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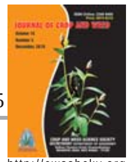

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Studies on combining ability, gene action and heterotic expression of tomato for various leaf and fruit pigments

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ABSTRACT

Genetical effects of eleven parents were assessed by deploying Line (7) × Tester (4) model. Choice of materials was justified with elucidation of non-significant replication mean sum of squares and significant effects due to lines, testers and hybrids. Among parents Arka Saurabh, Arka Vikas, Berika and Alisa Craig and amongst hybrids Arka Vikas × Berika considered best with insight of their per se performance and combining ability effects. Non-additive mode of inheritance was found for studied characters. Greater influence of lines concerning to total variance for leaf pigment, testers towards immature fruit pigment and for ripe fruit pigments was equally affected by lines and their interaction with tester. On heterosis components basis, Arka Saurabh × Pusa Ruby found to be supreme performing for leaf chlorophyll pigments. Similarly, Arka Alok × Patharkutchi for immature fruit chlorophyll pigments and Arka Vikas × Berika for lycopene and β-carotene content of firm ripe fruits.

Keywords: Combining ability, gene action, heterosis, line×tester and tomatob

Tomato (*Solanum lycopersicum* L.), owing to its miscellaneous usages such as uncooked, cooked, converted form (puree, paste, ketchup and whole canned fruits), health benefits, medicinal values regarded as a "protective food" (Triveni *et al*., 2017). It occupies a prominent space in the vegetable world because of its larger area of cultivation and high productivity. Antioxidant possessions are due to existence of lycopene and beta carotene which has the capacity to suppress free radicals, capable in neutralizing Reactive Oxygen Species (ROS), possesses anti-cancerous ability (Saleem *et al*., 2013; Vilas *et al*., 2015). Content of lycopene in fruits varies from 5mg/100gm to 50mg/100gm with being higher amount in red colored ones than in yellow colored fruits (Clinton, 1998). Although the genetic background governing the quality parameters have been studied long back, the strong focus on the genetic enhancement of the individual quality parameters such as carotenoids has started recently (Liu *et al*., 2003). So the crop improvement of tomatoes for quality parameters is very much necessary that can be achieved through heterosis breeding in most feasible way (Yogendra and Gowda, 2013). Keeping all this information in purview, an experiment was carried to assess an inheritance and heterotic patterns of significant pigment characters.

MATERIALS AND METHODS

Present investigation was undertaken during Autumn-Winter, 2017-18 and 2018-19 at Departmental experimental field of Vegetable Science, Horticulture faculty building, Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal locating at $26^{0}19'86''$ N latitude and $89^{0}\ 23'53''$ E longitude, with 43-meter elevation above MSL that lies under the Teesta alluvial plain with slightly acidic soil (5.5-6.5) of Terai agro climatic zone of West Bengal. Seven widely diversified lines (*viz*., Arka Abha, Arka Vikas, Arka Saurabh, Arka Meghali, Arka Alok, Arka Ahuti, Arka Ashish, received from Indian Institute of Horticultural Research, Bengaluru, Karnataka) were crossed with four testers (Patharkutchi, Berika, Alisa Craig and Pusa Ruby from Bidhan Chandra Krishi Viswavidyalaya, West Bengal) following Line x Tester model to produce 28 possible F_1 crosses. In the next year all the genotypes (including parents and F_1 hybrids) were raised following randomized block design with 3 replications for each treatment. Sample were collected from five randomly selected plant from each replications and data were recorded on leaf and 25 days immature fruit chlorophyll content as per Sadasivam and Manickam (1996), lycopene and β-carotene content of firm ripe fruits (mg100g^{-1}) by spectrophotometric method and expressed in mg 100^{-1} g of fruit pulp (Davies, 1976). Statistical procedures were carried out as per suggestions by Kempthorne (1957) for valuation of combining ability; Bitzer *et al.* (1967) and Wynne *et al.* (1970) for heterosis manifestation considering Pusa Ruby as a standard parent.

RESULTS AND DISCUSSION

ANOVA (Table 1) displayed high level of homogeneity with in parents irrespective of characters as revealed by non-significant replication mean sum of squares. Highly significant variance due to genotypes,

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Table 1: Analysis of variance for parents and hybrids for leaf and fruit pigments (mg 100^{-1} g)

Source of variation (df)	Mean sum of square for parents and hybrids							
	Mature leaf			Immature fruit			Ripe fruit	
	Chl A	Chl B	Total Chl	Chl A	Chl B	Total Chl	Lycopene	β carotene
Replication (2)	0.593	0.458	3.937	0.006	0.007	0.023	0.003	0.001
Genotypes (38)	4251.62**	911.98**	8539.08**	0.110	0.020	0.208	2.283**	0.325
Parents (10)	3508.62**	568.26**	6706.22**	0.106	0.036	0.238	2.857**	0.370
Hybrids (27)	4679.26**	1068.42**	9534.07**	0.089	0.013	0.160	2.100**	0.300
Parents *vs* Hybrids (1)	135.05**	125.27**	3.062	0.717	0.069	1.223	1.491	0.583
Lines (6)	7225.09**	2012.04**	15906.59**	0.142	0.020	0.262	4.230**	0.592
Testers (3)	16722.50**	1911.20**	29201.08**	0.030	0.002	0.043	2.040	0.244
Lines *vs* Testers (18)	1823.45**	613.42**	4132.06**	0.081	0.012	0.145	1.400	0.211
Error (76)	0.796	0.401	1.180	0.002	0.001	0.002	0.004	0.001

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

Table 2: Estimates of genetic components and proportional contribution to variance for leaf and fruit pigments (mg 100^{-1} g)

Components of genetic variation	Mature leaf			Immature fruit			Ripe fruit	
	Chl A	Chl B	Total Chl	Chl A	Chl B	Total Chl	Lycopene	Beta carotene
σ^2 GCA	63.46	10.11	120.04	0.0002	0.0001	0.0003	0.016	0.002
σ^2 A126.93	20.22	240.09	0.0004	0.0002	0.0006	0.031	0.004	
σ^2 SCA (σ^2 D)	2630.49	466.87	5030.52	0.0269	0.0034	0.0481	0.794	0.109
Predictability ratio	0.046	0.042	0.046	0.015	0.055	0.012	0.04	0.035
Proportional contribution to the total variance (%)								
Lines	34.31	41.85	37.08	35.53	35.22	36.46	44.76	43.92
Testers	39.71	19.88	34.03	3.79	1.37	2.99	10.80	9.04
Line X Tester	25.98	38.28	28.89	60.69	63.41	60.55	44.44	47.04

parents and hybrids on behalf of leaf chlorophyll pigments and lycopene suggested the preponderance of genetic diversity among the parents exercised and their derived off-springs. Manifestation of heterotic effects for the leaf chlorophyll pigments was illustrated by the significant parent *vs.* hybrid as well as line *vs.* tester variance that signifies its contribution towards specific combining ability (SCA). Significant diversity among lines and testers for most of pigments was indicator of their contribution towards the component of general combining ability (GCA) variance in an enormous amount. Insignificant variance for immature fruit pigment suggested that at this stage the bio-synthesis of pigment remained indifferent irrespective of genotypes and not suitable for consideration.

The magnitude of predictability ratio for all parameters under examination was very less than unity (Table 2) indicated incidence of non-additive gene action for the inheritance of examined characters. It was recorded more influence of lines in the direction of the entire variance for leaf pigment and hybrids towards most for the pigment of immature fruit. Whereas, ripe fruit pigment was equally affected by lines and their interaction with tester; this finding completely justified the choice of parent and were in accordance with earlier finding of Sikder *et al*., 2016 for chlorophyll, Savale and Patel, 2017 and Sherpa *et al*., 2014 for lycopene and Mondal *et al*., 2009 for *β*-carotene, irrespective of genotypes and place of experiment conducted.

Among the lines maximum average performance was observed in Arka Alok for leaf pigments (Chlorophyll A-264.46 mg100^{-1}g, chlorophyll B-85.79 mg100g^{-1} and total chlorophyll-350.25 mg100^{-1}g), Arka Saurabh for immature fruit chlorophyll pigments (chlorophyll A-1.43 mg 100^{-1}g, chlorophyll B-0.61mg100g^{-1} and total chlorophyll-2.03mg100^{-1}g) and Arka Meghali for lycopene (5.22 mg100^{-1}g) and *β*-carotene (1.91 mg 100^{-1}g) of firm ripe fruits (Table 3). Accordingly, among

Table 3: GCA effect and average performance of lines and testers for leaf and fruit pigments(mg 100^{-1} g)

Genotypes		Mature leaf			Immature fruit			Ripe fruit	
		Chl A	Chl B	Total Chl	Chl A	Chl B	Total Chl	Lycopene	Beta carotene
Lines									
Arka Alok	gca	**24.20****	**6.01****	**30.20****	**0.20****	**0.08****	**0.27****	**-0.08****	**-0.05**
(L1)	µ	264.46	85.79	350.25	0.88	0.29	1.16	2.28	0.88
Arka Abha	gca	**-23.58****	**-4.95****	**-28.53****	**-0.11****	**-0.04****	**-0.15****	**-0.29****	**-0.11**
(L2)	µ	207.45	68.34	275.79	0.96	0.31	1.27	2.68	1.03
Arka Ashish	gca	**-11.50****	**-3.24****	**-14.74****	**0.02**	**0.0004**	**0.02**	**-0.54****	**-0.18**
(L3)	µ	211.38	75.38	286.76	0.84	0.24	1.08	2.20	0.82
Arka Ahuti	gca	**-30.85****	**-14.97****	**-45.80****	**-0.05****	**-0.05****	**-0.10****	**0.15****	**0.07**
(L4)	µ	215.83	62.72	278.55	1.03	0.32	1.36	3.23	1.22
Arka Meghali	gca	**-5.04****	**-6.44****	**-11.47****	**0.08****	**0.02***	**0.10****	**-0.40****	**-0.17**
(L5)	µ	145.50	43.59	189.09	0.98	0.35	1.33	5.22	1.91
Arka Vikas	gca	**11.81****	**-2.19****	**9.61****	**-0.03***	**0.003**	**-0.03**	**1.24****	**0.46**
(L6)	µ	211.70	66.01	277.71	0.74	0.23	0.97	1.93	0.71
Arka Saurabh	gca	**34.96****	**25.78****	**60.73****	**-0.10****	**-0.02**	**-0.11****	**-0.08****	**-0.03**
(L7)	µ	221.78	72.64	294.42	1.43	0.61	2.03	2.29	0.90
S.E. (g_l)		**0.258**	**0.183**	**0.314**	**0.012**	**0.009**	**0.014**	**0.018**	**0.009**
Testers									
Patharkuchi	gca	**16.50****	**3.19****	**19.68****	**0.005**	**-0.004**	**0.001**	**-0.47****	**-0.16****
(T1)	µ	251.16	93.30	344.46	0.95	0.20	1.15	1.74	0.65
Berika (T2)	gca	**-33.55****	**-13.36****	**-46.92****	**0.02**	**0.010**	**0.03***	**0.14****	**0.03****
	µ	179.51	62.48	241.99	1.02	0.28	1.30	2.42	0.95
Alisa Craig	gca	**-12.03****	**1.04****	**-10.99****	**-0.05****	**-0.010**	**-0.06****	**0.13****	**0.07****
(T3)	µ	253.69	86.23	339.92	1.22	0.30	1.52	1.89	0.75
Pusa Ruby	gca	**29.09****	**9.13****	**38.24****	**0.03****	**0.004**	**0.04****	**0.20****	**0.06****
(T4)	µ	232.62	73.69	306.31	0.91	0.38	1.30	2.15	0.80
S.E. (g_t)		**0.195**	**0.138**	**0.237**	**0.009**	**0.007**	**0.010**	**0.014**	**0.007**

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

the testers Patharkutchi for leaf chlorophyll pigment and Berika for ripe fruit carotenoids content showed the maximum value. However, among lines significantly maximum GCA effects was recorded by Arka Saurabh for leaf chlorophyll A (34.96), chlorophyll B (25.78), total chlorophyll (60.73) and Arka Vikas for lycopene (1.24) and beta carotene (0.46). Among the testers best combiner was considered to be Pusa Ruby for almost all the important traits, Alisa Craig and Berika for ripe fruit carotenoids. Parents with peak mean performance did not found to be best combiner justified that the information pertaining to the nature and degree of combining ability is foremost important in order to recognize superior parents for inclusion in the breeding module (Sikder *et al*., 2016).

The average mean performance (Table 4) reveled that Arka Saurabh hybrids all together expressed higher magnitude for leaf pigment and Arka Vikas hybrids for fruit carotenoids indicated their potentiality in cross breeding programme. Whereas, considering the individual intercross Arka Saurabh × Pusa Ruby manifested highest values for leaf chlorophyll (chlorophyllA-288.57mg100g^{-1};chlorophyll B-108.30 mg100^{-1}g and total chlorophyll-396.87 mg 100^{-1} g) and Arka Vikas x Berika for lycopene and β-carotene (*i.e*., 5.40 mg 100^{-1}g and 2.08 mg 100^{-1}g, correspondingly). On account of average mean of parents (lines and testers together) with mean of hybrids in coveted path inferences the unstructured manifestation between them specifying the importance of heterosis for the expression of studied characters.

Table 5 indicated that highest significantly SCA effects for leaf chlorophyll A (33.83) and total leaf chlorophyll (53.99) pigment was recorded in Arka Abha × Berika; leaf chlorophyll B in Arka Saurabh × Alisa Craig (24.63); lycopene (1.22) and β-carotene (0.46) in Arka Vikas × Berika. The best identified crosses as per SCA effect were due to poor x poor & higher x lower cross combinations effects which might be due to dominance x dominance, additive x dominance, non-

Table 4: Average mean performance of the hybrids for the leaf and fruit pigments (mg 100^{-1} g)

Genotypes	Mature leaf			Immature fruit			Ripe fruit	
	Chl A	Chl B	Total Chl	Chl A	Chl B	Total Chl	Lycopene	Beta carotene
				Arka Alok hybrids				
L1 x T1	277.42	88.82	366.24	1.32	0.46	1.78	2.62	1.18
L1 x T2	209.70	51.29	260.99	0.90	0.33	1.23	2.55	0.98
L1 x T3	210.76	66.37	277.12	1.07	0.31	1.38	2.03	0.74
L1 x T4	279.42	95.69	375.11	0.79	0.26	1.04	3.66	1.39
L1 Hybrids (μ)	**244.33**	**75.54**	**319.87**	**1.02**	**0.34**	**1.36**	**2.72**	**1.07**
				Arka Abha hybrids				
L2 x T1	244.56	82.80	327.36	0.62	0.19	0.81	2.91	1.14
L2 x T2	196.82	71.38	268.20	0.96	0.32	1.28	1.63	0.66
L2 x T3	160.24	49.48	209.73	0.65	0.22	0.87	2.80	1.20
L2 x T4	184.56	54.68	239.24	0.60	0.18	0.78	2.71	1.05
L2 Hybrids (μ)	**196.55**	**64.59**	**261.13**	**0.71**	**0.23**	**0.94**	**2.51**	**1.01**
				Arka Ashish hybrids				
L3 x T1	210.64	56.47	267.11	0.77	0.24	1.00	1.76	0.70
L3 x T2	181.58	60.35	241.93	0.84	0.32	1.17	2.18	0.85
L3 x T3	184.50	66.70	251.20	0.77	0.17	0.95	2.55	1.03
L3 x T4	257.80	81.66	339.46	0.97	0.32	1.29	2.54	1.18
L3 Hybrids (μ)	**208.63**	**66.30**	**274.93**	**0.84**	**0.26**	**1.10**	**2.26**	**0.94**
				Arka Ahuti hybrids				
L4 x T1	198.55	57.65	256.19	0.76	0.22	0.99	2.67	1.11
L4 x T2	111.59	27.69	139.28	0.83	0.21	1.04	2.28	0.98
L4 x T3	201.23	60.27	261.50	0.72	0.26	0.98	3.82	1.47
L4 x T4	245.74	72.62	318.50	0.76	0.18	0.95	3.03	1.22
L4 Hybrids (μ)	**189.28**	**54.56**	**243.87**	**0.77**	**0.22**	**0.99**	**2.95**	**1.20**
				Arka Meghali hybrids				
L5 x T1	216.11	58.31	274.42	0.88	0.25	1.12	1.61	0.63
L5 x T2	191.60	56.46	248.06	0.78	0.24	1.02	3.35	1.31
L5 x T3	227.18	70.28	297.46	1.02	0.36	1.38	2.43	1.03
L5 x T4	225.46	67.34	292.85	0.93	0.29	1.22	2.19	0.83
L5 Hybrids (μ)	**215.09**	**63.10**	**278.20**	**0.90**	**0.29**	**1.19**	**2.40**	**0.95**
				Arka Vikas hybrids				
L6 x T1	242.65	77.66	320.30	0.76	0.26	1.02	2.47	1.07
L6 x T2	203.70	61.43	265.13	0.92	0.28	1.19	5.40	2.08
L6 x T3	218.44	59.95	278.38	0.56	0.22	0.78	4.08	1.64
L6 x T4	262.96	70.34	333.30	0.93	0.32	1.25	4.21	1.54
L6 Hybrids (μ)	**231.94**	**67.35**	**299.28**	**0.79**	**0.27**	**1.06**	**4.04**	**1.58**
				Arka Saurabh hybrids				
L7 x T1	266.44	87.34	353.78	0.68	0.21	0.88	2.29	0.89
L7 x T2	211.02	64.62	275.64	0.64	0.22	0.86	3.14	1.23
L7 x T3	254.33	120.98	375.31	0.57	0.24	0.82	2.80	1.20
L7 x T4	288.57	108.30	396.87	1.01	0.32	1.33	2.65	1.04
L7 Hybrids (μ)	**255.09**	**95.31**	**350.40**	**0.73**	**0.25**	**0.97**	**2.72**	**1.09**
Grand Mean	**220.13**	**69.53**	**289.67**	**0.82**	**0.26**	**1.09**	**2.80**	**1.12**
SEm (±)	**0.515**	**0.366**	**0.661**	**0.032**	**0.038**	**0.050**	**0.036**	**0.017**
CD(0.05)	**1.45**	**1.03**	**1.86**	**0.09**	**0.11**	**0.14**	**0.10**	**0.05**

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

Table 5: SCA effect of hybrids for leaf and fruit pigments (mg 100^{-1} g)

Genotypes	Mature leaf			Immature fruit			Ripe fruit	
	Chl A	Chl B	Total Chl	Chl A	Chl B	Total Chl	Lycopene	Beta carotene
L1 x T1	16.60**	10.09**	26.70**	0.30**	0.13**	0.42**	0.37**	0.27**
L1 x T2	-1.07*	-10.90**	-11.96**	-0.14**	-0.02	-0.16**	-0.30**	-0.13**
L1 x T3	-21.54**	-10.22**	-31.75**	0.11**	-0.02	0.09**	-0.82**	-0.40**
L1 x T4	6.01**	11.02**	17.01**	-0.27**	-0.09**	-0.35**	0.74**	0.25**
L2 x T1	31.52**	15.03**	46.55**	-0.09**	-0.04*	-0.13**	0.86**	0.29**
L2 x T2	33.83**	20.15**	53.99**	0.24**	0.08**	0.32**	-1.01**	-0.39**
L2 x T3	-24.27**	-16.15**	-40.41**	-0.001	-0.0001	-0.001	0.15**	0.12**
L2 x T4	-41.07**	-19.03**	-60.13**	-0.15**	-0.05**	-0.19**	-0.004	-0.02
L3 x T1	-14.49**	-13.01**	-27.50**	-0.08**	-0.02	-0.10**	-0.03	-0.08**
L3 x T2	6.50**	7.42**	13.93**	-0.01	0.05**	0.04	-0.21**	-0.13**
L3 x T3	-12.10**	-0.64	-12.73**	-0.01	-0.08**	-0.09**	0.16**	0.02
L3 x T4	20.08**	6.24**	26.30**	0.10**	0.05**	0.15**	0.08*	0.18**
L4 x T1	-7.22**	-0.10	-7.35**	-0.01	0.01	-0.001	0.19**	0.07**
L4 x T2	-44.13**	-13.51**	-57.67**	0.04	-0.02	0.02	-0.81**	-0.25**
L4 x T3	23.98**	4.67**	28.63**	0.005	0.05**	0.05	0.74**	0.21**
L4 x T4	27.37**	8.94**	36.39**	-0.04	-0.04*	-0.08**	-0.12**	-0.03
L5 x T1	-15.47**	-7.97**	-23.45**	-0.03	-0.03	-0.06*	-0.32**	-0.16**
L5 x T2	10.07**	6.72**	16.78**	-0.14**	-0.05**	-0.20**	0.82**	0.32**
L5 x T3	24.12**	6.14**	30.26**	0.18**	0.08**	0.26**	-0.09*	0.01
L5 x T4	-18.72**	-4.89**	-23.59**	-0.01	0.01	0.0005	-0.41**	-0.18**
L6 x T1	-5.78**	7.12**	1.35*	-0.04	-0.01	-0.04	-1.10**	-0.35**
L6 x T2	5.32**	7.45**	12.77**	0.11**	-0.0001	0.11**	1.22**	0.46**
L6 x T3	-1.47**	-8.44**	-9.90**	-0.18**	-0.04*	-0.22**	-0.09*	-0.01
L6 x T4	1.93**	-6.13**	-4.22**	0.11**	0.05*	0.15**	-0.03	-0.10**
L7 x T1	-5.15**	-11.16**	-16.30**	-0.05*	-0.04*	-0.09**	0.03	-0.04*
L7 x T2	-10.51**	-17.33**	-27.84**	-0.10**	-0.04*	-0.14**	0.29**	0.11**
L7 x T3	11.27**	24.63**	35.91**	-0.10**	0.01	-0.09**	-0.05	0.04*
L7 x T4	4.39**	3.86**	8.23**	0.25**	0.07**	0.32**	-0.27**	-0.11**
S.E. (s_{ij})	0.515	0.366	0.627	0.024	0.018	0.027	0.036	0.017

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

allelic gene interface and non-fixable genetic component, development of transgressive segregates for best exploitation of these character were highly suggested. Present finding was in corroboration with earlier findings of Akhtar and Hazra, 2013; Bhatarai *et al*., 2016; Sikder *et al*., 2016 and Savale and Patel, 2017.

Considering all the component of heterosis (Table 6) Arka Alok × Patharkutchi showed the maximum significant positive value for mid parent, better parent and standard parent heterosis for immature fruit chlorophyll 'a' (*i.e*., 44.79%, 39.44% and 44.53%, respectively), chlorophyll B (*i.e*., 90.41%, 61.63% and 20.01%, respectively) and total chlorophyll (*i.e*., 54.40%, 53.30% and 37.27%, respectively). Whereas, all the component of heterosis for leaf pigment at desired direction recorded maximum in Arka Saurabh × Pusa Ruby.

Arka Vikas × Berika ranked upper most with respect to heterobeltiosis (122.70%), standard heterosis (150.78) and mid-parent heterosis (148.12%) for lycopene. The same cross exhibited maximum magnitudes of average heterosis (151.11%) and standard heterosis (161.08%) for Beta carotene content. But, for this trait maximum heterobeltiosis (120.09%) was encountered in the cross Arka Vikas × Alisa Craig. These outcomes were in consonance with Hamisu *et al*., 2018 for chlorophyll pigment, Shankar *et al*., 2014; Sherpa *et al*., 2014; Yogendra *et al*., 2013 & Angadi and Dharmati, 2012 for lycopene and Mondal *et al*., 2009 & Mondal, 2003 for β-carotene.

It may be concluded from the above discussion that Arka Vikas and Arka Saurabh as mother parent and Berika as donor can effectively be incorporated in future breeding programme for enhancement of carotenoids content of ripe tomato. Considering relative performance,

Table 6: Heterosis (%) over mid parent, better parent and standard parent for leaf and fruit pigments (mg 100⁻¹ g)

Genotypes		Mature leaf			Immature fruit			Ripe fruit	
		Chl A	Chl B	Total Chl	Chl A	Chl B	Total Chl	Lycopene	Beta carotene
L1 x T1	MP	7.61**	-0.81	5.44**	44.79**	90.41**	54.40**	30.46**	55.36**
	BP	4.90**	-4.80**	4.57**	39.44**	61.63**	53.30**	15.08**	34.98**
	SP	19.26**	20.53**	19.57**	44.53**	20.01**	37.27**	21.67**	48.11**
L1 x T2	MP	-5.53**	-30.82**	-11.86**	-5.45*	17.16*	-0.27	8.51**	7.66**
	BP	-20.71**	-40.22**	-25.49**	-12.09**	15.12*	-5.40*	5.23**	3.51
	SP	-9.85**	-30.40**	-14.80**	-1.46	-13.91*	-5.14	18.42**	23.01**
L1 x T3	MP	-18.65**	-22.84**	-19.69**	1.91	7.43	3.11	-2.72	-8.42**
	BP	-20.31**	-23.03**	-20.88**	-12.53**	5.62	-8.99**	-10.98**	-15.21**
	SP	-9.40**	-9.93**	-9.53**	17.16**	-19.12**	6.42*	-5.73*	-7.12*
L1 x T4	MP	12.43**	20.00**	14.27**	-12.10**	-23.38**	-15.18**	65.09**	65.74**
	BP	5.66**	11.54**	7.10**	-13.87**	-33.04**	-19.54**	60.62**	58.18**
	SP	20.12**	29.85**	22.46**	-13.50**	-32.17**	-19.80**	69.97**	74.47**
L2 x T1	MP	6.65**	2.45**	5.56**	-34.50**	-26.80**	-32.87**	31.77**	36.26**
	BP	-2.63**	-11.25**	-4.96**	-34.84**	-39.79**	-36.05**	8.72**	11.04**
	SP	5.13**	12.36**	6.87**	-32.11**	-50.43**	-37.53**	35.14**	43.09**
L2 x T2	MP	1.73**	9.13**	3.60**	-2.87	9.09	-0.13	-35.95**	-33.56**
	BP	-5.12**	4.45**	-2.75**	-5.88*	3.23	-1.29	-38.98**	-36.04**
	SP	-15.39**	-3.13**	-12.44**	5.11	-16.51*	-1.29	-24.30**	-17.16**
L2 x T3	MP	-30.50**	-35.97**	-31.87**	-40.06**	-28.57**	-37.56**	22.48**	35.34**
	BP	-36.83**	-42.62**	-38.30**	-46.59**	-30.11**	-42.76**	4.48**	16.88**
	SP	-31.11**	-32.85**	-31.53**	-28.83**	-42.60**	-32.91**	30.03**	50.62**
L2 x T4	MP	-16.12**	-23.00**	-17.80**	-36.19**	-47.12**	-39.14**	12.08**	15.54**
	BP	-20.66**	-25.80**	-21.90**	-37.63**	-52.17**	-39.85**	1.12	2.60
	SP	-20.66**	-25.80**	-21.90**	-34.30**	-53.04**	-39.85**	25.85**	31.79**
L3 x T1	MP	-8.92**	-33.04**	-15.37**	-14.18**	8.40	-9.75**	-10.42**	-4.55
	BP	-16.14**	-39.47**	-22.46**	-19.01**	0.00	-12.50**	-19.73**	-14.63**
	SP	-9.45**	-23.37**	-12.80**	-15.69**	-37.39**	-22.88**	-18.26**	-12.14**
L3 x T2	MP	-7.10**	-12.44**	-8.49**	-9.32**	25.97**	-1.69	-5.48**	-3.96
	BP	-14.10**	-19.94**	-15.63**	-17.32**	16.87*	-10.03**	-9.90**	-10.53**
	SP	-21.94**	-18.10**	-21.02**	-8.03*	-16.51*	-9.77**	1.24	6.69*
L3 x T3	MP	-20.66**	-17.46**	-19.83**	-25.04**	-35.00**	-27.09**	24.63**	31.49**
	BP	-27.27**	-22.65**	-26.10**	-36.79**	-41.57**	-37.72**	15.93**	25.61**
	SP	-20.68**	-9.49**	-17.99**	-15.69**	-55.65**	-26.74**	18.42**	29.28**
L3 x T4	MP	16.13**	9.56**	14.48**	10.65**	3.23	8.71**	16.63**	46.39**
	BP	10.83**	8.33**	10.82**	6.20*	-16.52**	-0.51	15.48**	44.31**
	SP	10.83**	10.82**	10.82**	6.21	-16.51*	-0.52	17.96**	48.11**
L4 x T1	MP	-14.97**	-26.10**	-17.76**	-22.90**	-14.65*	-21.17**	7.65**	18.57**
	BP	-20.95**	-38.21**	-25.63**	-26.13**	-30.93**	-27.27**	-17.15**	-9.29**
	SP	-14.64**	-21.77**	-16.36**	-16.79**	-42.60**	-23.65**	24.00**	39.32**
L4 x T2	MP	-43.55**	-55.76**	-46.49**	-19.16**	-31.11**	-21.86**	-19.29**	-9.99**
	BP	-48.30**	-55.84**	-50.00**	-19.68**	-36.08**	-23.59**	-29.34**	-19.95**
	SP	-52.03**	-62.42**	-54.53**	-9.12*	-45.21**	-19.80**	5.88*	23.01**
L4 x T3	MP	-14.28**	-19.07**	-15.44**	-36.19**	-17.20**	-32.10**	49.32**	49.49**
	BP	-20.68**	-30.10**	-23.07**	-41.14**	-20.62**	-35.75**	18.39**	20.49**
	SP	-13.49**	-18.21**	-14.63**	-21.17**	-32.17**	-24.42**	77.40**	84.51**
L4 x T4	MP	9.59**	6.48**	8.92**	-21.58**	-48.11**	-28.64**	12.76**	20.99**
	BP	5.64**	-1.45**	3.98**	-26.13**	-52.17**	-30.22**	-5.99**	0.00
	SP	5.64**	-1.45*	3.98**	-16.79**	-53.04**	-26.74**	40.71**	53.13**

Contd.

Contd. table 6

Genotype		Mature leaf			Immature fruit			Ripe fruit	
		Chl A	**Chl B**	**Total Chl**	**Chl A**	**Chl B**	**Total Chl**	**Lycopene**	**Beta carotene**
L5 x T1	MP	8.97**	-14.80**	2.87**	-9.00**	-9.76	-9.16**	-53.83**	-50.65**
	BP	-13.96**	-37.50**	-20.33**	-10.54**	-28.85**	-15.33**	-69.22**	-66.96**
	SP	-7.10**	-20.87**	-10.41**	-3.65	-34.78**	-13.63**	-25.23**	-20.92**
L5 x T2	MP	17.90**	6.46**	15.09**	-22.33**	-23.00**	-22.49**	-12.34**	-8.52**
	BP	6.73**	-9.64**	2.51**	-23.86**	-30.77**	-23.37**	-35.82**	-31.47**
	SP	-17.63**	-23.38**	-19.02**	-14.60**	-37.39**	-21.34**	55.58**	64.43**
L5 x T3	MP	13.82**	8.28**	12.46**	-7.11**	10.88	-3.05	-31.55**	-22.36**
	BP	-10.45**	-18.49**	-12.49**	-16.35**	2.89	-9.21**	-53.38**	-45.98**
	SP	-2.34**	-4.63**	-2.89**	11.68**	-6.08	6.42*	12.85**	29.28**
L5 x T4	MP	19.25**	14.83**	18.23**	-1.76	-19.64**	-6.73**	-40.69**	-38.59**
	BP	-3.08**	-8.62**	-4.40**	-5.10*	-23.48**	-7.79**	-58.11**	-56.47**
	SP	-3.08**	-8.62**	-4.39**	1.83	-24.34**	-5.92	1.70	4.18
L6 x T1	MP	4.85**	-2.51**	2.96**	-9.88**	20.31*	-3.79	34.73**	58.13**
	BP	-3.39**	-16.76**	-7.01**	-19.72**	13.24	-11.34**	28.20**	51.42**
	SP	4.31**	5.39**	4.57**	-16.79**	-32.17**	-21.34**	14.71**	34.30**
L6 x T2	MP	4.14**	-4.37**	2.03**	4.17	9.93	5.45*	148.12**	151.11**
	BP	-3.78**	-6.93**	-4.53**	-10.13**	0.00	-7.97**	122.70**	118.95**
	SP	-12.43**	-16.64**	-13.44**	0.73	-26.95**	-8.23**	150.78**	161.08**
L6 x T3	MP	-6.13**	-21.24**	-9.85**	-42.62**	-17.20*	-37.27**	113.80**	126.15**
	BP	-13.90**	-30.48**	-18.10**	-53.95**	-26.97**	-48.68**	111.77**	120.09**
	SP	-6.09**	-18.65**	-9.12**	-38.68**	-42.60**	-39.85**	89.48**	105.85**
L6 x T4	MP	18.36**	0.71	14.14**	12.90**	3.83	10.46**	106.37**	104.88**
	BP	13.04**	-4.54**	8.81**	2.19	-17.39**	-3.60	95.51**	93.31**
	SP	13.04**	-4.55**	8.81**	1.83	-16.51*	-3.60	95.51**	93.30**
L7 x T1	MP	12.67**	5.27**	10.75**	-42.98**	-48.76**	-44.44**	13.48**	15.09**
	BP	6.08**	-6.39**	2.71**	-52.57**	-65.93**	-56.56**	-0.15	-1.11
	SP	14.54**	18.52**	15.50**	-25.54**	-45.21**	-32.14**	6.35**	11.71**
L7 x T2	MP	5.17**	-4.35**	2.77**	-47.41**	-50.19**	-48.15**	33.24**	32.97**
	BP	-4.85**	-11.04**	-6.38**	-54.91**	-63.74**	-57.54**	29.57**	29.47**
	SP	-9.28**	-12.31**	-10.01**	-29.92**	-42.60**	-33.68**	45.82**	54.39**
L7 x T3	MP	6.98**	52.30**	18.33**	-56.73**	-46.13**	-54.03**	34.13**	45.34**
	BP	0.25	40.30**	10.41**	-59.81**	-59.89**	-59.84**	22.42**	32.96**
	SP	9.33**	64.17**	22.53**	-37.59**	-37.39**	-36.76**	30.03**	50.62**
L7 x T4	MP	27.01**	48.03**	32.13**	-13.68**	-36.03**	-20.32**	19.13**	22.20**
	BP	24.05**	46.97**	29.57**	-29.21**	-47.80**	-34.75**	15.58**	15.19**
	SP	24.05**	46.97**	29.56**	10.59**	-16.51*	2.57	23.07**	30.54**

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

SCA effect and components of heterosis, Arka Vikas × Berika and Arka Vikas × Alisa Craig found to be best performing hybrid for enhancement of important pigment traits.

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