

Original Research Article

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Combining Ability, Gene Action and Heterotic Expression Studies for Yield Contributing Traits in Tomato

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ABSTRACT

Keywords

Analysis of Variance, Genetic variance, GCA, Heterosis, Line \times Tester, SCA, Tomato

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Investigation was carried out at the experimental field of Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal with seven lines, four testers and twenty-eight cross combinations derived from line \times tester model to study the genetic performance of tomato genotypes. The significant variances due to lines and testers, line *vs.* tester and parent *vs.* hybrid indicated the importance of their contribution towards general combining ability (GCA), specific combining ability (SCA) and presence of heterotic expression for important characters respectively. The magnitude of predictability ratio for all the traits studied was very less than unity indicated preponderance of non-additive gene action for the inheritance of all the traits. Among lines Arka Alok, Arka Saurabh, Arka Vikas and Arka Meghali and among testers Berika and Alisa Craig possess good GCA. Arka Saurabh \times Alisa Craig, Arka Ashish \times Berika and Arka Vikas \times Berika crosses identified as best with good SCA. Arka Saurabh \times Alisa Craig followed by Arka Alok \times Berika, Arka Meghali \times Berika and Arka Ahuti \times Berika were best identified crosses with heterotic expression for the yield contributing traits which was due to the involvement of the parents having high GCA and crosses with good specific combining ability.

Introduction

Among the different vegetable crops, tomato (*Solanum lycopersicum* L.) is one of the most popularly cultivated warm season vegetable throughout the world due to its multipurpose use (Triveni *et al.*, 2017). It can also be used as an excellent model crop for study with respect to breeding point of view due to having small diploid genome (930 Mb, $n = 12$) with numerous mapped traits, developed DNA markers and EST clones (Tanksley,

1993). Tomato under target specific selection resulted in increased productivity, but at the same time it has narrowed its genetic basis (Zorzoli *et al.*, 2007) that justified the further study and thorough genetic evaluation of tomato. In spite of all these, major constraints in the diminishing returns of the grower includes varietal fluctuation in the productivity under huge artificial genetic manipulation and contamination leading impure narrow genetic base (Chattopadhyay *et al.*, 2007). It indicated the need for

exploration for genetic diversity within the available germplasm and utilization of them in conventional cross breeding approach that will be more environmentally safe and practically viable to manifest the advantages in terms of high productivity, uniformity, improved quality, biotic resistance, wider adaptation, earliness and chance for combining of desirable different characters from contrasting parents or inbred (Tesi *et al.*, 1970). In order to select suitable parents and for success of hybridization programme the information pertaining with respect to genetic diversity, its nature and magnitude is important (Fernie *et al.*, 2006; Gami *et al.*, 2010). Line \times Tester design which is basically an extension of top cross is most reliable in estimating combining ability and gene action, offers an advantage in assessment of large number of lines by attempting minimum number of crosses and provides overall genetic background of materials employed under investigation to the breeder (Kempthorne, 1957). Heterosis phenomenon due to its enhanced expression for the manifestation of different characters in both (positive and negative) direction helps in a crop improvement, therefore heterosis breeding serves as an important tool in tomato (Fageria *et al.*, 2001; Duhan *et al.*, 2005; Thakur *et al.*, 2004).

Materials and Methods

A total of 11 genotypes comprising of 7 lines viz., Arka Abha, Arka Vikas, Arka Saurabh, Arka Meghali, Arka Alok, Arka Ahuti and Arka Ashish sourced from IIHR, Bengaluru, Karnataka as females and 4 widely diversified and highly adoptable testers viz., Patharkutchi, Berika, Alisa Craig received from Bidhan Chandra Krishi Viswavidyalaya, West Bengal and Pusa Ruby from Bihar Agricultural University, Sabour, Bihar as males were employed in Line \times Tester mating model with simple Randomized Block Design

(RBD) at a spacing of 60cm \times 60cm to fulfill the objectives of the study. Pusa Ruby was considered as a standard parent. The data was recorded on different yield contributing characters viz., flower/truss, fruit/truss, truss/plant, fruit/plant, polar diameter (cm), equatorial diameter (cm), pericarp thickness (mm), locule number and fruit weight (g) as per published descriptors of IBPGR, Rome and NBPGR, New Delhi. The combining ability analysis was done using the line \times tester method described by Kempthorne (1957). Significance for heterosis was tested as per the method suggested by Wynne *et al.*, (1970).

Results and Discussion

Analysis of variance for lines, testers and hybrids for set of yield contributing characters were represented in Table 1. In the present investigation, mean sum of square for replication was insignificant for irrespective of characters studied indicated that within the selected parents under the experiment were highly homogenous. Variance due to genotypes was partitioned into parents, hybrids and parent *vs.* hybrids components. The presence of high genetic diversity among the parents used and their derived off-springs was depicted by the highly significant variances due to the genotypes, parents and hybrids for the truss/plant, fruit/plant, fruit weight, polar diameter and pericarp thickness. Highly significant variance due to parents *vs.* hybrids for the fruits/plant, fruit weight, polar diameter, pericarp thickness and locule number suggested the manifestation of heterotic effects for these characters. The existence of enormous diversity among the parents and significant contribution of hybrids derived from them towards specific combining ability was demonstrated by the highly significant variances due to line *vs.* testers for the truss/plant, fruits/plant, fruit weight and pericarp thickness. Highly

significant variances due to lines for the truss/plant, fruit/plant, fruit weight, pericarp thickness and locule number and due to testers for the fruit/truss, truss/plant, fruit/plant, fruit weight, polar diameter, equatorial diameter and pericarp thickness revealed their contribution towards general combining ability. Insignificant variance due to genotypes for flower/truss and fruit/truss, due to parents for fruits/truss and locule number, due to hybrids for flower/truss, fruit/truss and locule number, due to parents *vs.* hybrids for flower/truss, fruit/truss, truss/plant and equatorial diameter, due to lines for flower/truss, fruit/truss, polar diameter and equatorial diameter, due to testers for flower per truss and locule number and due to lines *vs.* testers for flower/truss, fruit/truss, polar diameter, equatorial diameter and locule number were observed.

For designing the effective advanced breeding strategy, the knowledge about the gene action in manifestation of yield contributing traits are enormous important. Comparative assessment of the additive and non-additive gene effect was illustrated by the predictability ratio i.e., the proportion of additive genetic variance to the total genetic variance. In the investigation the magnitude of predictability ratio for all the traits under study was very less than unity (Table 2) indicated preponderance of non-additive gene action for the inheritance of all the traits. Regarding the contribution of lines, testers and lines \times testers towards the total variation, very much diversified response was evident (Table 2). It was observed that there was predominant contribution of lines \times testers interaction towards the total variance for maximum numbers of characters *viz.*, flower per truss, truss per plant, fruit per plant, pericarp thickness. More or less equal contribution of testers and line \times testers interaction towards the total variation was evident for fruit per truss, fruit weight, polar

and equatorial diameter of the fruit. There was predominant contribution of lines and lines \times testers interaction for locule number per fruit. These findings found ample support from the earlier workers (Raj *et al.*, 2017 for Pericarp thickness, Savale and Patel, 2017 for fruits/plant, Sherpa *et al.*, 2014 for Locule number/fruit, Shankar *et al.*, 2013 for Fruits/truss and Fruit weight, Yadav *et al.*, 2013 for polar diameter, Shende *et al.*, 2012 for Truss/plant and Equatorial diameter and Sekhar *et al.*, 2010 for Flower/truss).

Per se performance data of parents represented in Table 3 revealed that, Arka Ashish showed the maximum values for number of truss per plant (9.48), polar diameter (6.69 cm) and pericarp thickness (8.48 mm). Arka Vikas showed the maximum value for number of fruit per truss (5.32), number of fruit per plant (47.34). Whereas, Arka Saurabh exhibited highest magnitude for number of flower per truss (6.64). Among the testers highest magnitude towards desired direction was recorded in Berika for fruit weight (107.92 g), polar diameter (6.89 cm), equatorial diameter (5.45 cm), pericarp thickness (8.54 mm) and locule number (2.0) and by Patharkutchi for fruit per truss (5.45), truss per plant (8.21) and fruit per plant (44.72). Comparison between the average magnitude in desired direction between lines and testers indicated that among the 9 yield contributing characters studied, average performance of lines was higher than the testers for 6 characters that highly justified the selection of parents for investigation as well as greater genetic potentiality to develop the hybrids. It was depicted in the Table 4 that *Per se* performance considering the Arka Alok hybrids altogether was highest for the characters *viz.*, number of flower per truss, number of fruit per truss, fruit weight and equatorial diameter. Whereas, Arka Saurabh hybrids showed the maximum average value for number of fruit and truss per plant and

locule number per fruit. Mean pericarp thickness was recorded to be the highest at desired direction in the Arka Meghali hybrids. Average performance of Arka Ashish hybrids for polar diameter displayed highest. Considering the individual *Per se* performance separately it was found that the for flower per truss the maximum value recorded in Arka Saurabh × Berika (6.34). Similarly, for number of fruit per truss (5.56) and fruit weight (147.66 g) was recorded to be the highest in Arka Alok × Berika. Whereas, number of truss per plant (15.12) and fruit per plant (65.57) was recorded maximum in Arka Saurabh × Alisa Craig. Regarding the polar diameter (6.39 cm) and locule number per fruit (2.01) was recorded maximum (desired path) in Arka Ahuti × Berika. For the equatorial diameter the highest value was recorded in Arka Alok × Patharkutchi (6.71 cm). Whereas, for pericarp thickness it was observed that Arka Alok × Alisa Craig (9.09 mm) recorded the maximum magnitude.

Comparison between the average magnitude at desired direction between lines and testers together with the average performance of hybrids indicated that there was an unregulated manifestation among the hybrids in comparison to average performance of their parents suggested the importance of heterosis for manifestation of most of the characters.

The general combining ability (GCA) effect for all yield contributing characters were represented in Table 3 for lines as well as testers separately. The highest positive GCA effects among lines were recorded in Arka Alok for flower per truss (0.53), fruits per truss (0.67), fruit weight (21.60) and equatorial diameter (0.64). Whereas, in Arka Saurabh for truss per plant (1.82), fruits per plant (8.31) and locule number (0.60), Arka Ashish (0.53) for polar diameter, Arka Meghali (1.33) for pericarp thickness. Similarly, among testers Berika for flower per

truss (0.36), fruit per truss (0.35), fruit weight (24.48 and polar diameter (0.85), Alisa Craig for truss per plant (1.77), fruit per plant (9.69) and pericarp thickness (0.46), Pusa Ruby for equatorial diameter (0.38) and Patharkutchi for locule number (0.41) showed maximum positive GCA effects. Among lines Arka Alok, Arka Saurabh, Arka Vikas and Arka Meghali identified as good with general combining ability. Similarly, among testers Berika and Alisa Craig possess good general combining ability.

The specific combining ability effect (SCA) for all the studied characters was represented in Table 5. Regarding flower per truss highest values were recorded in Arka Ahuti × Alisa Craig (0.89) followed by Arka Alok × Patharkutchi (0.72) and Arka Saurabh × Berika (0.46). Similarly, for fruit per truss was recorded in Arka Abha × Alisa Craig (0.79) followed by Arka Saurabh × Berika (0.72) and Arka Ahuti × Patharkutchi (0.42), for the truss per plant was noted in Arka Saurabh × Alisa Craig (4.00) followed by Arka Ahuti × Alisa Craig (2.97) and Arka Abha × Berika (1.86), Arka Ahuti × Alisa Craig (16.97) followed by Arka Saurabh × Alisa Craig (14.17) and Arka Meghali × Patharkutchi (8.86) for fruit per plant. In case of individual mature ripe fruit weight Arka Ahuti × Pusa Ruby (35.42) followed by Arka Alok × Patharkutchi (30.43) and Arka Ashish × Alisa Craig (26.57) performed the maximum. Regarding the polar diameter, maximum recorded in Arka Abha × Alisa Craig (0.80) followed by Arka Ahuti × Berika (0.70) and Arka Meghali × Alisa Craig (0.66), for equatorial diameter in Arka Abha × Alisa Craig (0.85) followed by Arka Alok × Patharkutchi (0.83) and Arka Ahuti × Pusa Ruby (0.71), for pericarp thickness, in Arka Abha × Alisa Craig (1.96) followed by Arka Abha × Pusa Ruby (1.83) and Arka Vikas × Patharkutchi (1.76) and for locule number of fruit was recorded in Arka Ashish × Berika

(0.86) followed by Arka Saurabh × Alisa Crag (0.63) and Arka Vikas × Berika (0.62).

Arka Saurabh × Alisa Craig, Arka Ashish × Berika and Arka Vikas × Berika crosses identified as best with good specific combining ability which may be due to good × good and poor × good cross combinations of GCA effects of parents.

The range and magnitude of the heterosis estimated over mid parent (relative heterosis), better parent (heterobeltiosis) and standard parent considering Pusa Ruby as check

variety (Standard heterosis) have been presented in Table 6. For flower per truss the highest magnitude of average heterosis was observed in Arka Alok × Pusa Ruby (20.07%), heterobeltiosis in Arka Alok × Berika (16.92%) and standard heterosis in Arka Saurabh × Berika (55.77%). The cross Arka Abha × Alisa Craig displayed maximum average heterosis (30.43%) for fruit per truss and similarly Arka Alok × Berika exhibited maximum better parent heterosis (27.04%) and standard parent heterosis (59.92%) for the same character.

Table.1 Analysis of variance for parents and hybrids for yield contributing characters

Source of variation (d.f)	Mean Sum of Square for Parents and Hybrids for different yield contributing characters								
	Flower / truss	Fruit/ truss	Truss/ plant	Fruit/ plant	Fruit weight (g)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	Locule number
Replication (2)	0.003	0.012	0.0005	0.878	0.046	0.003	0.003	0.005	0.002
Genotypes (38)	1.372	1.176	11.05**	306.44**	2147.96**	2.469**	1.744*	9.626**	1.812**
Parents (10)	2.225*	1.638	2.188*	166.76**	535.09**	3.338**	0.679	9.125**	1.882
Hybrids (27)	1.083	1.043	14.60**	368.43**	2747.44**	2.089**	2.175**	9.988**	1.596
Parents vs Hybrids (1)	0.626	0.155	3.926	29.27**	2091.02**	4.048*	0.766	4.838*	6.880*
Lines (6)	1.260	1.530	10.80**	364.09**	2335.95**	2.130	1.922	15.65**	3.091**
Testers (3)	2.335	2.882*	33.26**	984.68**	9769.88**	6.886**	6.392**	5.153**	1.861
Lines vs Testers (18)	0.815	0.575	12.75**	267.17**	1714.19**	1.275	1.556	8.906**	1.056
Error (76)	0.003	0.002	0.003	0.268	0.247	0.002	0.002	0.011	0.002

**=Significance at 1% level; *= Significance at 5% level

Table.2 Estimates of genetic components and proportional contribution to variance for yield contributing characters

Components of genetic variation	Flower / truss	Fruit/ truss	Truss / plant	Fruit/ plant	Fruit weight (g)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	Locule number
σ^2 GCA	0.006	0.010	0.041	2.25	22.96	0.018	0.014	0.024	0.012
σ^2 A	0.012	0.021	0.082	4.50	45.92	0.036	0.027	0.048	0.024
σ^2 SCA (σ^2 D)	0.467	0.515	6.16	171.21	1451.29	1.078	1.046	3.209	0.623
Predictability ratio	0.025	0.039	0.013	0.026	0.031	0.033	0.026	0.015	0.037
Proportional contribution to the total variance (%)									
Lines	25.85	32.60	16.44	21.96	18.94	22.66	19.64	34.82	43.00
Testers	23.96	30.69	25.31	29.70	39.51	36.63	32.66	5.73	12.94
Line X Tester	50.19	36.72	58.24	48.34	41.59	40.70	47.70	59.44	44.06

Table.3 GCA effect and average performance of Lines and Testers for yield contributing characters

Genotype		Flower/ truss	Fruit/ truss	Truss/ plant	Fruit/ plant	Fruit weight (g)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	Locule number
Lines										
Arka Alok (L1)	gca	0.53**	0.67**	0.18**	5.58**	21.60**	0.30**	0.64**	0.43**	0.55**
	μ	5.23	4.19	7.22	30.23	123.60	6.08	5.88	8.14	4.39
Arka Abha (L2)	gca	-0.30**	-0.05**	-0.40**	-2.52**	-2.44**	-0.36**	0.17**	-0.77**	0.04**
	μ	4.30	3.27	8.06	26.34	92.67	4.28	5.30	4.65	4.66
Arka Ashish (L3)	gca	0.14**	0.06**	-0.56**	-2.18**	-3.32**	0.53**	-0.29**	0.93**	-0.47**
	μ	6.02	4.06	9.48	38.51	107.08	6.69	4.97	8.48	3.37
Arka Ahuti (L4)	gca	-0.25**	-0.09**	0.52**	2.23**	-9.66**	0.03*	-0.51**	0.41**	-0.79**
	μ	4.88	3.78	8.73	33.04	109.65	6.02	5.71	7.15	3.37
Arka Meghali (L5)	gca	-0.36**	-0.55**	-0.57**	-6.29**	13.27**	0.30**	0.15**	1.33**	-0.10**
	μ	4.95	3.90	7.46	29.08	111.10	4.99	5.71	5.48	3.68
Arka Vikas (L6)	gca	0.02	-0.07**	-1.00**	-5.13**	0.90**	-0.11**	0.18**	-0.29**	0.16**
	μ	6.41	5.32	8.89	47.34	109.26	4.52	5.63	4.07	4.32
Arka Saurabh (L7)	gca	0.21**	0.04*	1.82**	8.31**	-20.35**	-0.68**	-0.36**	-2.04**	0.60**
	μ	6.64	4.81	7.30	35.11	96.76	4.68	5.80	5.70	3.35
S.E. (g)		0.015	0.014	0.015	0.149	0.143	0.012	0.013	0.031	0.013
Testers										
Patharkuchi (T1)	gca	-0.29**	-0.30**	-1.00**	-6.37**	-2.52**	-0.22**	0.06**	-0.30**	0.41**
	μ	6.06	5.45	8.21	44.72	77.50	3.98	4.27	3.99	4.72
Berika (T2)	gca	0.36**	0.35**	-0.78**	-1.06**	24.48**	0.85**	0.35**	-0.54**	-0.30**
	μ	5.42	4.38	7.83	34.29	107.92	6.89	5.45	8.54	2.00
Alisa Craig (T3)	gca	0.21**	0.29**	1.77**	9.69**	-27.55**	-0.38**	-0.80**	0.46**	-0.11**
	μ	6.17	5.08	7.56	38.39	95.57	5.42	5.06	6.77	3.42
Pusa Ruby (T4)	gca	-0.28**	-0.34**	0.01	-2.25**	5.58**	-0.26**	0.38**	0.38**	0.001
	μ	4.07	3.48	6.54	22.73	84.40	3.99	5.19	4.72	4.12
S.E. (g)		0.018	0.011	0.011	0.113	0.108	0.009	0.010	0.023	0.010

**=Significance at 1% level; *= Significance at 5% level

Table.4 Average mean performance of the hybrids for the yield contributing characters

Genotypes	Flower/ truss	Fruit/ truss	Truss/ plant	Fruit/ plant	Fruit weight (g)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	Locule number
Arka Alok Hybrids									
L1 x T1	6.27	4.77	8.14	38.79	141.53	4.86	6.71	5.88	4.34
L1 x T2	6.33	5.56	7.45	41.44	147.66	6.18	6.34	7.18	3.01
L1 x T3	5.17	5.20	6.18	32.17	83.93	5.18	5.03	9.09	3.41
L1 x T4	5.58	4.80	9.07	43.57	81.34	4.23	5.21	6.00	4.34
L1 Hybrids(μ)	5.84	5.08	7.71	38.99	113.62	5.11	5.82	7.04	3.78
Arka Abha Hybrids									
L2 x T1	5.32	4.12	6.62	27.26	94.19	4.41	5.51	3.73	3.66
L2 x T2	4.69	4.23	8.21	34.74	94.60	4.35	5.28	3.32	2.67
L2 x T3	5.45	5.44	6.38	34.76	84.74	4.88	5.41	8.26	3.46
L2 x T4	4.58	3.66	7.32	26.83	84.79	4.19	5.23	8.04	3.28
L2 Hybrids(μ)	5.01	4.36	7.13	30.90	89.58	4.46	5.36	5.84	3.27
Arka Ashish Hybrids									
L3 x T1	4.84	3.97	5.65	22.44	76.56	4.93	5.02	8.16	3.55
L3 x T2	6.21	5.12	6.74	34.53	103.24	5.72	4.90	5.21	3.32
L3 x T3	5.50	4.59	6.94	31.88	87.72	5.48	4.61	8.72	2.05
L3 x T4	5.23	4.23	8.54	36.08	87.27	5.27	5.06	8.07	2.10
L3 Hybrids(μ)	5.45	4.48	6.97	31.23	88.70	5.35	4.90	7.54	2.76
Arka Ahuti Hybrids									
L4 x T1	4.77	4.45	6.36	28.30	60.46	4.12	4.49	4.97	2.67
L4 x T2	5.08	4.06	5.63	22.88	111.49	6.39	4.93	6.36	2.01
L4 x T3	6.16	4.87	12.79	62.31	34.12	3.67	3.51	7.64	2.62
L4 x T4	4.23	3.93	7.41	29.10	123.36	5.19	5.77	9.07	2.44
L4 Hybrids(μ)	5.06	4.33	8.05	35.65	82.36	4.84	4.68	7.01	2.44
Arka Meghali Hybrids									
L5 x T1	4.56	3.85	7.68	29.61	88.87	4.70	3.92	8.67	3.18
L5 x T2	5.07	4.13	6.43	26.53	143.88	6.13	6.38	8.93	3.27
L5 x T3	5.28	4.26	7.71	32.85	93.74	5.40	4.91	8.06	3.51
L5 x T4	4.87	3.23	6.04	19.51	94.65	4.24	6.11	6.08	2.55
L5 Hybrids(μ)	4.95	3.87	6.97	27.13	105.29	5.12	5.33	7.94	3.13
Arka Vikas Hybrids									
L6 x T1	4.94	4.10	5.38	22.06	108.66	4.79	5.89	7.77	3.68
L6 x T2	5.94	4.77	5.42	25.83	98.30	5.63	5.15	5.91	3.70
L6 x T3	5.28	4.23	9.98	42.18	46.25	3.91	4.18	4.74	2.43
L6 x T4	5.15	4.32	5.34	23.08	118.44	4.49	6.23	6.84	3.72
L6 Hybrids(μ)	5.33	4.36	6.53	28.29	92.91	4.71	5.36	6.32	3.38
Arka Saurabh Hybrids									
L7 x T1	4.45	3.54	5.89	20.84	56.21	4.40	5.14	4.92	4.32
L7 x T2	6.34	5.53	7.33	40.51	116.32	5.29	5.78	5.58	2.48
L7 x T3	5.77	4.34	15.12	65.57	20.77	2.56	3.03	2.98	4.35
L7 x T4	5.52	4.41	9.05	39.95	93.34	4.31	5.34	4.78	4.16
L7 Hybrids(μ)	5.52	4.46	9.35	41.72	71.66	4.14	4.82	4.57	3.83
Grand Mean	5.31	4.42	7.53	33.41	92.02	4.82	5.18	6.61	3.22
S.Em±	0.031	0.029	0.030	0.299	0.287	0.023	0.026	0.062	0.026
CD_(0.05)	0.09	0.08	0.09	0.84	0.81	0.07	0.07	0.17	0.07

*S.Em and CD (5%) showed included lines, testers and hybrids together

Table.5 SCA effect for Hybrids for yield contributing characters

Genotype	Flower/ truss	Fruit/ truss	Truss/ plant	Fruit/ plant	Fruit weight (g)	Polar diameter (cm)	Equatoria l diameter (cm)	Pericarp thicknes s (mm)	Locule number
L1 x T1	0.72**	-0.01	1.42**	6.17**	30.43**	-0.04	0.83**	-0.85**	0.16**
L1 x T2	0.14**	0.12**	0.53**	3.51**	9.56**	0.22**	0.16**	0.68**	-0.46**
L1 x T3	-0.88**	-0.17**	-3.30**	-16.51**	-2.14**	0.45**	0.01	1.59**	-0.26**
L1 x T4	0.03	0.06	1.35**	6.83**	-37.86**	-0.63**	-1.00**	-1.42**	0.56**
L2 x T1	0.59**	0.06	0.49**	2.73**	7.13**	0.17**	0.09**	-1.80**	-0.01
L2 x T2	-0.68**	-0.48**	1.86**	4.91**	-19.46**	-0.96**	-0.43**	-1.98**	-0.29**
L2 x T3	0.23**	0.79**	-2.52**	-5.83**	22.71**	0.80**	0.85**	1.96**	0.30**
L2 x T4	-0.14**	-0.37**	0.18**	-1.81**	-10.37**	-0.01	-0.51**	1.83**	0.01
L3 x T1	-0.32**	-0.20**	-0.32**	-2.42**	-9.62**	-0.20**	0.06*	0.92**	0.39**
L3 x T2	0.40**	0.29**	0.56**	4.36**	-9.94**	-0.48**	-0.35**	-1.80**	0.86**
L3 x T3	-0.16**	-0.18**	-1.80**	-9.04**	26.57**	0.51**	0.51**	0.72**	-0.60**
L3 x T4	0.07*	0.08**	1.56**	7.10**	-7.01**	0.18**	-0.22**	0.15*	-0.66**
L4 x T1	0.004	0.42**	-0.69**	-0.98**	-19.38**	-0.51**	-0.25**	-1.74**	-0.17**
L4 x T2	-0.34**	-0.62**	-1.63**	-11.71**	4.65**	0.70**	-0.10**	-0.11	-0.12**
L4 x T3	0.89**	0.26**	2.97**	16.97**	-20.69**	-0.79**	-0.37**	0.17**	0.29**
L4 x T4	-0.55**	-0.07*	-0.65**	-4.29**	35.42**	0.61**	0.71**	1.68**	0.002
L5 x T1	-0.10**	0.29**	1.72**	8.86**	-13.90**	-0.20**	-1.47**	1.04**	-0.35**
L5 x T2	-0.24**	-0.09**	0.25**	0.47	14.11**	0.16**	0.69**	1.53**	0.44**
L5 x T3	0.13**	0.11**	-1.03**	-3.96**	16.01**	0.66**	0.38**	-0.34**	0.49**
L5 x T4	0.21**	-0.30**	-0.94**	-5.36**	-16.22**	-0.62**	0.39**	-2.23**	-0.58**
L6 x T1	-0.11**	0.05	-0.15**	0.14	18.26**	0.30**	0.47**	1.76**	-0.11**
L6 x T2	0.25**	0.06*	-0.33**	-1.40**	-19.09**	0.07**	-0.57**	0.13*	0.62**
L6 x T3	-0.26**	-0.41**	1.68**	4.20**	-19.11**	-0.42**	-0.38**	-2.04**	-0.85**
L6 x T4	0.11**	0.30**	-1.20**	-2.95**	19.94**	0.05	0.49**	0.14*	0.33**
L7 x T1	-0.78**	-0.61**	-2.46**	-14.51**	-12.93**	0.48**	0.26**	0.66**	0.09**
L7 x T2	0.46**	0.72**	-1.23**	-0.14	20.17**	0.30**	0.61**	1.55**	-1.05**
L7 x T3	0.04	-0.40**	4.00**	14.17**	-23.34**	-1.21**	-1.00**	-2.05**	0.63**
L7 x T4	0.28**	0.29**	-0.30**	0.49	16.10**	0.42**	0.13**	-0.16*	0.33**
S.E. (s _{ij})	0.031	0.029	0.030	0.299	0.287	0.024	0.026	0.062	0.026

**=Significance at 1% level; *= Significance at 5% level

Table.6 Heterosis (%) over mid parent, better parent and standard parent for the yield contributing characters

Genotype		Flower/ truss	Fruit/ truss	Truss/ plant	Fruit/ plant	Fruit weight (g)	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (mm)	Locule number
L1 x T1	MP	11.11**	-1.07	5.488**	3.51**	40.76**	-3.41**	32.24**	-3.00**	-4.65**
	BP	3.52**	-12.49**	-0.89*	-13.26**	14.50**	-20.07**	14.12**	-27.72**	-7.98**
	SP	54.05**	37.20**	24.53**	70.68**	67.68**	21.70**	29.37**	24.66**	5.26**
L1 x T2	MP	18.97**	29.81**	-0.952*	28.47**	27.55**	-4.68**	11.92**	-13.89**	-5.69**
	BP	16.92**	27.04**	-4.85**	20.87**	19.46**	-10.30**	7.83**	-15.89**	-31.36**
	SP	55.53**	59.92**	13.97**	82.34**	74.95**	54.76**	22.24**	52.23**	-27.00**
L1 x T3	MP	-9.33**	12.26**	-16.291**	-6.24**	-23.41**	-9.86**	-8.02**	21.90**	-12.64**
	BP	-16.25**	2.43**	-18.17**	-16.20**	-32.10**	-14.75**	-14.41**	11.67**	-22.32**
	SP	27.03**	49.57**	-5.46**	41.55**	-0.56	29.72**	-3.02**	92.72**	-17.30**
L1 x T4	MP	20.07**	25.30**	31.847**	64.54**	-21.79**	-16.02**	-5.82**	-6.66**	1.88**
	BP	6.76**	14.64**	25.64**	44.12**	-34.20**	-30.43**	-11.34**	-26.29**	-1.22
	SP	37.10**	38.06**	38.76**	91.71**	-3.63**	5.93**	0.45	27.21**	5.26**
L2 x T1	MP	2.70**	-5.51**	-18.640**	-23.29**	10.70**	6.69**	15.08**	-13.69**	-21.96**
	BP	-12.22**	-24.42**	-19.37**	-39.06**	1.63**	2.96**	3.83**	-19.84**	-22.46**
	SP	30.71**	18.50**	1.27*	19.95**	11.60**	10.43**	6.23**	-20.92**	-11.24**
L2 x T2	MP	-3.50**	10.77**	3.250**	14.60**	-5.69**	-22.10**	-1.83**	-49.61**	-19.72**
	BP	-13.48**	-3.28**	1.78**	1.32	-12.35**	-36.85**	-3.12**	-61.07**	-42.63**
	SP	15.23**	21.67**	25.60**	52.86**	12.08**	8.93**	1.80*	-29.61**	-35.25**
L2 x T3	MP	4.04**	30.43**	-18.267**	7.39**	-9.97**	0.65	4.34**	44.52**	-14.32**
	BP	-11.77**	7.15**	-20.84**	-9.46**	-11.33**	-9.90**	1.95**	21.90**	-25.75**
	SP	33.91**	56.47**	-2.40**	52.95**	0.40	22.20**	4.31**	75.12**	-16.09**
L2 x T4	MP	9.56**	8.65**	0.274	9.35**	-4.23**	1.25*	-0.29	71.68**	-25.39**
	BP	6.67**	5.37**	-9.22**	1.85	-8.51**	-2.18**	-1.38**	70.53**	-29.69**
	SP	12.53**	5.27**	11.98**	18.05**	0.46	4.93**	0.83	70.46**	-20.45**
L3 x T1	MP	-19.81**	-16.41**	-36.172**	-46.08**	-17.04**	-7.59**	8.66**	30.82**	-12.20**
	BP	-20.03**	-27.05**	-40.46**	-49.83**	-28.50**	-26.30**	1.01	-3.81**	-24.79**
	SP	18.92**	14.19**	-13.56**	-1.26	-9.29**	23.46**	-3.21**	73.00**	-13.90**
L3 x T2	MP	8.57**	21.45**	-22.156**	-5.13**	-3.97**	-15.80**	-5.95**	-38.81**	23.60**
	BP	3.10**	17.06**	-28.93**	-10.34**	-4.34**	-17.02**	-10.10**	-39.01**	-1.49
	SP	52.58**	47.27**	3.11**	51.94**	22.32**	43.24**	-5.53**	10.46**	-19.48**
L3 x T3	MP	-9.81**	0.44	-18.505**	-17.10**	-13.42**	-9.52**	-8.05**	14.34**	-39.46**
	BP	-10.91**	-9.65**	-26.78**	-17.23**	-18.08**	-18.13**	-8.89**	2.83**	-39.90**
	SP	35.14**	32.02**	6.17**	40.28**	3.93**	37.23**	-11.12**	84.88**	-50.28**
L3 x T4	MP	3.70**	12.16**	6.575**	17.84**	-8.84**	-1.31**	-0.39	22.30**	-43.93**
	BP	-13.12**	4.11**	-9.98**	-6.31**	-18.50**	-21.22**	-2.51**	-4.84**	-49.07**
	SP	28.50**	21.67**	30.65**	58.76**	3.40**	31.97**	-2.44**	71.09**	-49.07**
L4 x T1	MP	-12.77**	-3.65**	-24.887**	-27.22**	-35.39**	-17.67**	-10.09**	-10.77**	-34.02**
	BP	-21.24**	-18.36**	-27.14**	-36.73**	-44.86**	-31.58**	-21.47**	-30.49**	-43.43**
	SP	17.20**	27.99**	-2.70**	24.52**	-28.37**	3.17**	-13.43**	5.37**	-35.25**
L4 x T2	MP	-1.39*	-0.49	-31.992**	-32.04**	2.48**	-0.96*	-11.65**	-18.87**	-25.06**
	BP	-6.28**	-7.24**	-35.50**	-33.28**	1.67**	-7.25**	-13.71**	-25.46**	-40.32**
	SP	24.82**	16.78**	-13.87**	0.67	32.09**	60.02**	-4.95**	34.84**	-51.25**
L4 x T3	MP	11.52**	9.97**	56.988**	74.46**	-66.75**	-35.76**	-34.84**	9.74**	-22.73**
	BP	-0.16	-4.07**	46.41**	62.30**	-68.88**	-38.95**	-38.57**	6.85**	-23.22**
	SP	51.35**	40.08**	95.66**	174.17**	-59.58**	-8.10**	-32.33**	61.98**	-36.46**
L4 x T4	MP	-5.55**	8.17**	-2.947**	4.38**	27.14**	3.76**	5.93**	52.87**	-34.90**
	BP	-13.39**	3.79**	-15.15**	-11.91**	12.50**	-13.68**	1.05*	26.85**	-40.83**

	SP	3.93**	13.04**	13.36**	28.04**	46.16**	29.97**	11.25**	92.30**	-40.82**
L5 x T1	MP	-17.17**	-17.55**	-1.936**	-19.76**	-5.76**	4.79**	-21.38**	83.11**	-24.21**
	BP	-24.71**	-29.25**	-6.42**	-33.79**	-20.01**	-5.81**	-31.33**	58.18**	-32.56**
	SP	12.04**	10.74**	17.49**	30.29**	5.29**	17.70**	-24.42**	83.81**	-22.88**
L5 x T2	MP	-2.28**	-0.28	-15.955**	-16.28**	31.39**	3.14**	14.28**	27.34**	15.02**
	BP	-6.46**	-5.71**	-17.96**	-22.63**	29.51**	-11.07**	11.61**	4.57**	-11.23**
	SP	24.57**	18.79**	-1.63*	16.73**	70.47**	53.51**	23.01**	89.33**	-20.69**
L5 x T3	MP	-5.09**	-5.05**	2.642**	-2.62**	-9.28**	3.78**	-8.79**	31.47**	-1.08
	BP	-14.47**	-16.08**	1.99**	-14.43**	-15.62**	-0.31	-14.00**	18.95**	-4.62**
	SP	29.73**	22.53**	17.95**	44.54**	11.06**	35.23**	-5.33**	70.88**	-14.87**
L5 x T4	MP	7.87**	-12.43**	-13.741**	-24.69**	-3.18**	-5.64**	12.11**	19.28**	-34.73**
	BP	-1.75**	-17.18**	-19.08**	-32.92**	-14.81**	-15.09**	6.94**	10.94**	-38.24**
	SP	19.66**	-7.10**	-7.60**	-14.15**	12.14**	6.18**	17.80**	28.90**	-38.16**
L6 x T1	MP	-20.80**	-23.86**	-37.088**	-52.08**	16.37**	12.58**	18.92**	92.97**	-18.54**
	BP	-22.99**	-24.73**	-39.51**	-53.40**	-0.55	5.90**	4.50**	91.15**	-21.96**
	SP	21.38**	17.93**	-17.70**	-2.93	28.74**	19.95**	13.56**	64.73**	-10.75**
L6 x T2	MP	0.45	-1.72**	-35.233**	-36.71**	-9.47**	-1.34**	-7.10**	-6.16**	17.13**
	BP	-7.33**	-10.46**	-39.09**	-45.43**	-10.03**	-18.33**	-8.64**	-30.73**	-14.34**
	SP	45.95**	37.20**	-17.08**	13.65**	16.46**	40.99**	-0.71	25.30**	-10.27**
L6 x T3	MP	-16.08**	-18.74**	21.337**	-1.59*	-54.84**	-21.33**	-21.76**	-12.61**	-37.21**
	BP	-17.63**	-20.60**	12.22**	-10.89**	-57.67**	-27.86**	-25.74**	-30.07**	-43.79**
	SP	29.73**	21.67**	52.68**	85.60**	-45.20**	-2.09*	-19.41**	0.49	-41.07**
L6 x T4	MP	-1.65**	-1.82*	-30.741**	-34.12**	22.32**	5.56**	15.22**	55.67**	-11.92**
	BP	-19.61**	-18.85**	-39.92**	-51.24**	8.40**	-0.59	10.65**	44.95**	-13.96**
	SP	26.54**	24.26**	-18.31**	1.55	40.33**	12.44**	20.11**	45.02**	-9.78**
L7 x T1	MP	-29.97**	-30.95**	-24.108**	-47.80**	-35.48**	1.65**	2.22**	1.51	7.11**
	BP	-33.07**	-35.01**	-28.30**	-53.41**	-41.91**	-5.91**	-11.27**	-13.74**	-8.48**
	SP	9.34**	1.82	-9.89**	-8.30**	-33.40**	10.18**	-0.90	4.31*	4.77**
L7 x T2	MP	5.09**	20.36**	-3.149**	16.76**	13.65**	-8.53**	2.88**	-21.63**	-7.23**
	BP	-4.62**	14.98**	-6.43**	15.39**	7.78**	-23.21**	-0.23	-34.64**	-25.90**
	SP	55.77**	59.06**	12.14**	78.25**	37.81**	32.47**	11.44**	18.30**	-39.85**
L7 x T3	MP	-10.01**	-12.27**	103.499**	78.43**	-78.40**	-49.37**	-44.24**	-52.28**	28.64**
	BP	-13.20**	-14.63**	100.09**	70.81**	-78.53**	-52.83**	-47.79**	-56.05**	27.32**
	SP	41.77**	24.83**	131.31**	188.52**	-75.39**	-35.89**	-41.58**	-36.82**	5.50**
L7 x T4	MP	2.99**	6.56**	30.829**	38.16**	3.05**	-0.69	-2.76**	-8.19**	11.38**
	BP	-16.96**	-8.18**	23.96**	13.80**	-3.53**	-7.98**	-7.88**	-16.13**	0.89
	SP	35.63**	26.84**	38.45**	75.78**	10.59**	7.93**	2.96**	1.34	0.89**

**=Significance at 1% level; *= Significance at 5% level

Standard heterosis for truss per plant was ranged from 131.31% (Arka Saurabh × Alisa Craig) to -18.31% (Arka Vikas × Pusa Ruby), the extent of heterosis over better parent was ranged from -40.46% (Arka Ashish × Patharkutchi) to 100.09% (Arka Saurabh × Alisa Craig) and the magnitude of average heterosis ranged from -37.09% (Arka Vikas × Patharkutchi) to 103.50% (Arka Saurabh × Alisa Craig). For fruits per plant the cross Arka Saurabh × Alisa Craig displayed highest values of average heterosis (78.43%), Heterobeltiosis (70.81%) and Standard

heterosis (188.52%). Similarly, for polar diameter highest values of Mid-parent heterosis (12.58%) and better parent heterosis (5.90%) in the cross Arka Vikas × Patharkutchi and standard parent heterosis (60.02%) in the cross Arka Ahuti × Berika. Arka Alok × Patharkutchi hybrid displayed maximum values of heterosis over mid parent (32.24%), better parent (14.12%) and standard parent (29.37%) for the trait equatorial diameter of the fruit. For fruit weight, range of average heterosis was from -78.40% (Arka Saurabh × Alisa Craig) to

40.76% (Arka Alok × Patharkutchi) and heterobeltiosis range was from -78.53% (Arka Saurabh × Alisa Craig) to 29.51% (Arka Meghali × Berika). Similarly, the range of standard heterosis for fruit weight was from -75.39% (Arka Saurabh × Alisa Craig) to 74.95% (Arka Alok × Berika). The extreme magnitude of average heterosis (92.97%) and heterobeltiosis (91.15%) for pericarp thickness was shown by cross Arka Vikas × Patharkutchi and standard heterosis (92.72%) by Arka Alok × Alisa Craig. The range of magnitude of heterosis over mid parent ranged from 28.64% (Arka Saurabh × Alisa Craig) to -43.93% (Arka Ashish × Pusa Ruby), from 27.32% (Arka Saurabh × Alisa Craig) to -49.07% (Arka Ashish × Pusa Ruby) over better parent and over standard parent from 5.50% (Arka Saurabh × Alisa Craig) to -51.25% (Arka Ahuti × Berika) for the locule number. Low locule number indicates more dry matter, fruit firmness, suitable for long distance transportation and for processing. The discoveries in the present investigation were in conformation with the finding of Triveni *et al.*, (2017) for flower per truss; Yogendra *et al.*, (2013) for fruit per truss, (Saeed *et al.*, 2014; Renuka and Sadashiva, 2016) for truss per plant, (Yashavantkumar, 2008; Sekhar *et al.*, 2010) for fruits per plant, (Agarwal *et al.*, 2014; Aisyah *et al.*, 2016) for fruit weight, (Chauhan *et al.*, 2014; Kumar *et al.*, 2017) for polar diameter, (Yadav *et al.*, 2013; Sherpa *et al.*, 2014) for equatorial diameter, (Chattopadhyay and Paul, 2012; Renuka and Sadashiva, 2016) for pericarp thickness and (Mondal *et al.*, 2009; Saeed *et al.*, 2014; Mali and Patel 2014) for locule number. Considering all the heterosis manifested factors into an account the best cross identified was Arka Saurabh × Alisa Craig followed by Arka Alok × Berika, Arka Meghali × Berika and Arka Ahuti × Berika for the yield contributing traits which is due to the involvement of the parents having high GCA and crosses with good specific

combining ability.

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