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Genetic studies for productivity and its related traits in tomato (*Solanum lycopersicum* L.)

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Abstract
A set of 40 genotypes including seven females, four males, their 28 single F_1 hybrids and one standard check (Abhinav) were sown at Vegetable Research Scheme, R.H.R.S., NAU, Navsari. During to study the heterosis in tomato (*Solanum lycopersicum* L.) for ten characters following Line × Tester mating design. High heterosis recorded by cross JTL-12-12× JT-3 was 295.83%, followed by NTL-1 × AT-3 (273.39%), JTL-12-12 × GT-2 (196.52%), JTL-12-12 × AT-3 (177.53%), NTL-1 × JT-3 (160.31%), JTL-12-10 × GT-2 (156.80%) and JTL-12-11 × GT-2 (155.55%) in positive direction. The crosses of either average × good, poor × good as well as average × poor yielding parents showed higher standard heterosis than good × good yielding parents. Thus, further breeding programme exploitation of heterosis is feasible.

Keywords: Heterosis, standard heterosis Tomato, Line × Tester, yield

Introduction

Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crops of Peru – Ecuador origin (Rick, 1969) [35] after potato. It belongs to family Solanaceae. Because of its wider adaptability and versatility, tomato is grown throughout the world either in outdoors or indoors. It is universally treated as "productive" as well as "protective food" having medicinal value, too. In many countries it is considered as poor man‘s orange, because of its attractive appearance and nutritive value (Singh *et al.*, 2004) [47]. As they are high in nutrient contents, they can be used as raw vegetables in sandwiches and salads or it can be processed to several products like puree, paste, soup, juices, ketchup, whole canned fruits, etc (Bose *et al.*, 2002) [5]. In order to increase the yield potential of genotype, knowledge of variability, inheritance direction and magnitude of association between various traits and their stable performance is essential for the plant breeder. In development of high yielding hybrids, choice of suitable parents is the crucial stage. For this purpose, knowledge of genetic architecture of different and yield component traits as well as the exploration of such information about newly developed lines is scanty. The improvement in different quantitative and qualitative traits in tomato through heterosis breeding was observed by Tiwari and Lal (2004) [49]. The present study was undertaken to estimate the extent of heterosis among the crosses, obtained from diverse tomato parental lines, crossed in Line **×** Tester pattern (Kempthorne, 1957) [21].

Materials and Methods

The present investigation was carried out at Vegetable Research Scheme, Regional Horticultural Research Station (R.H.R.S.), Navsari Agricultural University, Navsari during *Rabi* – 2013 (Crossing programme) and *Rabi*– 2014 (Evaluation). The experimental material comprised of 11 parents who involves seven females, four males and their 28 F_1 hybrids along with one commercial check (Hybrid- Abhinav). The above materials (40) were used for the experiment to study the combining ability. The seeds of 28 F_1s crosses were transplanted in Randomized Block Design with three replications. The parents and F_1s were sown in plots having rows of 10 plants with a spacing of 90 × 60 cm, recommended agronomic package and practices were applied to raise a healthy crop. Observations were recorded on days to 50% flowering, number of primary branches per plant, number of fruits per plant, plant height (cm), fruit yield per plant (kg), first flowering node, number of fruits per truss, average fruit weight

(g) and Pericarp thickness (mm). The data was subjected to line x tester analysis suggested by Kempthorne (1957) [21].

Results and Discussion

Fruit yield is the most important economic attribute in tomato. Standard heterosis is manifested in tomato for greater vigour, faster growth and development, earliness in maturity, increased productivity, better quality attributes and higher levels of resistance to biotic stresses. Yield is a complex polygenic character, but in tomato, fruit yield is mainly depends on the number of fruits per plant and fruit weight. In this experiment, number of fruits per plant and fruit weight showed significant and positive standard heterosis for both the characters. Hence, both these characters were important for fruit yield. These findings were also reported by Aruna and Veeraragavathatham (1995) [2], Narasimhamurthy and Gowda (2013) [29], Yadav *et al.* (2013) [51], Patwary *et al.* (2013) [31], and Chauhan *et al.* (2014) [6].

In this investigation high *per se* performance for fruit yield has been observed in JTL-12-12 (4.30 kg) among the parents. It is due to higher average fruit weight, higher plant height and also more number of primary branches per plant. Other parents like, JTL-12-12 (4.29 kg) and JTL-12-10 (4.23 kg) recorded higher fruit yield due to more number of fruits per plants, higher average fruit weight, more number of fruits per truss, more number of primary branches per plant and more plant height [Ghosh *et al.* (1997) [15], Kurian *et al.* (2001) [25], Sekar *et al.* (2001) [36], Kumar *et al.* (2006) [22], Sharma and Thakur (2008) [38], Kumar *et al.* (2012) [23], Joshi and Thakur (2012) [19], and Souza *et al.*, (2012) [48]].

The heterotic response of F1 is indicative of genetic diversity among the parents involved. The maximum standard heterosis recorded by cross JTL-12-12× JT-3 was 295.83%, followed by NTL-1×AT-3 (273.39%), JTL-12-12×GT-2 (196.52%), JTL-12-12×AT-3 (177.53%), NTL-1×JT-3 (160.31%), JTL-12-10×GT-2(156.80%) and JTL-12-11×GT-2 (155.55%). Almost identical results have been reported by Dhaliwal and Cheema (2011) [7], Negi *et al.* (2012) [30], Singh *et al.* (2012) [46], Kumar *et al.*(2012) [23], Angadi *et al.* (2012) [1], Farzane *et al.* (2012) [13], Shende *et al.* (2012) [40], Gaikwad and Cheema (2012) [14], Narasimhamurthy and Gowda (2013) [29], Yadav *et al.* (2013) [51], Patwary *et al.* (2013) [31], and Chauhan *et al.* (2014) [6]. It is interesting to note that top ranking crosses based on *per se* performance and standard heterosis was same.

For the character of fruits per plant has been observed in JTL-12-10 (35.79) among the parents. Other parents like, JTL-12-04 (30.90) and JTL-12-11 (29.02) recorded more no. of fruits per plant. In crosses, nine crosses *viz.,* JTL-12-12 × JT-3, NTL-1 × AT-3, JTL-12-12 × GT-2, JTL-12-12 × AT-3, NTL-1 × JT-3, JTL-12-11 × GT-2, JTL-12-04 × AT-3, JTL-12-04 × GT-1 and JTL-12-10 × JT-3 showed high standard heterosis for number of fruits per plant a major fruit yield component. Almost identical results have been reported by Dixit *et al.* (1980) [8], Tiwari and Lal (2004) [49], Duhan *et al.*(2005) [11], Premalakshme *et al.* (2005) [33], Premalakshme *et al.*(2006) [32], Hannan *et al.* (2007) [17], Asati *et al.* (2007) [3], Singh *et al.* (2008) [44], Himanshu *et al.* (2008) [18], Singh *et al.* (2009) [43], Mondal *et al.* (2009) [27], Dordevik *et al.* (2010) [10], Sekhar *et al.* (2010) [37], Kumari and Sharma (2011) [24], Shende *et al.* (2012) [40], Angadi *et al.* (2012) [1], Negi *et al.* (2012) [30], Mulge *et al.* (2012) [28], Kumar *et al.* (2012) [23], Patwary *et al.* (2013) [31], Yadav *et al.* (2013) [51] and Chauhan *et al.* (2014) [6] for number of fruits per plant.

Fruit weight also a positive character for the yield. In the parent JTL-12-12 (186.19 g) has been top most for fruit weight, other parents like, JTL-12-14 (186.02 g) and JTL-12-10 (120.28 g) has been reported. The crosses like, NTL-1 X AT-3 (226.46 g), JTL-12-10 GT-2 (190.42 g) and JTL-12-12 X AT-3 (184.48 g) were also showing significant and positive standard heterosis for average fruit weight. Hence this character was important for fruit yield. This findings was in agreement with earlier workers like, Virdelwala *et al.* (1980) [50], Dixit *et al.* (1980) [8], Sidhu *et al.* (1981) [41], Mandal *et al.* (1989) [26], Dod *et al.* (1992) [9], Reddy and Reddy (1994) [34], Aruna and Veeraragavathatham (1995) [2], Baishya *et al.* (2001) [4], Sharma *et al.* (2001) [39], Fageria *et al.* (2001) [12], Singh and Singh (2003) [45], Tiwari and Lal (2004) [49], Asati *et al.* (2007) [3], Sharma and Thakur (2008) [38], Mondal *et al.* (2009) [27], Gul *et al.* (2010) [16], Dordevik *et al.* (2010) [19], Sekhar *et al.* (2010) [37], Kumari and Sharma (2011) [24], Singh and Asati (2011) [42], Dhaliwal and Cheema (2011) [7], Negi *et al.* (2012) [30], Mulge *et al.* (2012) [28], Gaikwad and Cheema (2012) [14], Singh *et al.* (2012) [46], Patwary *et al.* (2013) [31], and Chauhan *et al.* (2014) [6].

Out of these crosses, crosses *viz.,* JTL-12-12 × JT-3, NTL-1 × AT-3, JTL-12-12 × GT-2, JTL-12-12 × AT-3, NTL-1 × JT-3, JTL-12-10 × GT-2, JTL-12-04 × AT-3 and JTL-12-10 × JT-3 showed significant and positive heterosis for plant height at maturity. These results revealed that plant height may be considered as a major yield component in tomato. Crosses, *viz.,* JTL-12-12 × JT-3, JTL-12-12 × GT-2, JTL-12-12 × AT-3 and NTL-1 × JT-3 were showed significant and positive heterosis for number of primary branches per plant. These results revealed that number of primary branches per plant may or may not be considered as a major yield components in tomato. Almost identical results have been summarized by Kanthaswamy and Balakrishnan (1989) [20], Dod *et al.* (1992) [9], Premalakshme *et al.* (2006) [32], Hannan *et al.* (2007) [17], Asati *et al.* (2007) [3], Sharma and Thakur (2008) [38], Singh *et al.* (2008) [44], Himanshu *et al.* (2008) [18], Singh *et al.* (2009) [43], Sekhar *et al.* (2010) [37], Kumari and Sharma (2011) [24], Singh and Asati (2011) [42], Angadi *et al.* (2012) [1], Negi *et al.* (2012) [30], Singh *et al.* (2012) [46], Kumar *et al.* (2012) [23], Shende *et al.* (2012) [40], Patwary *et al.* (2013) [31], Yadav *et al.* (2013) [51] and Narasimhamurthy and Gowda (2013) [29] for plant height. The number of primary branches might be resulted into more number of trusses per plant and it might be resulted in more number of fruits per plant which resulted in high fruit yield. These results were in agreement with several earlier workers like, Kanthaswamy and Balakrishnan (1989) [20], Fageria *et al.* (2001) [12], Duhan *et al.* (2005) [11], Hannan *et al.* (2007) [17], Sharma and Thakur (2008) [38], Mondal *et al.* (2009) [27], Kumar *et al.* (2012) [23], Angadi *et al.* (2012) [1], Shende *et al.* (2012) [40] and Narasimhamurthy and Gowda (2013) [29].

These is a biological balance between the principal yield components *i.e.* number of fruits per plant, average fruit weight, on one hand and number of primary branches per plant, first flowering node on the other hand, for high heterotic expression of fruit yield. It is evident from the result that it is not necessary that high heterosis for all the yield components only will result in high heterosis for yield but increase in any one or two yield components may also result in to high degree of heterosis for fruit yield. Almost identical results reported by Kumar *et al.* (2006) [22], Sharma and Thakur (2008) [38] and Joshi and Thakur (2012) [19].

The results of the present study indicate that through heterosis over mid-parent, better parent and standard check contributed significantly to the contribution of the for all characters.

Table 1: Analysis of variance for parents and hybrids in respect of yield contributing characters in tomato

Sr. No.	Sources of variances	D. F.	Days to 50 per cent flowering	Number of primary branches per plant	Number of fruits per plant	Plant height (cm)	Fruit yield per plant (kg)	First flowering node	Number of fruits per truss	Average fruit weight (g)	Pericarp thickness (mm)
1	Replications	2	40	0.05	26.60	125.27	0.20	0.07	0.47	31.52	0.00
2	Treatments	38	47.63**	4.04**	430.85**	550.64**	6.87**	10.13**	1.68**	5168.77**	11.47**
3	Parents	10	61.58**	7.56**	201.50**	478.02**	3.37**	10.79**	3.64**	6676.24**	8.80**
(a)	Among females (lines)	6	60.20**	0.46**	78.40**	68.51**	2.82**	11.43**	1.49**	7608.28**	11.09**
(b)	Among males (testers)	3	84.82**	0.40**	426.13**	369.45**	4.39**	5.78**	6.00**	1322.05**	5.55**
(c)	Females vs. Males (L vs. T)	1	0.19**	3.59**	266.23**	3260.82**	3.63**	21.95**	9.44**	17146.56**	4.84**
4	Hybrids (Crosses)	27	43.86**	4.97**	456.58**	436.25**	7.45**	10.21**	0.99**	4801.75**	12.75**
5	Parents vs. Hybrids (Parents vs. Crosses)	1	9.55	12.03**	2029.65**	4365.27**	26.14**	1.24	0.66	3.42	3.34**
6	Error	76	15.83	0.04	10.25	53.42	0.07	0.70	0.14	13.01	0.00
7	Total	116	26.67	1.36	148.31	217.54	2.30	3.78	0.65	1702.29	3.76

*****- Significant at 5% and **- Significant at 1%

Table 2: Mean performance of parents, hybrids and standard check for various characters in Tomato

Genotypes	Days to 50 per cent flowering	Number of primary branches per plant	Number of fruit per plant	Plant height (cm)	Fruit yield per plant (kg)	First flowering node	Number of fruits per truss	Average fruit weight (g)	Pericarp thickness (mm)
Female Parents									
NTL-1	54.94	6.87	29.69	93.8	3.42	8.47	4.94	106.59	7.19
NTL-50	54.87	5.8	27.90	89.6	1.76	11.67	6.07	50.50	7.21
JTL-12-04	54.47	6.74	30.90	95.87	2.66	8.74	3.8	93.22	1.91
JTL-12-10	55.07	6.2	35.79	95.8	4.23	12.67	4.27	120.28	5.77
JTL-12-11	47.54	6.27	29.02	86.4	4.30	10.87	4.87	155	7.46
JTL-12-12	44.6	6.8	22.17	96.4	4.29	13.67	4.87	186.19	6.55
JTL-12-14	55.87	6.27	20.94	85.07	3.82	12.07	4.54	186.02	5.65
Male Parent									
GT-1	53.07	5.54	20	84.94	1.04	10.74	2.67	61.01	5.91
GT-2	44.6	5.47	45	63.8	3.78	8.2	3.6	75.32	5.09
JT-3	55.34	5.67	42.67	60.74	3.28	8.34	2.67	76.64	6.38
AT-3	56.27	6.27	28.17	75.27	3.12	10.6	5.67	110.52	3.29
Hybrids									
NTL-1 × GT-1	54.8	7.94	31.34	111.8	2.07	7.94	5.07	65.73	5.38
NTL-1 × GT-2	50.34	7.97	21.84	121.47	2.23	9.27	5.14	101.07	5.74
NTL-1 × JT-3	47.867	7.47	54.157	106.14	5.41	10.14	3.74	96.39	5.64
NTL-1 × AT-3	43.67	5.47	34.34	100.07	7.76	12.07	4.4	226.46	3.74
NTL-50 × GT-1	51.07	5.4	49	93.4	3.76	13.14	5.2	79.66	7.14
NTL-50 × GT-2	46.47	7.14	60.2	87.54	4.45	12.47	5.6	73.54	3.45
NTL-50 × JT-3	48.54	5	46	86.4	3.41	8.14	5.4	73.33	8.15
NTL-50 × AT-3	59.87	5.34	21.64	80.4	1.49	11.67	4.4	73.95	7.14
JTL-12-04 × GT-1	50.47	6.07	47.54	77.4	5.22	9	4.34	110.68	4.66
JTL-12-04 × GT-2	55.67	7.74	44.57	101.4	4.18	7.67	4.87	93.71	7.26
JTL-12-04 × JT-3	52.6	7.54	28.9	97.87	3.59	8.67	4.94	123.58	3.37
JTL-12-04 × AT-3	51.07	5.67	53.67	110.67	5.27	8.54	4.54	94.99	6.22
JTL-12-10 × GT-1	53.47	7.47	29.84	114.4	4.25	13.07	3.54	143.85	7.14
JTL-12-10 × GT-2	50.54	5.8	27.80	95.07	5.32	10.34	3.87	190.42	1.83
JTL-12-10 × JT-3	54.2	7.14	48.55	99.07	4.58	9.94	3.67	93.30	1.73
JTL-12-10 × AT-3	53.2	5.34	23.83	82.54	4.22	12.47	5	177.58	5.98
JTL-12-11 × GT-1	51.27	7.6	36.17	115.34	3.71	9.74	4.4	101.32	2.79
JTL-12-11 × GT-2	58.4	6	38.44	86.27	5.34	8.6	4.44	131.2	5.77
JTL-12-11 × JT-3	53.87	8.54	40.84	92.47	4.44	12.27	4.67	101.48	7.71
JTL-12-11 × AT-3	49.47	8.67	39.59	101.07	4.18	11.34	4.87	106.70	2.80
JTL-12-12 × GT-1	52	7.27	37.74	111.2	3.22	12.67	4.4	86.67	4.51

JTL-12-12 × GT-2	49.2	8.54	65	99.27	6.17	9.8	3.74	92.50	7.71
JTL-12-12 × JT-3	54.87	9.07	64.49	108.47	8.23	11.4	3.87	128.54	2.10
JTL-12-12 × AT-3	48.47	6.87	31.37	96.34	5.77	11.6	5.4	184.48	7.34
JTL-12-14 × GT-1	55	5.2	36.47	103.27	3.34	12.2	4.6	95.7	6.28
JTL-12-14 × GT-2	55	9	28.52	101.27	2.08	8.54	4.47	67.86	2.37
JTL-12-14 × JT-3	54.47	5.73	35.57	79.07	3.86	6.93	4.40	100.59	7.06
JTL-12-14 × AT-3	44.13	5.80	27.49	81.80	2.75	9.33	3.80	104.09	7.35
Standard Check									
Abhinav	58.27	6.34	26	82.2	2.08	10.47	4.14	80.5	9.49

Table 3a: Heterosis of hybrids for different traits

Crosses	Days to 50% flowering			Number of primary branches per plant			Number of fruit per plant		
	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)
NTL-1 × GT-1	1.48	-0.24	-5.95	27.96**	15.53**	25.26**	26.12**	5.55	20.51*
NTL-1 × GT-2	1.14	-8.37	-13.62*	29.19**	16.02**	25.79**	-41.53**	-51.48**	-16.03
NTL-1 × JT-3	-13.18*	-13.49*	-17.85**	19.15**	8.74**	17.89**	49.70**	26.93**	108.29**
NTL-1 × AT-3	-21.46**	-22.39**	-25.06**	-16.75**	-20.39**	-13.68**	18.69*	15.65	32.05**
NTL-50 × GT-1	-5.37	-6.93	-12.36*	-4.71	-6.90*	-14.74**	104.62**	75.67**	88.46**
NTL-50 × GT-2	-6.57	-15.31*	-20.25**	26.63**	22.99**	12.63**	65.17**	33.78**	131.54**
NTL-50 × JT-3	-11.92*	-12.29*	-16.70**	-12.79**	-13.79**	-21.05**	30.39**	7.81	76.92**
NTL-50 × AT-3	7.74	6.40	2.75	-11.60**	-14.89**	-15.79**	-22.82**	-23.20*	-16.79
JTL-12-04 × GT-1	-6.14	-7.34	-13.39*	-1.09	-9.90**	-4.21	86.78**	53.85**	82.82**
JTL-12-04 × GT-2	12.38*	2.20	-4.46	26.78**	14.85**	22.11**	17.44**	-0.96	71.41**
JTL-12-04 × JT-3	-4.19	-4.94	-9.73	21.51**	11.88**	18.95**	-21.43**	-32.27**	11.15
JTL-12-04 × AT-3	-7.77	-9.24	-12.36*	-12.82**	-15.84**	-10.53**	81.73**	73.70**	106.41**
JTL-12-10 × GT-1	-1.11	-2.91	-8.24	27.27**	20.43**	17.89**	6.96	-16.63*	14.74
JTL-12-10 × GT-2	1.40	-8.23	-13.27*	-0.57	-6.45*	-8.42**	-31.19**	-38.24**	6.90
JTL-12-10 × JT-3	-1.81	-2.05	-6.98	20.22**	15.05**	12.63**	23.76**	13.77*	86.71**
JTL-12-10 × AT-3	-4.43	-5.45	-8.70	14.44**	-14.89**	-15.79**	-25.49**	-33.42**	-8.37
JTL-12-11 × GT-1	1.92	-3.39	-12.01*	28.81**	21.28**	20.00**	47.57**	24.64**	39.10**
JTL-12-11 × GT-2	26.77**	22.86**	0.23	2.27	-4.26	-5.26	3.85	-14.59*	47.82**
JTL-12-11 × JT-3	4.73	-2.65	-7.55	43.02**	36.17**	34.74**	13.93*	-4.30	57.05**
JTL-12-11 × AT-3	-4.69	-12.09*	-15.10**	38.30**	38.30**	36.84**	38.44**	36.42**	52.24**
JTL-12-12 × GT-1	6.48	-2.01	-10.76	17.84**	6.86**	14.74**	78.97**	70.23**	45.13**
JTL-12-12 × GT-2	10.31	10.31	-15.56**	39.13**	25.49**	34.74**	93.55**	44.44**	150.00**
JTL-12-12 × JT-3	9.81	-0.84	-5.84	45.45**	33.33**	43.16**	98.92**	51.13**	148.01**
JTL-12-12 × AT-3	-3.90	-13.86*	-16.82**	5.10	0.98	8.42**	24.62**	11.35	20.63*
JTL-12-14 × GT-1	0.98	-1.55	-5.61	-11.86**	-17.02**	-17.89**	78.19**	74.22**	40.27**
JTL-12-14 × GT-2	9.49	-1.55	-5.61	53.41**	43.62**	42.11**	-13.50*	-36.63**	9.68
JTL-12-14 × JT-3	-2.04	-2.51	-6.52	-3.91	-8.51**	-9.47**	11.84	-16.64**	36.79**
JTL-12-14 × AT-3	-21.28**	-21.56**	-24.26**	7.45**	-7.45**	-8.42**	11.95	-2.43	5.71
CD (5%)	5.64	6.51	6.51	0.30	0.35	0.35	4.54	5.24	5.24
CD (1%)	7.51	8.67	8.67	0.40	0.46	0.46	6.04	6.98	6.98

***-** Significant at 5% and **- Significant at 1%

Table: 3b: Heterosis of hybrids for different traits

Crosses	Plant height (cm)			Fruit yield per plant (kg)			First flowering node		
	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)	MP (%)	BP (%)	SC (%)
NTL-1 × GT-1	25.10**	19.19**	36.01**	-7.45	-39.63**	-0.79	-17.36**	-26.09**	-24.20**
NTL-1 × GT-2	54.15**	29.50**	47.77**	-38.11**	-41.11**	7.20	11.20	9.45	-11.46
NTL-1 × JT-3	37.36**	13.15*	29.12**	61.54**	58.38**	160.31**	20.63**	19.69*	-3.18
NTL-1 × AT-3	18.38**	6.68	21.74**	137.80**	127.18**	273.39**	26.57**	13.84*	15.29*
NTL-50 × GT-1	7.03	4.24	13.61	168.27**	113.55**	80.53**	17.26**	12.57*	25.48**
NTL-50 × GT-2	14.12*	-2.31	6.49	60.48**	17.50**	113.91**	25.50**	6.86	19.11**
NTL-50 × JT-3	14.94*	-3.57	5.11	35.30**	3.86	64.04**	-18.67**	-30.29**	-22.29**
NTL-50 × AT-3	-2.47	-10.27	-2.19	-38.95**	-52.23**	-28.50**	4.79	0.00	11.46
JTL-12-04 × GT-1	-14.38*	-19.26**	-5.84	182.20**	96.34**	151.01**	-7.53	-16.15*	-14.01*
JTL-12-04 × GT-2	27.01**	5.77	23.36**	29.69**	10.38	100.95**	-9.45	-12.21	-26.75**
JTL-12-04 × JT-3	24.99**	2.09	19.06*	20.87**	9.35	72.71**	1.56	-0.76	-17.20*
JTL-12-04 × AT-3	29.33**	15.44*	34.63**	82.51**	69.20**	153.26**	-11.72	-19.50**	-18.47**
JTL-12-10 × GT-1	26.60**	19.42**	39.17**	61.40**	0.54	104.62**	11.68*	3.16	24.84**
JTL-12-10 × GT-2	19.13**	-0.77	15.65*	32.56	25.57**	155.55**	-0.96	-18.42**	-1.27
JTL-12-10 × JT-3	26.58**	3.41	20.52**	21.95**	8.30	120.40**	-5.40	-21.58**	-5.10
JTL-12-10 × AT-3	-3.51	-13.85*	0.41	14.91**	-0.29	102.92**	7.16	-1.58	19.11**
JTL-12-11 × GT-1	34.63**	33.49**	40.31**	39.14**	-13.59**	78.63**	-9.88	-10.43	-7.01
JTL-12-11 × GT-2	14.87*	-0.15	4.95	32.11**	24.22**	156.80**	-9.79	-20.86**	-17.83**
JTL-12-11 × JT-3	25.69**	7.02	12.49	16.96**	3.16	113.25**	27.78**	12.88*	17.20*
JTL-12-11 × AT-3	25.03**	16.98*	22.95**	12.85*	-2.72	101.11**	5.99	4.29	8.28

JTL-12-12 × GT-1	22.65**	15.35*	35.28**	20.96**	-24.85**	55.10**	3.83	-7.32	21.02**
JTL-12-12 × GT-2	23.93**	2.97	20.76**	52.67**	43.66**	196.52**	-10.37	-28.29**	-6.37
JTL-12-12 × JT-3	38.06**	12.52*	31.95**	117.29**	91.78**	295.83**	3.64	-16.59**	8.92
JTL-12-12 × AT-3	12.23*	0.07	17.19*	55.88**	34.46**	177.53**	-4.40	-15.12**	10.83
JTL-12-14 × GT-1	21.49**	21.39**	25.63**	37.76**	-12.34*	60.92**	7.02	1.10	16.56*
JTL-12-14 × GT-2	36.05**	19.04**	23.20**	-45.31**	-45.53**	-0.02	-15.79**	-29.28**	-18.47**
JTL-12-14 × JT-3	8.46	-7.05	-3.81	8.55	0.97	85.35**	-32.03**	-42.54**	-33.76**
JTL-12-14 × AT-3	2.04	-3.84	-0.49	-20.43**	-27.78**	32.58**	17.65**	-22.65**	-10.83
CD (5%)	10.36	11.96	11.96	0.36	0.42	0.42	1.19	1.37	1.37
CD (1%)	13.80	15.93	15.93	0.49	0.56	0.56	1.58	1.82	1.82

***-** Significant at 5% and **- Significant at 1%

Table 3c: Heterosis of hybrids for Pericarp thickness

Crosses	Pericarp thickness (mm)		
	MP (%)	BP (%)	SC (%)
NTL-1 × GT-1	-17.86**	-25.18**	-43.32**
NTL-1 × GT-2	-6.46**	-20.13**	-39.32**
NTL-1 × JT-3	-16.92**	-21.57**	-40.59**
NTL-1 × AT-3	-28.68**	-48.01**	-60.62**
NTL-50 × GT-1	8.84**	-1.04	-24.75**
NTL-50 × GT-2	-43.91**	-52.17**	-63.63**
NTL-50 × JT-3	19.86**	12.96**	-14.11**
NTL-50 × AT-3	35.92**	-1.05	-24.76**
JTL-12-04 × GT-1	19.22**	-21.11**	-50.90**
JTL-12-04 × GT-2	107.38**	42.59**	-23.51**
JTL-12-04 × JT-3	-18.75**	-47.22**	-64.49**
JTL-12-04 × AT-3	139.07**	88.92**	-34.49**
JTL-12-10 × GT-1	22.37**	20.93**	-24.72**
JTL-12-10 × GT-2	66.35**	-68.32**	-80.75**
JTL-12-10 × JT-3	-71.58**	-72.95**	-81.80**
JTL-12-10 × AT-3	32.15**	3.77**	-36.92**
JTL-12-11 × GT-1	-58.36**	62.70**	-70.67**
JTL-12-11 × GT-2	-8.11**	-22.71**	-39.23**
JTL-12-11 × JT-3	11.43**	3.39**	-18.71**
JTL-12-11 × AT-3	-47.90**	-62.46**	-70.49**
JTL-12-12 × GT-1	-27.64**	-31.21**	-52.49**
JTL-12-12 × GT-2	32.49**	17.68**	-18.71**
JTL-12-12 × JT-3	-67.53**	-67.95**	-77.86**
JTL-12-12 × AT-3	49.17**	12.02**	-22.62**
JTL-12-14 × GT-1	8.59**	6.27**	-33.85**
JTL-12-14 × GT-2	-55.92**	-58.11**	-75.04**
JTL-12-14 × JT-3	17.44**	10.72**	-25.51**
JTL-12-14 × AT-3	64.55**	30.15**	-22.45**
CD (5%)	0.076	0.087	0.087
CD (1%)	0.101	0.116	0.116

***-** Significant at 5% and **- Significant at 1%

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