**	59.41**	25.07*	-1.66	98.15**	69.74**
3.	TP1 x TP25	-38.64**	11.80*	-40.02**	-21.84**	-12.39	-12.39	-6.18	-5.29
4.	TP5 x TP40	12.50**	77.95**	16.26**	30.05**	7.03	-17.64*	60.57**	44.23**
5.	TP5 x TP29	15.92**	88.41**	36.02**	56.28**	25.96*	-0.96	81.39**	70.56**
6.	TP5 x TP25	-23.36**	21.22**	-18.18**	-8.48*	0.59	0.59	34.06**	34.06**
7.	TP15x TP40	10.14*	59.73**	25.78**	40.14**	-3.83	-6.88	47.95**	51.56**
8.	TP15 x TP29	-7.07*	51.04**	-21.44**	-9.74*	-3.26	-6.33	21.99**	24.97**
9.	TP15 x TP25	-8.21*	33.13**	-36.04**	-34.93**	1.23	1.23	-7.95	-5.70
10.	TP19 x TP40	28.82**	86.02**	18.87**	32.44**	-20.29*	-26.00**	-12.58	6.51
11.	TP19 x TP29	13.38**	84.27**	12.63**	29.41**	-13.61	-19.80*	-8.24	11.80
12.	TP19 x TP25	-22.55**	10.25	-38.58**	-38.58**	-7.49	-7.49	-30.85**	-15.74
13.	TP24 x TP40	7.53*	61.08**	-15.57**	-5.93	51.18**	22.76**	86.56**	67.57**
14.	TP24 x TP29	-1.46	60.14**	-15.68**	-3.11	10.99	-9.87	19.62*	12.48
15.	TP24 x TP25	-28.47**	7.14	-38.59**	-38.59**	-7.36	-7.36	-36.64**	-36.64**
16.	TP26 x TP40	17.51**	85.51**	18.44**	31.96**	19.96	-13.74	61.63**	45.18**
17.	TP26 x TP29	-1.27	60.46**	-9.51**	3.97	32.48**	4.17	23.38*	16.01
18.	TP26 x TP25	-29.84**	10.77	-27.89**	-27.89**	-5.95	-5.95	-18.86*	-18.86*
19.	TP27 x TP40	5.37	52.28**	-16.63**	-7.11	42.19**	20.58**	69.49**	52.24**
20.	TP27 x TP29	0.13	62.73**	0.98	16.03**	43.43**	21.02**	72.01**	61.74**
21.	TP27 x TP25	-17.34**	19.46**	-35.47**	-35.47**	-3.26	-3.26	-19.13*	-19.13*
22.	TP44 x TP40	7.17*	102.80**	19.10**	67.30**	43.12**	-2.20	39.91**	62.29**
23.	TP44 x TP29	-15.21**	60.46**	-7.51*	29.92**	12.13	-11.83	33.61**	55.36**
24.	TP44 x TP25	-27.52**	37.16**	-38.67**	-13.85**	2.42	2.42	-14.82	-0.95
25.	TP45 x TP40	30.21**	97.20*	27.09**	41.59**	-14.59	-22.67**	50.30**	35.01**
26.	TP45 x TP29	8.41*	76.19**	4.91	20.54**	-12.77	-21.03**	23.95*	16.55
27.	TP45x TP25	-10.39**	35.71**	39.70**	39.70**	12.35	12.35	60.11**	60.11**
28.	TP46 x TP40	-9.63**	62.32**	-4.70	16.19**	1.31	-20.60**	26.47**	22.52*
29.	TP46 x TP29	-10.95**	59.94**	-10.66**	8.93*	7.89	-15.17	20.87*	17.10
30.	TP46 x TP25	-25.99**	32.92**	-15.04**	3.58	18.94*	18.94*	58.89**	58.89**
31.	TP48 x TP40	7.41*	65.01**	-10.93**	7.68	12.36	-13.62	28.85**	18.18*
32.	TP48 x TP29	5.80	71.95**	-1.22	19.42**	32.33**	4.05	67.24**	57.26**
33.	TP48 x TP25	-21.90**	19.98**	-40.02**	-27.49**	8.99	8.99	1.09	1.09
34.	TP50 x TP40	13.70**	75.26**	13.27**	38.86**	20.96	-18.36*	57.55**	41.52**
35.	TP50 x TP29	3.18	67.70**	-6.57	14.55**	-1.15	-22.28**	20.06*	12.89
36.	TP50 x TP25	0.60	55.07**	-16.39**	2.51	18.63*	18.63**	53.32**	53.32**
37.	TP51 x TP40	9.99**	82.30**	1.93	13.56**	12.67	-23.96**	37.46**	23.47**
38.	TP51 x TP29	7.81*	78.67**	18.47**	36.11**	-8.70	-28.21**	23.38*	16.01
39.	TP51 x TP25	-30.79**	14.70*	6.35	9.71*	-5.01	-5.01	54.27**	54.27**
40.	TP59 x TP40	7.48*	71.01**	7.54*	19.81**	25.06*	-15.59	54.90**	39.35**
41.	TP59 x TP29	5.54	71.53**	14.74**	31.83**	46.62**	15.28	56.85**	47.49**
42.	TP59 x TP25	-9.24*	44.41**	5.21	10.03*	-0.75	-0.75	29.72**	29.72**
	S.Em±	**0.185**	**0.185**	**3.487**	**3.487**	**3.951**	**3.951**	**0.217**	**0.217**
	C.D. at 5%	**0.513**	**0.513**	**9.665**	**9.665**	**10.953**	**10.953**	**0.600**	**0.600**
	C.D. at 1%	**0.675**	**0.675**	**12.722**	**12.722**	**14.417**	**14.417**	**0.790**	**0.790**

* and ** indicate significance of values at p=0.05 and p=0.01, respectively.
BP – Heterosis over better parent; SP – Heterosis over standard parent (TP25)

Electronic Journal of Plant Breeding, 7(4): 911-918 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00124.1

Table 3. General combining ability effects (*gca*) for growth, earliness and yield parameters in tomato parents

Sl. No	Lines	Plant height at 90 DAT (cm)	Days to 50 per cent flowering	Per cent bacterial wilt incidence			Equatorial diameter of fruit (cm)	Average fruit weight (g)	No. of fruits/ plant	Total yield/ plant (kg)
				Mean	Arcsine value	GCA effects				
1	TP1	-5.34**	0.42	82.22	65.79	27.76**	0.07	5.89**	-4.54*	-0.11
2	TP5	-2.03	0.85	77.77	61.85	-32.31**	0.18*	12.10**	-0.14	0.52**
3	TP15	-7.87**	1.31*	77.77	61.85	28.47**	-0.29**	-10.64**	0.85	-0.12
4	TP19	-6.89**	0.31	86.66	69.66	28.33**	0.10	-2.97*	-5.97**	-0.68**
5	TP24	7.53**	0.21	73.33	59.21	-32.31**	-0.46**	-22.53**	3.75*	-0.34**
6	TP26	-3.93**	-0.56	82.21	66.11	25.15**	-0.15	-7.17**	0.27	-0.35**
7	TP27	0.72	-0.40	86.66	69.01	-32.31**	-0.39**	-16.72**	9.18**	0.08
8	TP44	3.55**	0.04	65.55	54.34	-6.30**	0.32**	13.62**	0.91	0.26*
9	TP45	-2.23	-0.88	2.22	5.37	-30.71**	0.41**	18.71**	-2.35	0.21*
10	TP46	1.36	-2.12**	2.22	5.37	-29.11**	-0.17*	-1.47	0.05	0.11
11	TP48	3.74*	-0.39	46.66	41.16	18.60**	-0.15	-9.49**	2.74	-0.07
12	TP50	5.33**	-1.41**	75.55	61.57	-13.16**	0.29**	6.04**	-0.80	0.18
13	TP51	1.20	2.38**	59.99	50.80	21.81**	0.05	7.00**	-6.62**	0.07
14	TP59	4.86**	0.26	77.77	63.08	26.10**	0.17*	7.63**	2.66	0.25*
	S.Em±	**1.483**	**0.521**		**3.90**	**2.13**	**0.078**	**1.462**	**1.834**	**0.099**
	CD at 5%	**4.153**	**1.459**		**10.81**	**5.98**	**0.219**	**4.094**	**5.135**	**0.277**
	CD at 1%	**5.516**	**1.939**		**14.23**	**7.94**	**0.291**	**5.438**	**6.821**	**0.368**
	Testers									
1	TP44	1.30	1.32**	2.22	5.37	-3.92**	0.60**	10.97**	-3.13**	0.21**
2	TP29	-2.71**	-0.07	2.22	5.37	-1.66	0.42**	9.15**	-0.45	0.16**
3	TP25	1.40*	-1.25**	2.22	5.37	-5.57**	-1.02**	-20.13**	3.58**	-0.37**
	S.Em±	**0.686**	**0.241**		**3.90**	**0.99**	**0.036**	**0.677**	**0.849**	**0.046**
	CD at 5%	**1.923**	**0.676**		**10.81**	**2.77**	**0.101**	**1.895**	**2.377**	**0.128**
	CD at 1%	**2.554**	**0.897**		**14.23**	**3.67**	**0.135**	**2.517**	**3.158**	**0.170**
	GCA:SCA	**1:7.19**	**1:4.176**			**1:32.15**	**1:24.26**	**1:22.31**	**1:1.06**	**1:2.46**

* and ** indicates significance of values at P=0.05 and P=0.01, respectively.

Electronic Journal of Plant Breeding, 7(4): 911-918 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00124.1

Table 4. Specific combining ability effects growth, earliness and yield traits in tomato hybrids

Sl. No.	Cross	Plant height at 90 DAT (cm)	Days to 50 per cent flowering	Per cent bacterial wilt incidence Mean	Arcsine value	*sca* effects	Equatorial diameter of fruit (cm)	Average fruit weight (g)	No. of fruits/ plant	Total yield/ plant (kg)
1.	TP1 x TP40	-3.50	-0.54	82.22	65.15	3.63	0.10	-11.52**	-4.65	-0.61**
2.	TP1 x TP29	9.43**	0.04	84.44	67.51	3.73	0.40**	24.75**	7.00*	0.96**
3.	TP1 x TP25	-5.92*	0.50	79.95	63.64	-7.36*	-0.50**	-13.23**	-2.35	-0.35*
4.	TP5 x TP40	-5.46*	-0.12	2.22	5.37	3.92	-0.11	-7.58**	-2.64	-0.34*
5.	TP5 x TP29	4.61	0.10	2.22	5.37	1.66	0.42**	15.96**	2.95	0.32*
6.	TP5 x TP25	0.85	0.02	2.22	5.37	-5.57	-0.31*	-8.37**	-0.31	-0.01
7.	TP15x TP40	-7.95**	0.21	86.66	69.01	6.78	-0.22	23.50**	1.70	0.48**
8.	TP15 x TP29	3.40	-1.83*	82.22	65.79	1.30	-0.32*	-15.96**	-0.71	-0.13
9.	TP15 x TP25	4.55	1.62	79.99	63.64	-8.08*	0.54**	-7.54**	-0.99	-0.35*
10.	TP19 x TP40	1.47	1.67	79.99	63.64	1.55	0.23	9.46**	-0.95	-0.07
11.	TP19 x TP29	-7.27**	1.53	79.99	67.51	3.16	0.36**	8.77**	-0.56	0.11
12.	TP19 x TP25	5.79*	-3.20**	84.44	66.86	-4.71	-0.59**	-18.23**	1.52	-0.04
13.	TP24 x TP40	5.69*	-3.14**	0.01	0.57	-0.88	-0.01	-2.74	13.51**	1.10**
14.	TP24 x TP29	4.57	1.31	6.66	10.16	6.45	0.14	1.42	-5.37	-0.21
15.	TP24 x TP25	-10.26**	1.83*	4.44	5.37	-5.57	-0.13	1.32	-8.14*	-0.89**
16.	TP26 x TP40	2.50	-0.34	73.33	59.02	0.12	0.47**	13.27**	-1.11	0.55**
17.	TP26 x TP29	1.14	0.91	79.99	63.64	2.48	-0.15	-8.09**	5.08	-0.11
18.	TP26 x TP25	-3.63	-0.57	82.22	65.79	-2.60	-0.32*	-5.18*	-3.96	-0.44**
19.	TP27 x TP40	4.33	-1.42	2.22	5.37	3.92	-0.36**	-9.53**	7.00*	0.30
20.	TP27 x TP29	1.57	1.62	2.22	5.37	1.66	0.16	11.45**	4.53	0.58**
21.	TP27 x TP25	-5.89*	-0.20	2.22	5.37	-5.57	0.20	-1.91	-11.53**	-0.88**
22.	TP44 x TP40	8.47**	0.45	4.44	10.16	-17.30**	0.56**	21.74**	3.96	0.37*
23.	TP44 x TP29	-3.11	0.80	6.66	14.96	-14.76**	-0.62**	-7.39**	-3.50	0.24
24.	TP44 x TP25	-5.36*	-1.25	86.66	69.01	32.06**	0.06	-14.35**	-0.46	-0.61**
25.	TP45 x TP40	-0.02	-0.90	2.22	5.37	2.32	0.28*	-4.64	-2.93	-0.26
26.	TP45 x TP29	-9.73**	0.46	2.22	5.37	0.06	-0.21	-20.25**	-4.80	-0.67**
27.	TP45x TP25	9.75**	0.44	4.44	10.16	-2.38	-0.08	24.89**	7.73*	0.93**
28.	TP46 x TP40	-1.15	2.90**	4.44	10.16	5.52	-0.26	-5.49*	-4.30	-0.46**
29.	TP46 x TP29	-0.63	-3.76**	4.44	10.16	3.26	-0.15	-9.68**	-4.30	-0.55**
30.	TP46 x TP25	1.78	0.86	2.22	5.37	-8.77*	0.41**	15.17**	8.60**	1.01**
31.	TP48 x TP40	6.68*	0.23	66.66	54.80	2.45	-0.19	-4.51	-3.53	-0.39*
32.	TP48 x TP29	-0.87	-1.19	73.33	59.02	4.41	0.22	7.03**	2.55	0.62**
33.	TP48 x TP25	-5.81*	0.97	66.66	54.99	-6.86	-0.02	-2.52	0.98	-0.23
34.	TP50 x TP40	-6.26*	0.62	4.44	10.16	-10.44**	-0.31*	5.77*	-2.33	-0.07
35.	TP50 x TP29	-3.23	-1.03	2.22	5.37	-17.50**	-0.36**	-12.54**	-6.97*	-0.73**
36.	TP50 x TP25	9.49**	0.40	71.60	58.03	27.93**	0.67**	6.77**	9.30**	0.80**
37.	TP51 x TP40	-2.31	-0.23	73.33	59.02	3.45	0.16	-16.13**	0.70	-0.40*
38.	TP51 x TP29	6.96**	0.30	75.55	60.42	2.58	0.23	4.36	-4.09	-0.53**
39.	TP51 x TP25	-4.65	-0.07	73.33	59.02	-6.04	-0.39**	11.78**	3.39	0.93**
40.	TP59 x TP40	-2.48	0.61	66.66	54.80	-5.05	-0.32*	-11.59**	-4.43	-0.20
41.	TP59 x TP29	-6.83**	0.75	79.98	63.64	1.52	-0.12	0.18	8.20*	0.05
42.	TP59 x TP25	9.32**	-1.36	91.10	72.88	3.53	0.44**	11.41**	-3.77	0.14
	S.Em±	**2.568**	**0.903**		**3.90**	**3.70**	**0.135**	**2.532**	**3.177**	**0.171**
	C.D. at 5%	**7.193**	**2.528**		**10.81**	**10.35**	**0.379**	**7.091**	**8.895**	**0.479**
	C.D. at 1%	**9.554**	**3.358**		**14.23**	**13.75**	**0.504**	**9.419**	**11.815**	**0.637**

* and ** indicate significance of values at p=0.05 and p=0.01, respectively