International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 75-79

Received: 25-07-2019
Accepted: 27-08-2019

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Combining ability and gene action for fruit yield and its attributes in Brinjal (*Solanum melongena* L.)

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Abstract
Genetic studies for fruit yield per plant and its attributing traits in brinjal was conducted by following line x tester mating design comprising of eight lines and four testers at Vegetable Research Station, Junagadh Agricultural University, Juangadh, Gujarat. The analysis of combining ability revealed the predominant role of non –additive gene effects in the inheritance of fruit yield and its component traits. The genotypes AB-15-07, NSR-1 and Swarna Mani Black, displayed high gca effects for fruit yield per plant and some of the desirable traits like; days to last picking, fruit length, fruit weight, number of fruits per plant and fruit borer infestation. The estimates of sca effects of the crosses indicated that eleven hybrids manifested significant and positive sca effect for fruit yield per plant. The crosses NB-15-5 x GJB-3, NBR-14-01 x Swarna Mani Black, AB-15-08 x Pant Rituraj, AB-15-07 x GJLB-4 and NSR-1 x Swarna Mani Black were emerged as best specific combinations. These crosses also showed desirable sca effect for important yield traits. These hybrids may be exploited for obtaining transgressive segregants toward developing hybrid varieties in brinjal.

Keywords: Brinjal, combing ability, fruit yield, gene action

Introduction
Brinjal (*Solanum melongena* L.), also known as eggplant, is an important solanaceous vegetable crop grown round the year in India. It is grown for its immature, unripe fruits, which are used in the variety of ways as cooked vegetable in curries. It is grown extensively in all part of India except at higher altitude. It is popular among the people of all social strata and hence, it is rightly called as vegetable of masses (Patel and Sarnaik, 2003) [11]. With increasing popularity of F_1 hybrids in brinjal, it is imperative to obtain hybrid having excellent quality coupled with high fruit yield. A knowledge of general combining ability (gca) and specific combining ability (sea) helps in choice of parents and hybrids, respectively and the nature of gene action acts as a basis for choosing effective breeding strategies. The present investigation, therefore, was undertaken to identify superior hybrids of excellent qualities coupled with high fruit yield per plant in brinjal.

Materials and methods
The experimental material comprised of parents and their F_1s derived by crossing eight lines *viz*., AB-08-14, AB-15-07, AB-15-08, JB-12-06, JBR-14-07, NSR-01, NBR-14-01 and NBR-01, NBR-14-01 and NBR-15-05 and four testers *viz.*, Swarna Mani Black, GJLB-4, Pant Rituraj and GJB-3 in a line x tester fashion. The genotypes were selected on the basis of morphological variability for growth, maturity, fruit size and shape, fruit yield and yield contributing characters. The experiment was laid out in a randomized block design with three replications during kharif-2017 at Vegetable Research Station, Junagadh Agricultural University, Junagadh, Gujarat. The observations were recorded on 13 characters *viz*., days to 50% flowering, days to first picking, days to last picking, number of pickings, fruit length (cm), fruit girth (cm), fruit weight (g), number of fruits per plant, number of branches per plant, plant height (cm), total fruit yield per plant (kg), total soluble solids (^oB) and fruit borer infestation (%). Combining ability analysis was carried out by the method suggested by Kemthorne (1957) [8].

Results and discussion

Analysis of variance for combining ability indicated that the mean squares due to lines were significant for days to 50% flowering and fruit girth when tested against error mean square, whereas, the mean squares due to testers were significant for days to first picking, number of pickings, fruit weight plant height and total fruit yield per plant when tested against error mean square. The mean squares due to line x tester were found significant for all the characters when tested against error mean square. This indicated the role of both additive and non-additive gene effects in the in the inheritance of all these traits (Table 1).

Table 1: Analysis of variance for combining ability and variance components for different characters in brinjal

Source	d. f.	Days to 50% flowering	Days to first picking	Days to last picking	Number of pickings	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
		1	2	3	4	5	6	7
Replications	2	0.32	13.78	10.04	1.53	0.05	0.13	271.72**
Lines	7	16.52**	124.76	269.79	3.16	4.72	43.74**	554.86
Testers	3	7.73	212.84*	507.37	5.56*	7.53	13.01	5017.02*
Lines x Testers	21	3.35*	55.34**	185.16**	1.58*	3.02**	4.99**	1480.58**
Error	62	1.91	14.83	7.66	0.86	0.02	0.11	54.59
Variance components								
σ^2 l	-	1.21	9.16	21.84	0.19	0.39	3.63	42.77
σ^2 t	-	0.24	8.25	20.82	0.19	0.31	0.53	207.30
σ^2 lt	-	0.48	13.50	59.16	0.24	1.00	1.62	479.66
σ^2 gca	-	0.56	8.55	21.16	0.19	0.33	1.57	152.46
σ^2 sca	-	0.48	13.50	59.16	0.24	1.00	1.62	479.66
σ^2 gca / σ^2 sca	-	1.16	0.63	0.35	0.79	0.33	0.96	0.31

Source	d. f.	Number of fruits per plant	Number of branches per plant	Plant height (cm)	Total fruit yield per plant (kg)	Total soluble solids (TSS) (ºB)	Fruit borer infestation (%)
		8	9	10	11	12	13
Replications	2	8.58*	0.11**	110.25	0.09*	0.18**	8.90**
Lines	7	68.87	1.35	244.46	0.90	0.93	8.18
Testers	3	34.66	1.41	1225.78**	1.85*	0.18	11.23
Lines x Testers	21	69.79**	0.69**	249.97**	0.55**	0.42**	10.76**
Error	62	1.87	0.02	47.34	0.02	0.03	1.45
Variance components							
σ^2 l	-	5.58	0.11	16.42	0.07	0.07	0.56
σ^2 t	-	1.36	0.05	49.10	0.07	0.01	0.40
σ^2 lt	-	22.63	0.22	67.54	0.17	0.13	3.10
σ^2 gca	-	2.77	0.07	38.20	0.07	0.02	0.45
σ^2 sca	-	22.63	0.22	67.54	0.17	0.13	3.10
σ^2 gca / σ^2 sca	-	0.12	0.31	0.56	0.41	0.15	0.14

The ratio of σ^2 gca/ σ^2 sca was less than unity for all the characters except for days to 50% flowering indicated the importance of additive gene action for this trait. For remaining characters *viz*., days to first picking days to last picking, number of pickings, fruit length, fruit girth, fruit weight, number of fruits per plant, number of branches per plant, plant height, total fruit yield per plant, total soluble solids and fruit borer infestation the ratio of σ^2 gca/ σ^2 sca was less than unity indicating the importance of non-additive gene action for these traits. These results are in accordance with those earlier obtained by Singh and Singh (2004) [13], Kamalakkannan *et al*. (2007) [6] and Gharge *et al*. (2016) [3] for days to first picking, days to last picking and number of picking; Singh *et al*. (1981) [15], Kamal *et al*. (2006) [5], Kamalakkannan *et al*. (2007) [6] and Sao and Mehta (2010) [12] for fruit length, fruit girth and fruit weight; Sharma *et al*. (2004), Kamalakkannan *et al*. (2007) [6], Umaretia *et al*. (2008) [17] and Sao and Mehta (2010) [12] for number of branches per plant and plant height; Singh *et al*. (1981) [15], Choudhary and Pathania (2000) [1], Sharma *et al*. (2004), Kamal *et al*. (2006) [5], Vaddoria (2007) [18], Suneetha *et al*. (2008), Umaretial *et al*. (2008) [17], Sao and Mehta (2010) [12], Nalini *et al*. (2011). Thangavel (2011) [16], Gharge *et al*. (2016) [3] and Viradiya *et al*. (2016) [19] for total fruit yield per plant and Vaddoria (2007) [18] for total soluble solids and fruit borer infestation.

The estimates of gca effects (Table 2) indicated that among the lines, NSR-1 ranked first as it was good general combiner for most of the characters *viz*., fruit length, fruit weight, number of fruits per plant, number of branches per plant, plant height, total fruit yield per plant and total soluble solids. Likewise, the line AB-15-08 was good general combiner for days to 50% flowering, days to first picking, number of pickings, days to last picking and number of branches per plant. The male parent, Swarna Mani Black was good combiner for days to last picking, fruit length, fruit weight, fruit girth, number of fruits per plant, total fruit yield per plant and fruit borer infestation. The parent GJLB-4 was found good combiner for fruit length, fruit girth, number of fruits per plant, number of branches per plant, plant height and total soluble solids. The male parent, GJB-3 showed good general combining ability effects for days to 50% flowering, days to first picking, number of picking, fruit girth, number of fruits per plant and plant height. Good general combining ability effect for days to last- picking, fruit girth, fruit weight and number of branches perr plant was exerted by AB-08-14. The line JB-12-06 was good general combiner for fruit length and total soluble solids, while, good general combining ability

effect for number of fruits per plant, plant height, total fruit yield per plant and total soluble solids was exhibited by the line JBR-14-07. The line AB-15-07 had good general combining ability effects for fruit length, number of fruits per plant, total fruit yield per plant and fruit borer infestation. Good combining ability effect was exerted by the line NBR-14-01 for the traits like; days to first picking, number of picking and total soluble solids. The male line Pant Rituraj registered good general combining ability effects for days to plant picking, fruit weight and total fruit yield per plant. The parent NBR-15-5 was found good combiner for days to 50% flowering, days to last picking and total soluble solids. Similar findings were reported by Das and Barua (2001) [2], Singh *et al*. (2003) [14], Kamal *et al*. (2006) [5] and Kumar *et al*. (2012) [9] in brinjal.

Table 2: General combining ability effects for different characters in brinjal

Sr. No.	Parents	Days to 50% flowering	Days to first picking	Days to last picking	Number of pickings	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of fruits per plant	Number of branches per plant	Plant height (cm)	Total fruit yield per plant (kg)	Total soluble solids (TSS) (ºB)	Fruit borer infestation (%)
Lines														
1	AB-08-14	-0.53	-0.21	4.26**	0.30	-0.27**	4.58**	13.56**	-2.03**	0.08*	3.66	0.10	-0.41**	-0.46
2	AB-15-07	2.30**	3.86**	-3.49**	-0.53*	1.30**	-1.34**	-1.21	2.90**	-0.08	-6.00*	0.28**	-0.41**	-1.35**
3	AB-15-08	-1.53**	-5.46--	3.09**	0.63*	-0.51**	-0.22*	-6.20**	-0.50	0.51**	-3.29	-0.22**	-0.40**	0.56
4	JB-12-06	0.55	3.28**	-3.15**	-0.61*	0.24**	-0.50**	-5.78**	-3.71**	-0.09*	-0.54	-0.44**	0.20**	1.26**
5	JBR-14-07	-0.28	-0.21	-3.99*	0.05	-0.61**	-0.58**	-2.80	2.90**	0.06	4.82*	0.14**	0.18**	0.15
6	NSR-1	0.71	0.94	-4.49**	-0.36	0.31**	-1.34**	6.92**	1.76**	0.32**	6.53*	0.35**	0.20**	-0.13
7	NBR-14-01	-0.44	-3.71**	-0.65	0.71**	-0.41**	-0.17	-1.82	0.05	-0.22**	-1.46	-0.01	0.22**	0.59
8	NBR-15-5	-0.78*	1.53	8.42**	-0.19	-0.04	-0.40**	-2.65	-1.34**	-0.59**	-3.71	-0.20**	0.14**	-0.63
	SE(g_i)	0.39	1.11	0.79	0.26	0.04	0.09	1.86	0.39	0.04	1.98	0.04	0.05	0.34
	SE(g_i-g_j)	0.56	1.57	1.12	0.37	0.06	0.14	2.63	0.55	0.06	2.80	0.05	0.07	0.49
Testers														
1	Swarna Mani Blck	0.76**	1.24	2.71**	-0.57**	0.58**	0.51**	8.91**	1.20**	-0.11**	-9.61**	0.29**	-0.07*	-0.74**
2	GJLB-4	-0.24	-0.21	-3.49**	0.26	0.13**	0.30**	-10.29**	0.83**	0.33**	6.22**	-0.09**	0.08*	-0.02
3	Pant Rituraj	0.05	2.99**	5.05**	-0.19	-0.75**	-1.09**	15.53**	-0.77**	-0.23**	-1.06	0.14**	0.06	0.90**
4	GJB-3	-0.57*	-4.01**	-4.28**	0.51**	0.03	0.27**	-14.15**	1.26**	0.01	4.49**	-0.34**	-0.07*	-0.14
	SE(g_i)	0.28	0.78	0.56	0.18	0.03	0.07	1.13	0.27	0.03	1.40	0.02	0.03	0.24
	SE(g_i-g_j)	0.39	1.11	0.79	0.26	0.04	0.09	1.86	0.39	0.04	1.98	0.04	0.05	0.34

*, ** Significant at 5 and 1 per cent level, respectively

The estimates of sca effects of the crosses indicated that ten hybrids manifested significant and positive sca effects for fruit yield per plant. The best five specific combinations were NBR-15-5 x GJB-3, NBR-14-01 x Swaran Mani Black, AB-15-08 x Pant Rituraj, AB-15-07 x GJLB-4 and NSR-1 x Swaran Mani Black (Table 3). Similar results were reported by Kele *et al*. (1992) [4] and Singh *et al*. (2003) [14]. The cross NBR-15-5 x GJB-3 was also found specific combination for fruit length. Likewise, NBR-14-01 x Swaran Mani Black was also found good specific combination for days to last picking and fruit borer infestation. The cross AB-15-8 x Pant Rituraj was found good specific combination for the days to last picking and plant height Thus, these hybrid could be exploited in practical plant breeding for selection of batter transgressive sergeants and they may also be exploited through heterosis breeding programme in brinjal.

Table 3: Specific combining ability effects for days to 50% flowering, days to first picking days to last picking, number of picking, fruit length (cm), fruit girth (cm) and fruit weight (g) in brinjal

Crosses	Days to 50% flowering	Days to first picking	Days to last picking	Number of pickings	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
AB-8-14 x Swarna Mani Black	-1.17	-2.40	3.61*	0.90	0.20*	2.96**	12.40**
AB-8-14 x GJLB-4	0.82	-0.94	0.15	-0.26	-0.29**	1.07**	18.17**
AB-8-14 x Pant Rituraj	0.53	2.84	-9.38**	-0.46	0.02	-3.26**	-16.38**
AB-8-14 x GJB-3	-0.17	0.51	5.61**	-0.17	0.06	-0.77**	-14.19**
AB-15-07 x Swarna Mani Black	-1.01	2.8	8.03**	0.07	0.01	-0.15	19.49**
AB-15-07 x GJLB-4	-1.34	-7.36**	0.24	1.24*	1.39**	-0.55**	-1.92
AB-15-07 x Pant Rituraj	0.69	8.09**	-3.63	-0.96	-0.19*	1.47**	-19.68**
AB-15-07 x GJB-3	1.65*	-3.57	-4.63**	-0.34	-1.22**	-0.76**	2.11
AB-15-08 x Swarna Mani Black	1.82*	5.17*	-9.88.**	-1.09*	-0.83**	-1.14**	-0.77
AB-15-08 x GJLB-4	-0.17	-0.36	3.65*	0.40	0.59**	0.11	-19.94**
AB-15-08 x Pant Rituraj	-1.46	-5.90*	1.44	0.86	-0.10	0.40*	-12.07**
AB-15-08 x GJB-3	-0.17	1.09	4.78**	-0.17	0.34**	0.61**	32.78**
JB-12-06 x Swarna Mani Black	0.07	-3.57	6.03**	-0.17	1.03**	0.69//	-12.74**
JB-12-06 x GJLB-4	-1.26	-2.11	-6.76	0.65	-1.16**	-1.12**	14.68**
JB-12-06 x Pant Rituraj	0.11	4.01	-1.30	0.11	0.28**	-0.74	5.72
JB-12-06 x GJLB-4	1.07	1.67	2.03	-0.59	-0.15	1.16**	-7.67
JBR-14-07 x Swarna Mani Black	-0.76	-4.74*	-4.80**	0.82	0.69**	0.09	-20.45**
JBR-14-07 x GJLB-4	-0.09	1.38	-5.59**	-0.34	-0.33**	-0.09	2.70

JBR-14-07 x Pant Rituraj	0.28	-1.82	10.53**	0.11	0.35**	0.54**	35.64**
JBR-14-07 x GJLB-4	0.57	5.17*	-0.13	-0.59	-0.71**	-0.53**	-17.89**
NSR-1 x Swarna Mani Black	0.24	-1.24	-9.63**	-0.09	0.91**	-0.71**	-25.63*
NSR-1 x GJLB-4	0.57	2.55	12.24**	-0.92	-1.06**	0.25	12.99**
NSR-1 x Pant Rituraj	-0.05	-0.65	5.69**	0.19	0.56	0.27	24.85**
NSR-1 x GJLB-4	-0.76	-0.65	-8.30**	0.82	-0.42**	0.19	-12.21**
NBR-14-01 x Swarna Mani Black	0.74	1.09	8.53**	0.15	-1.08**	-1.51**	-0.76
NBR-14-01 x GJLB-4	1.07	255	-9.92**	-0.4	1.34**	0.65**	-24.91**
NBR-14-01 x Pant Rituraj	-0.55	-2.99	4.86**	0.11	-0.07	0.61**	15.30
NBR-14-01 x GJLB-4	-1.26	-0.65	-3.46*	0.07	-0.18*	0.24	10.36**
NBR-15-5 x Swarna Mani Black	0.07	2.84	-1.88	-0.59	-0.95**	-0.22	28.48**
NBR-15-5 x GJLB-4	0.40	4.30	5.99**	-0.42	-0.47**	-0.31	-1.78
NBR-15-5 x Pant Rituraj	0.44	-3.57	-8.21**	0.03	-0.86**	0.69**	-33.39**
NBR-15-5 x GJLB-4	-0.92	-3.57	4.11*	0.99	2.29**	-0.15	6.69
SE(S_{ij})	0.79	2.22	1.59	0.53	0.08	0.19	3.72

*, ** Significant at 5 and 1 per cent levels, respectively.

Table 3: Specific combining ability effects for number of fruits per plant, number of branches per plant, plant height (cm), total fruit yield per plant (kg), total soluble solids (TSS) (°B) and fruit borer infestation (%) in brinjal

Crosses	Number of fruits per plant	Number of branches per plant	Plant height (cm)	Total fruit yield per plant (kg)	Total soluble solids (TSS) (°B)	Fruit borer infestation (%)
AB-8-14 x Swarna Mani Black	-2.27**	-0.22*	8.10*	-0.03	0.49**	2.91**
AB-8-14 x GJLB-4	1.33	-0.24**	-8.76*	0.35**	-0.42**	-0.07
AB-8-14 x Pant Rituraj	3.28**	0.61**	6.35	0.01	0.09	-2.92**
AB-8-14 x GJB-3	-2.34**	-0.14	-5.70	-0.33**	-0.16	0.07
AB-15-07 x Swarna Mani Black	-1.38	0.56**	-2.72	0.23**	-0.17	2.43**
AB-15-07 x GJLB-4	5.17**	0.28**	1.56	0.41**	0.06	-2.28**
AB-15-07 x Pant Rituraj	2.12**	-0.07	3.69	-0.07	0.24*	0.75
AB-15-07 x GJB-3	-5.91**	-0.77**	-2.53	-0.58**	-0.23*	-0.91
AB-15-08 x Swarna Mani Black	-4.53**	0.17	6.23	-0.47**	0.05	-1.60*
AB-15-08 x GJLB-4	3.20**	-0.46**	-8.47*	0.04	0.26*	2.60**
AB-15-08 x Pant Rituraj	5.83**	0.35**	16.48**	0.51**	-0.51**	-1.18
AB-15-08 x GJB-3	-4.50**	-0.06	-14.24**	0.01	00.19	0.19
JB-12-06 x Swarna Mani Black	-1.51	0.41**	5.15	-0.41**	0.31**	-0.90
JB-12-06 x GJLB-4	-0.42	-0.33**	1.44	0.14	-0.20	-0.30
JB-12-06 x Pant Rituraj	0.93	-0.30**	-3.59	0.19*	0.07	1.56*
JB-12-06 x GJLB-4	1.01	0.23**	-2.99	0.08	-0.18	-0.35
JBR-14-07 x Swarna Mani Black	1.47	-0.95**	-8.39*	-0.02	0.29**	-1.50*
JBR-14-07 x GJLB-4	-3.31**	0.11	-5.07	-0.19	0.34**	-1.69*
JBR-14-07 x Pant Rituraj	-5.99**	0.12	2.35	-0.08	-0.70**	0.44
JBR-14-07 x GJLB-4	7.83**	0.72**	11.13**	0.31**	0.07	2.76**
NSR-1 x Swarna Mani Black	7.76**	-0.18*	4.76	0.38**	-0.42**	0.57
NSR-1 x GJLB-4	-4.67**	0.02	*1.47	-0.17*	-0.08	-1.09
NSR-1 x Pant Rituraj	-1.25	0.09	-4.01	0.25**	0.49**	0.20
NSR-1 x GJLB-4	-1.84*	0.06	10.25*	-0.46**	0.01	0.30
NBR-14-01 x Swarna Mani Black	5.73**	0.49**	-5.43	0.62**	*0.07	-2.64**
NBR-14-01 x GJLB-4	-2.52**	0.08	12.69**	-0.62**	*0.30**	2.00**
NBR-14-01 x Pant Rituraj	-4.47**	-0.62**	-10.18*	-0.36**	0.18	1.47*
NBR-14-01 x GJLB-4	1.26	0.03	2.92	0.35**	0.19	-0.83
NBR-15-5 x Swarna Mani Black	-5.25**	-0.28**	1.81	-0.29**	-0.59**	0.72
NBR-15-5 x GJLB-4	1.22	0.53	8.10*	0.11	0.34**	0.85
NBR-15-5 x Pant Rituraj	-0.45	-0.17*	-11.09**	-0.44**	0.13	-0.34
NBR-15-5 x GJLB-4	4.48**	-0.07	1.17	0.63**	0.11	-1.23
SE(S_{ij})	0.79	0.08	3.97	0.08	0.10	0.69

*, ** Significant at 5 and 1 per cent levels, respectively

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