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General and Specific Combining Ability for Quantitative Characters in Brinjal (*Solanum melongena* L.)

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Abstract Nine genotypes of brinjal (*Solanum melongena* L.) were crossed in an incomplete 9 × 9 half-diallel design to produce 36 F_1 full-sib families in accordance with Griffing's second method. These lines were used to estimate general combining ability (GCA) and specific combining ability (SCA) effects for marketable fruit yield per plant and other contributing characters in order to select suitable parents for hybridization and to identify the promising hybrids. Nine parents and their 36 F_1s were sown under four environments(two year and two date of sowing) in a randomized block design with three replication. The environment wise combining ability analysis revealed significant differences for GCA and SCA variances for all the characters indicating importance of both additive and non-additive gene effects in the genetic control of all the characters studied. As regards general combining ability effects and *per se* performance, the parents H-8, Pusa Uttam and GOB-1 emerged as good general combiner for yield and most of the contributing characters. Out of 36 crosses studied Kashi Sandesh × Pusa Uttam, H-8 × Pant Samart, Pusa Shyamal × GOB-1 and Pusa Shyamal × Pant Rituraj had high *per se* performance, SCA effects and in desirable direction for yield and most of the associated traits. The cross combination viz. Kashi Sandesh × Pusa Uttam in E_1 and E_4, H-8 × Pusa Uttam in E_1 and Kashi Sandesh × H-8 in E_4 for marketable fruit yield per plant with high SCA effects involving good × good general combiners were identified. All these crosses offer good promise for improvement of respective component characters in specific environment and ultimately marketable fruit yield per plant.

Keywords Combining ability, Brinjal, Diallel, GCA, SCA.

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Introduction

Brinjal belongs to family Solanaceae. It is supposed to have originated in India. The flowers are hermophrodite and the stamens dehisce at the same time when the stigma is receptive so that the self-pollination is the rule, although there is some degree of cross-pollination by insects. Inflorescence is often solitary but sometines it constitutes a cluster of 2-5 flowers. The flower types in brinjal are long styled, medium styled, short styled and pseudostyled but only long styled and medium styled flowers set fruit. The position of stigma in relation to stamens varies with cultivars and can also vary different flowers of the same cultivar. Moreover, the size of the flower is fairly big which helps in attempting crosses in brinjal.

In the breeding program, it is very important to know the combining abilities of inbred lines that are used as parents in hybrids. Plant breeders can take advantage from such information on combining ability for developing high yielding lines and hybrids. Therefore, knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids in breeding program. The GCA is the average performance of a particular inbred in a series of hybrid combinations, whereas SCA refers to the performance of a combination of specific inbred in a particular cross. The GCA and SCA variances provide estimation for additive and non-additive gene actions, respectively. Hence, by estimating general and specific combining ability effects, the suitable combiner lines and crosses may be selected which may be used in developing the suitable combiner lines and crosses may be selected which may be used in developing improved genotypes as well as suitable hybrids.

This experiment was conducted to estimate GCA and SCA for days to 50% flowering, plant spread, fruit diameter, fruit weight, dry matter of fruit and marketable fruit yield per plant in 9 inbred lines and to determine perspective parental lines and hybrids of Brinjal.

Materials and Methods

The experiment was conducted during *kharif* 2013 and *zyad* 2014 at Experimentation Farm, College of Agriculture, SKRAU Bikaner. Nine genetically diverse parents namely, Kashi Sandesh (P_1), H-8 (P_2), Pusa Shyamal (P_3), Pusa Uttam (P_4), Pant Samrat (P_5), Pant Brinjal-5 (P_6), GOB-1 (P_7), Manjari Gota (P_8) and Pant Rituraj (P_9) were crossed in diallel fashion excluding reciprocals. All the nine parents and 36 Fls were evaluated in randomized block design with three replications under four different environments viz. July 5, 2013 (E_1), July 25, 2013 (E_2), January 5, 2014 (E_3) and January 25, 2014 (E_4). Observations were recorded for the characters namely days to 50% flowering, plant spread, fruit diameter, fruit weight, dry matter of fruit and marketable fruit yield per plant. Observations for all the characters except days to 50% flowering were recorded on five randomly selected plants of each genotype in each replication in each environment avoiding border plants. Data on days to 50% flowering was recorded on plot basis. This combining ability was calculated according to the Model-1 and Method - II of Griffing.

Results and Discussion

The combining ability analysis revealed that the GCA and SCA variances were significant for all the characters in each of the four environments, indicating the importance of both additive and non-additive genetic control of all the characters under study. Bhakta et al. [1] and Rai and Asati [2] also obtained similar results

Table 1. Analysis of variance for combining ability for yield and its contributing characters of brinjal in different environments. * Significant at 5%, **Significant at 1%.

Source of variation	df		Days to 50% flowering	Plant spread (m^2)	Fruit diameter (cm)	Fruit weight (g)	Dry matter of fruit (g)	Marketable fruityield per plant (kg)
GCA	8	E_1	2.06**	0.015**	2.29**	3318.91**	2.20**	0.99**
		E_2	2.98**	0.009**	1.27**	2625.04**	1.35**	0.27**
		E_3	7.39**	0.015**	1.23**	2636.93**	0.88**	0.37**
		E_4	4.34**	0.020**	3.48**	2637.65**	1.30**	0.46**
SCA	35	E_1	2.91**	0.017**	1.60**	734.45**	0.53**	0.28**
		E_2	3.34**	0.015**	0.99**	767.18**	0.56**	0.20**
		E_3	8.27**	0.009**	1.00**	824.30**	0.86**	0.22**
		E_4	3.42**	0.016**	1.36**	635.33**	0.50**	0.15**
Error	88	E_1	0.3	0.0003	0.04	29.06	0.07	0.01
		E_2	0.55	0.0003	0.05	34	0.03	0.01
		E_3	1.48	0.0003	0.06	32.46	0.07	0.01
		E_4	1.31	0.0003	0.07	20.05	0.08	0.01
GCA : SCA Ratio		E_1	0.71	0.88	1.43	4.52	4.15	3.54
		E_2	0.89	0.6	1.28	3.42	2.41	1.35
		E_3	0.89	1.67	1.23	3.2	1.02	1.68
		E_4	1.27	1.25	2.56	4.15	2.6	3.07

Table 2. Estimates of general and specific combining ability effects for yield and its contributing characters of brinjal in different environments.

Genotypes	Days to 50% flowering				Genotypes	Plant spread (m^2)			
GCA effects	E_1	E_2	E_3	E_4	GCA effects	E_1	E_2	E_3	E_4
P_1	-0.37**	-0.50**	-0.08	0.44**	P_1	0.005	-0.016**	0.019**	0.018**
P_2	0.19	0.18	0.12	-0.2	P_2	-0.015**	-0.016**	-0.015**	-0.029**
P_3	-0.32**	-0.65**	-0.85**	-0.96**	P_3	0.065**	0.042**	0.072**	0.072**
P_4	0.26	0.33**	-0.23	0.34**	P_4	-0.006	0.007	0.007	0.039*
P_5	-0.79**	-0.19	-0.94**	-0.78**	P_5	0.049**	0.05**	0.012**	0.023**
P_6	0.21	0.33**	1.64**	1.09**	P_6	-0.035**	-0.004	-0.064**	-0.067**
P_7	-0.07	0.03	-0.54**	0.27	P_7	0.003	-0.011**	-0.021**	-0.022**
P_8	0.24	-0.49**	0.85**	-0.16	P_8	-0.045**	-0.034**	0.011**	-0.006
P_9	0.65**	0.98**	0.03	-0.05	P_9	-0.021**	-0.017**	-0.02**	-0.029**
SE (g_i)	0.02	0.04	0.12	0.11	SE (g_i)	0.00002	0.00002	0.00002	0.00002
SE (g_i-g_j)	0.05	0.1	0.27	0.24	SE (g_i-g_j)	0.00005	0.00005	0.00005	0.00005
SCA effects					SCA effects				
$P_1 \times P_2$	0.27	-0.49	2.86**	1.3	$P_1 \times P_2$	0.063**	0.001	-0.003	-0.016
$P_1 \times P_3$	0.49	2.14**	-2.84**	-0.34	$P_1 \times P_3$	-0.012	0.049**	0.073**	0.061**
$P_1 \times P_4$	-3.76**	-3.64**	-6.71**	-3.24**	$P_1 \times P_4$	0.196**	0.142**	0.167**	0.088**
$P_1 \times P_5$	1.96**	0.88	2.26**	1.51	$P_1 \times P_5$	-0.075**	-0.086**	-0.075**	-0.071**
$P_1 \times P_6$	0.42	0.96	1.68	-1.72	$P_1 \times P_6$	-0.02	-0.044**	0.024	-0.012
$P_1 \times P_7$	-0.16	-1.07	0.53	-0.5	$P_1 \times P_7$	-0.201**	-0.139**	-0.152**	-0.181**
$P_1 \times P_8$	0.19	-0.28	0.47	0.86	$P_1 \times P_8$	0.036**	0.012	0.150**	0.357**
$P_1 \times P_9$	0.05	0.31	0.29	-0.91	$P_1 \times P_9$	-0.062**	-0.045**	-0.041**	-0.050**
$P_2 \times P_3$	-0.41	-0.33	-0.04	0.47	$P_2 \times P_3$	-0.033**	-0.047**	0.051**	0.097**
$P_2 \times P_4$	1.14**`	-0.05	2.35**	-1.07	$P_2 \times P_4$	-0.045	-0.061**	-0.021	-0.060**
$P_2 \times P_5$	-2.60**	-1.86**	-3.62	-3.28**	$P_2 \times P_5$	0.066**	0.092**	0.164**	0.131**
$P_2 \times P_6$	-0.61	-0.05	-1.86	1.19	$P_2 \times P_6$	0.157**	0.153**	-0.078**	-0.065**
$P_2 \times P_7$	-0.72	0.39	2.99**	0.34	$P_2 \times P_7$	-0.044**	-0.152**	0	0.011
$P_2 \times P_8$	-1.73**	-0.06	2.26**	0.44	$P_2 \times P_8$	-0.186**	-0.17**	-0.185**	-0.208
$P_2 \times P_9$	-0.58	2.63**	-1.59	0.99	$P_2 \times P_9$	0.032**	0.036**	0.084**	0.087**
$P_3 \times P_4$	0.66	0.78	2.32**	3.02**	$P_3 \times P_4$	0.095**	0.002	-0.049**	0.050**
$P_3 \times P_5$	1.91**	0.64	1.69	0.54	$P_3 \times P_5$	0.001	0.028	0.067**	0.042**
$P_3 \times P_6$	-0.42	0.78	-0.22	-0.39	$P_3 \times P_6$	-0.151**	-0.116**	-0.056**	-0.088**
$P_3 \times P_7$	-2.67**	-0.75	-4.37**	-2.90**	$P_3 \times P_7$	0.239**	0.198**	0.100**	0.085**
$P_3 \times P_8$	0.75	-2.73**	2.90**	0.93	$P_3 \times P_8$	-0.087**	-0.062**	-0.122**	-0.124**
$P_3 \times P_9$	-2.39**	-3.80**	-5.95**	-3.58**	$P_3 \times P_9$	0.133**	0.074**	0.105**	0.080**
$P_4 \times P_5$	-0.77	0.66	1.74	1.91	$P_4 \times P_5$	-0.201**	-0.224**	-0.145**	-0.119**
$P_4 \times P_6$	2.79**	-0.19	-0.17	-1.02	$P_4 \times P_6$	-0.041**	0.185**	0.026	0.058**
$P_4 \times P_7$	3.74**	-1.69**	0.65	-1	$P_4 \times P_7$	-0.009	0.022	-0.050**	-0.015
$P_4 \times P_8$	-1.24**	0.69	-2.38**	0.23	$P_4 \times P_8$	-0.069**	-0.049**	-0.087**	-0.140**
$P_4 \times P_9$	-0.58	-0.85	-0.56	-1.21	$P_4 \times P_9$	-0.105**	-0.067**	-0.052**	-0.006
$P_5 \times P_6$	0.05	0.66	-1.47	0.76	$P_5 \times P_6$	0.001	-0.009	0.018	0.079**
$P_5 \times P_7$	-0.54	0.16	0.72	-0.42	$P_5 \times P_7$	0.118**	0.107**	0.048**	0.193**
$P_5 \times P_8$	-2.18**	-5.18**	-7.34**	-3.32**	$P_5 \times P_8$	0.174**	0.228**	0.104**	0.023
$P_5 \times P_9$	0.59	-0.33	1.81	0.9	$P_5 \times P_9$	0.045**	0	-0.032**	0.105**
$P_6 \times P_7$	-1.21**	-1.89**	0.47	-0.61	$P_6 \times P_7$	-0.128**	-0.150**	-0.110**	-0.037**
$P_6 \times P_8$	1.48**	1.96**	-1.92	-1.05	$P_6 \times P_8$	0.001	-0.033**	0.014	0.009
$P_6 \times P_9$	-0.59	-0.52	-1.1	-1.63	$P_6 \times P_9$	-0.085**	-0.057**	-0.012	0.031
$P_7 \times P_8$	0.1	0.93	0.6	0.03	$P_7 \times P_8$	-0.271**	-0.234**	-0.054**	-0.248**
$P_7 \times P_9$	1.02**	1.12	-0.25	-1.34	$P_7 \times P_9$	-0.103**	-0.053**	-0.037**	-0.062**
$P_8 \times P_9$	3.05**	2.44**	3.02**	0.42	$P_8 \times P_9$	0.065	0.042**	0.045**	0.060**
SE(Sij)	0.2	0.36	0.97	0.86	SE (Sij)	0.0002	0.0002	0.0002	0.0002
SE (Sij)	0.25	0.46	1.24	1.1	SE (Sij)	0.0003	0.0003	0.0003	0.0003
SE (Sij-Sij)	0.38	0.7	1.88	1.67	SE (Sij-Sij)	0.0004	0.0004	0.0004	0.0004
SE (Sij-Sij)	0.55	1	2.69	2.38	SE (Sij-Sij)	0.0005	0.0005	0.0005	0.0005
SE (Sij-Sik)	0.49	0.9	2.42	2.14	SE (Sij-Sik)	0.0005	0.0005	0.0005	0.0005

Table 2. Continued.

Genotypes GCA effects	Fruit diameter (cm) E_1	E_2	E_3	E_4
P_1	-0.43**	-0.37**	-0.04	-0.05
P_2	0.11	0.1	0.13**	0.38**
P_3	0.1	-0.26**	0.12**	-0.91**
P_4	0.25**	0.25**	0.37**	-0.25**
P_5	-0.52**	-0.15**	-0.46**	-0.07
P_6	-0.56**	-0.46**	-0.43**	0.15**
P_7	0.69**	0.51**	0.31**	0.56**
P_8	-0.18**	-0.01	-0.35**	-0.65**
P_9	0.55**	0.38**	0.33**	0.85**
SE (g_i)	0.003	0.004	0.005	0.006
SE (g_i-g_j)	0.01	0.01	0.01	0.01
SCA effects				
$P_1 \times P_2$	-1.09**	-0.59**	-0.73**	-1.41**
$P_1 \times P_3$	-0.50**	-0.66**	-0.61**	-0.88**
$P_1 \times P_4$	2.70**	1.64**	1.74**	2.77**
$P_1 \times P_5$	-1.00**	-0.79**	-0.65**	-0.93**
$P_1 \times P_6$	-0.38**	-0.38	-1.13**	0.54**
$P_1 \times P_7$	-1.25**	-1.06**	-0.77**	-0.36
$P_1 \times P_8$	-0.66**	-0.84**	0.32	-0.42
$P_1 \times P_9$	-1.47**	0.05	-0.01	-1.17**
$P_2 \times P_3$	-1.25**	-0.92**	-2.18**	-0.70**
$P_2 \times P_4$	-0.81**	-0.61**	-0.24	-1.14**
$P_2 \times P_5$	1.88**	0.65**	0.78**	2.02**
$P_2 \times P_6$	-0.2	0.15	0.84**	0.05
$P_2 \times P_7$	-1.44**	-0.59**	-0.52**	-0.74**
$P_2 \times P_8$	0.91**	-0.3	-0.51**	-0.94**
$P_2 \times P_9$	-0.58**	0.09	0.05	1.13**
$P_3 \times P_4$	1.51**	-1.34**	0.79**	-0.24
$P_3 \times P_5$	0.88**	0.02	0.43	-0.39
$P_3 \times P_6$	0.73**	1.42**	1.17**	0.42
$P_3 \times P_7$	1.35**	0.06	0.39	0.90**
$P_3 \times P_8$	0.15	2.37**	2.02**	0.09
$P_3 \times P_9$	-0.04	0.58**	-0.34	-0.02
$P_4 \times P_5$	0.24	0.82**	0.09	1.06**
$P_4 \times P_6$	1.07**	0.92**	-0.63**	0.34
$P_4 \times P_7$	0.58**	-0.46**	-0.21	-0.49**
$P_4 \times P_8$	-0.43**	-0.39	-0.39	-0.46
$P_4 \times P_9$	0.39**	-0.43**	-0.46**	-1.69**
$P_5 \times P_6$	0.27	1.34**	1.65**	0.45
$P_5 \times P_7$	-1.46**	0.24	0.49**	0.87**
$P_5 \times P_8$	0.31	0.04	-1.06**	-0.18
$P_5 \times P_9$	1.62**	1.19**	0.70**	0.90**
$P_6 \times P_7$	-0.67**	0.37	0.36	-1.34**
$P_6 \times P_8$	-1.33**	-0.58**	0.62**	1.56**
$P_6 \times P_9$	-0.25	-0.94**	-1.02**	1.88**
$P_7 \times P_8$	0.99**	1.06**	-1.50**	0.36
$P_7 \times P_9$	1.46**	-0.81**	0.86**	0.33
$P_8 \times P_9$	0.13	0.43**	0.76**	0.94**
SE (sij)	0.03	0.03	0.04	0.05
SE (sij)	0.03	0.04	0.05	0.06
SE (sij-sij)	0.05	0.06	0.08	0.09
SE (sij-sij)	0.07	0.09	0.11	0.13
SE (sij-sik)	0.07	0.08	0.1	011

Table 2. Continued.

Genotypes GCA effects	Fruit weight (g) E$_1$	E$_2$	E$_3$	E$_4$	Genotypes GCA effects	Dry matter of fruit (g) E$_1$	E$_2$	E$_3$	E$_4$
P_1	4.19**	1.41	6.93**	6.88**	P_1	0.48**	0.14**	0.5	-0.07
P_2	25.55**	23.74**	24.08**	23.15**	P_2	0.61**	0.37**	0.41**	0.50**
P_3	-19.11**	-16.62**	-16.4**	-5.82**	P_3	-0.33**	-0.55**	-0.37**	-0.44**
P_4	21.98**	22.35**	21.84**	26.85**	P_4	0.00	0.39	0.35	0.53**
P_5	-9.02**	-9.96**	-11.86**	-10.85**	P_5	-0.24**	-0.23**	-0.19**	-0.14
P_6	-19.48**	-15.17**	-10.95**	-13.76	P_6	-0.4**	-0.25**	-0.31**	-0.33**
P_7	11.82**	9.07**	3.32**	-5.94**	P_7	0.45**	0.42**	0.02	-0.09
P_8	1.19	-2.59	-0.46	-6.49	P_8	0.1	0	0.22*	0.21**
P_9	-17.11**	-12.23**	-16.49**	-14.00**	P_9	-0.68**	-0.28**	-0.17**	-0.17**
SE (gi)	2.35	2.75	2.62	1.62	SE (gi)	0.01	0.002	0.006	0.006
SE (gi-gi)	5.28	6.18	5.9	3.65	SE (gi-gi)`	0.01	0.01	0.01	0.01`
SCA effects					SCA effects				
$P_1 \times P_2$	19.93**	26.07**	20.61**	17.81**	$P_1 \times P_2$	-0.27	0.43**	1.02**	0.77**
$P_1 \times P_3$	-26.07**	-21.57**	-12.57**	-35.56**	$P_1 \times P_3$	-0.69	-0.19	-0.53**	-0.45
$P_1 \times P_4$	73.38**	67.46**	62.85**	44.78**	$P_1 \times P_4$	0.85**	1.39**	1.34**	0.59**
$P_1 \times P_5$	-27.82**	-20.24**	-32.45**	-17.53**	$P_1 \times P_5$	-0.83**	-0.61**	-0.73**	-0.58**
$P_1 \times P_6$	-7.37	-5.02	-17.36**	-8.28**	$P_1 \times P_6$	0.07	-0.65**	-0.63**	-0.31
$P_1 \times P_7$	-13.34**	1.73	-3.63	2.9	$P_1 \times P_7$	0.09	-0.14	-0.33	-0.59**
$P_1 \times P_8$	10.63**	-20.93**	6.82	16.11**	$P_1 \times P_8$	0.59**	-0.91**	-0.2	0.89**
$P_1 \times P_9$	-11.07**	-10.96**	-3.15	-3.71	$P_1 \times P_9$	0.05	-0.62**	-0.79**	-0.62**
$P_2 \times P_3$	-29.1**	-29.24**	-22.39**	-40.16**	$P_2 \times P_3$	-0.42	-0.62**	-0.96**	-0.86**
$P_2 \times P_4$	45.15**	51.46**	49.04**	42.50**	$P_2 \times P_4$	1.06**	0.54**	1.20**	0.51
$P_2 \times P_5$	64.15**	65.43**	66.07**	49.20**	$P_2 \times P_5$	0.35	1.33**	1.69**	1.18**
$P_2 \times P_6$	-28.07	-26.69	-34.51**	-29.89**	$P_2 \times P_6$	0.87**	-0.84**	-1.13**	-0.74**
$P_2 \times P_7$	-21.37**	-14.93**	-39.78**	-15.38**	$P_2 \times P_7$	-0.27	-0.68**	-1.32**	-0.5
$P_2 \times P_8$	-14.07**	-9.93	-13.66**	2.5	$P^2 \times P_8$	0.27	-0.40**	-0.65**	-0.33
$P_2 \times P_9$	-34.43**	-33.63**	-29.63**	-33.65**	$P_2 \times P_9$	-0.48	-0.68**	-1.12**	-1.02**
$P_3 \times P_4$	-30.19**	-35.51**	-33.15**	53.47**	$P_3 \times P_4$	-0.4	-0.79	-1.01	1.19**
$P_3 \times P_5$	-6.52	2.46	-0.12	-3.83	$P_3 \times P_5$	0.39	0.04	-0.33	-0.24
$P_3 \times P_6$	18.60**	15.34**	1.98	3.08	$P_3 \times P_6$	0.92**	0	0.69	-0.01
$P_3 \times P_7$	29.96**	22.10**	24.04**	22.26	$P_3 \times P_7$	0.70**	0.18	0.50**	-0.22
$P_3 \times P_8$	20.60**	31.43**	43.49**	21.47**	$P_3 \times P_8$	0.85	0.67**	1.26**	0.5
$P_3 \times P_9$	20.90**	13.40**	13.85**	4.32	$P_3 \times P_9$	-0.18	-0.01	0.63**	-0.09
$P_4 \times P_5$	-32.28**	-27.84**	-33.36**	-41.83**	$P_4 \times P_5$	-0.87**	-0.86**	-1.49**	-0.12
$P_4 \times P_6$	-21.82**	-25.96**	-30.93**	-23.25**	$P_4 \times P_6$	-1.00**	-0.75**	-0.91**	-0.06
$P_4 \times P_7$	-11.13**	-13.54**	-5.21	-10.41**	$P_4 \times P_7$	0.71**	0.43**	0.15	-0.28
$P_4 \times P_8$	-32.49**	-25.21**	-10.75**	-25.19**	$P_4 \times P_8$	-1.41**	-0.41**	0.56**	-0.54**
$P_4 \times P_9$	-21.19**	-23.90**	-27.72**	-30.35**	$P_4 \times P_9$	-0.43	0.11	-0.13	-1.12**
$P_5 \times P_6$	1.18	-6.99	-3.9	6.11	$P_5 \times P_6$	-0.35	0.04	-0.32	-0.35
$P_5 \times P_7$	6.54	12.10**	31.82**	2629**	$P_5 \times P_7$	0.64**	0.74**	1.55**	0.41
$P_5 \times P_8$	17.18**	-2.9	-6.05	-6.83	$P_5 \times P_8$	0.75**	0.53**	0.09	0.28
$P_5 \times P_9$	17.48**	12.40**	13.31**	19.35**	$P_5 \times P_9$	-0.33	-0.23	0.52**	0.52**
$P_6 \times P_7$	16.99**	10.64**	24.25**	-1.13	$P_6 \times P_7$	-0.34	0.06	0.26	0.64**
$P_6 \times P_8$	-6.7	30.64**	34.7**	11.08**	$P_6 \times P_8$	-0.91**	1.59**	0.27	0.37
$P_6 \times P_9$	29.27**	24.95**	24.73**	20.26**	$P_6 \times P_9$	-0.35	0.98**	1.52**	0.66**
$P_7 \times P_8$	6.33	8.07	10.43**	-15.07**	$P_6 \times P_8$	-1.00**	0.67**	0.83**	0.19
$P_7 \times P_9$	7.96	21.04**	-3.87	5.11	$P_7 \times P_9$	-0.99**	0.71**	0.21	1.53**
$P_8 \times P_9$	7.93	22.70**	-2.75	-0.35	$P_8 \times P_9$	0.77**	0.47**	0.07	0.91**
SE (sii)	19.02	22.25	21.25	13.12	SE (sii)	0.05	0.02	0.05	0.05
SE (sij)	24.3	28.44	27.15	16.77	SE (sij)	0.06	0.03	0.06	0.07
SE (sij-sjj)	36.99	43.27	41.31	25.52	SE (sij-sjj)	0.09	0.04	0.09	0.1
SE (sij-sik)	52.84	61.82	59.02	36.45	SE (sij-sik)	0.13	0.05	0.13	0.15

Table 2. Continued.

Genotypes GCA effects	Marketable fruit yield per plant (g) E_1	E_2	E_3	E_4
P_1	0.11**	-0.06**	0.03	0.08**
P_2	0.55**	0.28**	0.35**	0.31**
P_3	-0.11**	-0.13**	-0.16**	-0.01
P_4	0.28**	0.17**	0.17**	0.34**
P_5	-0.10**	-0.11**	-0.09**	-0.12**
P_6	0.48**	-0.18**	-0.21**	-0.21**
P_7	0.02	0.1**	0.07**	-0.08**
P_8	0	0.04	0.03	-0.14**
P_9	-0.27**	-0.11**	-0.19**	-0.17**
SE (gi)	0.00006	0.0006	0.0011	0.0006
SE (gi-gj)	0.001	0.001	0.002	0.001
SCA effect				
$P_1 \times P_2$	0.61**	0.57**	0.65**	0.55**
$P_1 \times P_3$	-0.53**	-0.30**	-0.2	-0.5**
$P_1 \times P_4$	0.99**	0.91**	0.84**	0.56**
$P_1 \times P_5$	-0.46**	-0.30**	-0.58**	-0.27**
$P_1 \times P_6$	0.22**	-0.03	-0.15	0
$P_1 \times P_7$	-0.01	-0.09	-0.15	-0.02
$P_1 \times P_8$	0.26**	-0.36**	0.08	0.23**
$P_1 \times P_9$	-0.9	-0.20**	-0.09	-0.03
$P_2 \times P_3$	0.76**	-0.25**	-0.09	-0.67**
$P_2 \times P_4$	0.79**	0.54**	0.64**	0.44**
$P_2 \times P_5$	0.95**	0.58**	0.71**	0.78**
$P_2 \times P_6$	-0.35**	-0.44**	-0.54**	-0.41**
$P_2 \times P_7$	-0.12	-0.04	-0.48**	-0.21**
$P_2 \times P_8$	-0.17**	-0.32**	-0.32**	0.1
$P_2 \times P_9$	-0.60**	-0.19**	-0.21**	-0.49**
$P_3 \times P_4$	-0.38**	-0.45**	-0.48**	0.96**
$P_3 \times P_5$	-0.26**	-0.12	-0.23**	-0.14
$P_3 \times P_6$	0.34**	0.02	0.03	-0.04
$P_3 \times P_7$	1.13**	0.66**	0.59**	0.45**
$P_3 \times P_8$	0.18**	0.03	0.35**	0.16**
$P_3 \times P_9$	0.84**	0.92**	0.78**	0.39**
$P_4 \times P_5$	-0.46**	-0.38**	-0.51**	-0.63**
$P_4 \times P_6$	-0.38**	-0.33**	-0.33**	-0.33**
$P_4 \times P_7$	-0.81**	-0.18**	-0.02	-0.08
$P_4 \times P_8$	-0.08	-0.30**	0.02	-0.09
$P_4 \times P_9$	-0.22**	-0.33**	-0.37**	-0.47**
$P_5 \times P_6$	-0.20**	-0.20**	-0.15	0.04
$P_5 \times P_7$	0.19**	0.08	0.38**	0.37**
$P_5 \times P_8$	0.76**	0.72**	1.10**	0.17**
$P_5 \times P_9$	0.09	0.05	0.07	0.22**
$P_6 \times P_7$	-0.31**	-0.03	0.25**	-0.05
$P_6 \times P_8$	-0.35**	1.17**	0.43**	0.13
$P_6 \times P_9$	0.02	0.23**	0.37**	0.31**
$P_7 \times P_8$	-0.63**	-0.05	0.09	-0.22*
$P_7 \times P_9$	0.04	0.08	-0.22**	-0.08
$P_8 \times P_9$	0.17**	0.09	-0.18	-0.05
SE (sii)	0.005	0.005	0.009	0.005
SE (sij)	0.006	0.006	0.011	0.006
SE (sij-sjj)	0.009	0.009	0.017	0.009
SE (sij-sik)	0.013	0.013	0.024	0.013

in brinjal having influence of both additive and non - additive gene effect for the characters used in their study. However, the GCA/SCA ratio being more than unity showed (Table 1) that the additive genefaction was more important for most of the traits for the characters namely, fruit diameter, fruit weight, dry matter of fruit, marketable fruit yield per plant in the all environments, days to 50% flowering in E_4 and plant spread in E_3 and $E_{4.}$ On the other hand, the non-additive gene effects has greater role in the inheritance of days to 50% flowering in E_1, E_2 and E_3 and plant spread in E_1 and $E_{2.}$ Similarly Bhakta et al. [1] also reported preponderance of additive gene effect in the crop.

General and specific combining ability effects

The combining ability effects were computed to obtain information on selection of suitable parents and crosses for their further use in the breeding program. Estimates of general combining ability effects (gi) and specific combining effects (S_{ij}) in all the four environments have been presented in Table 2 and described separately. Sane et al. [3] and Mishra et al. [4] emphasized the importance of combining ability analysis in selecting the parental lines in brinjal.

GCA effect

Early flowering is desirable in brinjal, which is reflected by the negative combining ability effects. The parental lines P_3, P_1 (except E_3 and E_4), P_5 (escept E_2), P_7 (in E_3 only) and P_8 (in E_2 only) possessed significantly negative GCA effects in all the environments. High plant spread is desirable in brinjal, which is reflected by the positive combining ability effects Looking to GCA effects, parents viz. P_3 and P_5 was most desirable parent for plant spread. Fruit diameter is desirable trait, which is reflected by the positive GCA effects. The significant positive GCA effects were recorded for parents P_7 and P_9 in all the environments, P_4 in E_1, E_2 and E_3, P_2 in E_3 and E_4, P_3 in E_3 and P_6 in E_4. Higher fruit weight directly contributes to yield, therefore, higher fruit weight is considered as desirable, which is reflected by the positive combining ability effects. The parents P_2, P_4 in all the environments,F_1 in E_1, E_3 and E_4 and P_7 in E_1, E_2 and E_3 showed positive GCA effects. The parental lines P_2, P_4 (except E_1), P_1 and P_7 (except E_3 and E_4) and P_8 (except E_1 and E_2) possessed significant positive GCA effects in all the environments for High dry matter of fruit which is desirable in brinjal reflected by the positive combining ability effects. Higher marketable fruit yield per plant is desirable, which is reflected by the positive combining ability effect. The parents viz., P_2 and P_4 in all the environment, P_1 in E_1 and E_4 and P_7 in E_2 and E_3 exhibited significant positive GCA effects. Hence considered as good general combiner for marketable fruit yield per plant. The results obtained in the present study are corroborative with the findings of Mishra et al. [4] and Singh et al. [5] in brinjal. In general, it was observed that top parents on the basis of high *per se* performance also had high general combining ability effects e.g. P_2, P_4 and $P_{7.}$. Top four parents and crosses for *per se* performance, GCA effects and SCA effects are presented in Table 3. It was observed that top four parents on the basis of high *per se* performance, also included some of the parents with top GCA effects in individual unvironment for various characters. This suggested that for these parents GCA effects could reasonably be predicted from their *per se* performance. Similar results were also obtained by Mishra et al. [4] in brinjal.

SCA effect

A total of 8 crosses in E_1, 7 crosses in E_2 and E_3 and 5 crosses in E_4 showed significant negative SCA effect. The crosses viz., $P_1 \times P_4$, $P_2{\times}P_5$, $P_3{\times}P_9$ and $P_5{\times}P_8$ in all the environments, $P_3{\times}P_7$ (except E_2), $P_4{\times}P_8$ (except E_2 and E_4), $P_6{\times}P_7$ (except E_3 and E_4), $P_2{\times}P_8$ (in E_1), $P_3{\times}P_8$ and $P_4{\times}P_7$ in E_2 and $P_1{\times}P_3$ in E_3 had negative significant SCA effects. Hence, these crosses were considered as desirable for days to 50% flowering. For plant spread total of 13 crosses in E_1, 10 in E_2, 12 in E_3 and 15 crosses in E_4 showed significant positive SCA effect. The crosses viz. $P_1{\times}P_4$, $P_2{\times}P_5$, $P_2{\times}P_9$, $P_3{\times}P_7$, $P_3{\times}P_9$, $P_5{\times}P_7$ and $P_8{\times}P_9$ in all the environments, $P_5{\times}P_8$ in E_1, E_2 and E_3, $P_1{\times}P_3$ in E_2, E_3 and E_4. $P_1{\times}P_8$ in E_1, E_3 and E_4, $P_2{\times}P_6$ in E_1 and E_2, $P_3{\times}P_4$ and $P_5{\times}P_4$ in E_1 and E_4, $P_4{\times}P_6$ in E_2 and E_4, $P_2{\times}P_3$ and $P_3{\times}P_5$ in E_3 and E_4 possessed significant positive SCA effects. Hence, these were considered desirable for plant spread. Total of fourteen crosses in E_1, eleven in E_3, E_3 and E_4 showed significant positive SCA effect for fruit diameter. The crosses $P_1{\times}P_4$, $P_2{\times}P_5$, $P_3{\times}P_6$ and $P_5{\times}P_9$ in all the four environments, $P_6{\times} P_8$ in E_1, E_3 and E_4, $P_8{\times}P_9$ in E_2, E_3

Table 3. Best four parents and four crosses based on per se performance, general and specific combining ability under different environments for yield and other associated traits.

Env	*Per se* performance Parents	*Per se* performance F_1	GCA	SCA	Env	*Per se* performance Parents	*Per se* performance F_{11}	GCA	SCA	Env	*Per se* performance Parents	*Per se* performance F_1	GCA	SCA
Character : Days to 50% flowering					Character : Plant spread					Character: Fruit diameter				
E_1	P_6	$P_1 \times P_4$	P_5	$P_1 \times P_4$ (H×L)	E_1	P_7	$P_3 \times P_7$	P_3	$P_3 \times P_7$ (H×L)	E_1	P_7	$P_7 \times P_6$	P_7	$P_1 \times P_4$ (L×H)
	P_1	$P_2 \times P_5$	P_1	$P_3 \times P_7$ (H×L)		P_8	$P_1 \times P_4$	P_5	$P_1 \times P_4$ (L×L)		P_2	$P_1 \times P_4$	P_9	$P_2 \times P_5$ (L×L)
	P_4	$P_3 \times P_7$	P_3	$P_2 \times P_5$) (L×H)		P_4	$P_5 \times P_8$		$P_5 \times P_8$ (H×L)		P_1	$P_3 \times P_7$	P_4	$P_5 \times P_9$ (L×H)
	P_5	$P_5 \times P_8$		$P_3 \times P_9$ (H×L)		P_6	$P_3 \times P_9$		$P_2 \times P_6$ (L×L)		P_9	$P_3 \times P_4$		$P_3 \times P_4$ (L×H)
E_2	P_1	$P_5 \times P_8$	P_3	$P_5 \times P_8$ (L×H)	E_2	P_7	$P_5 \times P_8$	P_5	$P_5 \times P_8$ (H×L)	E_2	GOB-1	$P_3 \times P_8$	P_7	$P_3 \times P_8$ (L×L)
	P_6	$P_3 \times P_8$	P_1	$P_3 \times P_9$) (H×L)		P_8	P3×GOB-1	P_3	$P_3 \times P_7$ (H×L)		P_2	$P_3 \times P_8$	P_9	$P_1 \times P_4$ (L×H)
	P_8	$P_1 \times P_4$	P_8	$P_1 \times P_4$ (H×L)		P_2	$P_4 \times P_6$		$P_4 \times P_6$ (L×L)		P_9	$P_7 \times P_4$	P_4	$P_3 \times P_6$ (L×L)
	P_2	$P_3 \times P_9$		$P_3 \times P_8$ (H×H)		P_4	P_5×GOB-1		$P_2 \times P_6$ (L×L)		P_1	$P_5 \times P_9$		$P_5 \times P_6$ (L×L)
E_3	P_2	$P_5 \times P_8$	P_5	$P_5 \times P_8$ (H×L)	E_3	P_4	$P_1 \times P_4$	P_3	$P_1 \times P_4$ (H×L)	E_3	P_2	$P_1 \times P_4$	P_4	$P_3 \times P_8$ (H×L)
	GOB-1	$P_1 \times P_4$	P_3	$P_1 \times P_4$ (L×L)		P_8	$P_1 \times P_8$	P_1	$P_2 \times P_5$ (L×H)		GOB-1	$P_3 \times P_8$	P_9	$P_1 \times P_4$ (L×H)
	P_5	$P_3 \times P_9$	P_7	$P_3 \times P_9$ (H×L)		P_7	$P_1 \times P_3$	P_5	$P_1 \times P_8$) (H×H)		P_1	$P_7 \times P_9$	GOB-1	$P_5 \times P_6$ (L×L)
	P_1	P_3×GOB-1		$P_3 \times P_7$ (H×H)		P_3	$P_2 \times P_5$	P_8	$P_3 \times P_9$ (H×L)		P_4	$P_3 \times P_4$	P_2	$P_3 \times P_6$ (H×L)
E_4	P_5	$P_3 \times P_9$	P_3	$P_3 \times P_9$ (H×L)	E_4	P_4	$P_1 \times P_8$	P_3	$P_1 \times P_8$ (H×L)	E_4	P_2	$P_6 \times P_9$	P_9	$P_1 \times P_4$ (L×L)
	P_3	$P_2 \times P_5$	P_5	$P_5 \times P_8$ (H×L)		P_8	P_5×GOB-1	P_4	$P_5 \times P_7$) (H×L)		GOB-1	$P_1 \times P_4$	P_7	$P_2 \times P_5$ (H×L)
	P_2	$P_5 \times P_8$		$P_2 \times P_5$ (L×H)		P_7	P3×P4	P_5	$P_2 \times P_5$ (L×H)		P_1	$P_2 \times P_9$	P_2	$P_6 \times P_9$ (H×H)
	P_8	P_3×GOB-2		$P_1 \times P_4$ (L×L)		P_3	P1×P3	P_1	$P_5 \times P_9$ (H×L_0		P_9	$P_2 \times P_5$	P_6	$P_6 \times P_8$ (H×L)

Table 3. Continued.

Env	*Per se* performance Parents	*Per se* performance F_1	GCA	SCA	Env	*Per se* performance Perents	*Per se* performance F_1	GCA	SCA	Env	*Per se* performance Parents	*Per se* performance F_1	GCA	SCA
Character: Fruit weight					Character : Dry matter of fruit					Character: Marketable fruit yield per plant				
E_1	P_4	$P_1 \times P_4$	P_2	$P_1 \times P_4$ (H×H)	E_1	P_7	$P_2 \times P_4$ (H×L)	P_2	$P_2 \times P_4$	E_1	P_2	$P_2 \times P_4$	P_2	$P_3 \times P_7$ (L×L)
	P_2	$P_2 \times P_4$	P_4	$P_2 \times P_5$ (H×L)		P_1	$P_1 \times P_4$ (L×L)	P_1	$P_3 \times P_6$		P_4	$P_2 \times P_5$	P_4	$P_1 \times P_4$ (H×H)
	P_7	$P_2 \times P_5$	P_7	$P_2 \times P_4$ (L×H)		P_2	$P_1 \times P_8$ (H×L)	P_7	$P_2 \times P_6$		P_7	$P_1 \times P_4$	P_1	$P_2 \times P_5$ (H×L)
	P_1	$P_1 \times P_2$	P_1	$P_3 \times P_7$ (H×H)		P_4	$P_4 \times P_7$ (H×L)		$P_1 \times P_4$		P_5	$P_1 \times P_2$		$P_3 \times P_9$ (L×L)
E_2	P_4	$P_2 \times P_4$	P_2	$P_1 \times P_4$ (L×H)	E_2	P_2	$P_1 \times P_4$ (L×L)	P_7	$P_6 \times P_8$	E_2	P_4	$P_6 \times P_8$	P_2	$P_6 \times P_8$ (L×L)
	P_2	$P_1 \times P_4$	P_4	$P_2 \times P_5$ (H×L)	`	P_4	$P_2 \times P_5$ (H×H)	P_4	$P_1 \times P_4$		P_2	$P_1 \times P_4$	P_4	$P_3 \times P_9$ (L×L)
	P_1	$P_2 \times P_5$	P_7	$P_2 \times P_4$ (H×H)		P_1	$P_6 \times P_8$ (H×L)	P_2	$P_2 \times P_5$		P_7	$P_2 \times P_4$	P_7	$P_1 \times P_4$ (L×H)
	P_7	$P_1 \times P_2$		$P_3 \times P_8$ (L×L)		P_7	$P_2 \times P_4$ (L×L)	P_1	$P_6 \times P_9$		P_1	$P_3 \times P_7$		$P_5 \times P_8$ (L×L)

Table 3. Continued.

Env	*Per se* performance Parents	F$_1$	GCA	SCA	Env	*Per se* performance Parents	F$_1$	GCA	SCA	Env	*Per se* parformance Parents	F$_1$	GCA	SCA
	Characters: Fruit weight					Character: Dry matter of fruit					Character: Marketable fruit yield per plant			
E_3	P_4	$P_2×P_4$	P_2	$P_2×P_5$ (H×L)	E_3	P_2	$P_2×P_4$	P_2	$P_2×P_5$ (H×L)	E_3	P_2	$P_2×P_4$	P_2	$P_5×P_8$ (L×L)
	P_2	$P_1×P_4$	P_4	$P_1×P_4$ (H×H)		P_4	$P_2×P_5$	P_4	$P_5×P_7$ (L×L)		P_4	$P_1×P_2$	P_4	$P_1×P_4$ (L×H)
	P_1	$P_2×P_5$	P_1	P_2P_4 (H×H)		P_1	$P_1×P_4$	P_8	$P_6×P_9$ (H×L)		P_7	$P_1×P_4$	P_7	$P_3×P_9$ (L×L)
	P_7	$P_1×P_2$	P_7	$P_3×P_8$ (L×L)		P_6	$P_1×P_6$		$P_1×P_4$ (L×H)		P_1	$P_5×P_8$		$P_2×P_5$ (H×L)
E_4	P_2	$P_2×P_4$	P_4	$P_3×P_4$ (L×H)	E_4	P_2	$P_2×P_4$	P_4	$P_7×P_9$ (L×L)	E_4	P_2	$P_5×P_4$	P_4	$P_3×P_4$ (L×H)
	P_4	$P_1×P_4$	P_2	$P_2×P_5$ (H×L)		P_4	$P_2×P_5$	P_2	$P_3×P_4$ (L×H)		P_4	$P_2×P_4$	P_2	$P_2×P_5$ (H×L)
	P_1	$P_3×P_4$	P_1	$P_1×P_4$ (H×H)		P_1	$P_3×P_4$	P_8	$P_2×P_5$ (H×L)		P_1	$P_1×P_4$	P_1	$P_1×P_4$ (H×H)
	P_8	$P_2×P_5$		$P_2×P_4$ (H×H)		P_9	$P_7×P_9$		$P_8×P_9$ (H×L)		P_8	$P_2×P_5$		$P_1×P_2$ (H×H)

and E_4, $P_5× P_7$ in E_3 and E_4, $P_3× P_8$ and E_4, $P_3×P_8$ in E_2 and $P_4×P_5$ each in E_2 and E_4, $P_5×P_6$ in E_2 in E_1 and E_3 and $E_{4,}$ P_3 $×P_4$ and $P_7×P_9$ each in E_1 and E_3 and $P_4×P_6$ and $P_4×P_6$ and $P_7×P_8$ in E_1 and E_2 exhibibited significant positive SCA effects, hence considered as desirable for fruit diameter. A total of thirteen crosses each in E_1 and E_3, fifteen in E_2 and tweleve in E_4 showed significant positive SCA effect for fruit weight. The crosses $P_1×P_2$, $P_1×P_4$, $P_2×P_4$, $P_2×P_5$, $P_3×P_7$, $P_3×P_8$, $P_5×P_9$, $P_6×P_9$, $P_5×P_7$ (except E_1), $P_6×P_8$ (except E_1), $P_3×P_9$ (except in E_4), $P_6×P_7$) (except in E_4), $P_1×P_8$ (except E_2 and E_3) and $P_3×P_6$ (except E_3 and E_4) exhibited significant positive SCA effects in all the environments, hence considered to be desirable for induction of fruit weight. A total of eleven crosses in E_1, 13 each in E_2 and E_3 and 10 crosses in E_4 showed significant positive SCA effect for high dry matter of fruit. The crosses viz., $P_1×P_4$ in all the environments; $P_1×P_2$, $P_2×P_5$ and $P_6×P_9$ in E_2, $E_3$and E_4; $P_8×P_9$ in E_1, E_2 and E_4 ; $P_2×P_4$, $P_3×P_8$ and $P_5×P_7$ in E_1, E_2 and E_3; $P_7×P_9$ in E_2 and E_4, $P_7×P_8$ in E_2 and E_3; $P_1×P_8$ in E_1 and E_4; $P_3×P_6$ and $P_3×P_7$ in E_1 and E_3 and $P_4×P_7$ and $P_5×P_8$ in E_1 and E_2, exhibited significant positive SCA effects, thus might be useful for high dry matter of fruit. A total of thirteen crosses in E_1, nine in E_2, twelve in E_3 and thirteen in E_4 showed significant positive SCA effect for higher total fruits yield per plant. The crosses $P_1×P_2$, $P_1×P_4$, $P_2×P_4$, $P_2×P_5$, $P_3×$GP7, $P_3×P_9$ and $P_5×P_8$ in all the environments, $P_3×P_8$ and $P_5 × P_7$ in E_1,E_3 and E_4, $P_6×P_9$ in E_2, E_3 and E_4, $P_1×P_8$ in E_1 and E_4 and $P_6×P_8$ in E_2 and E_4 exhibited significant positive SCA effects, hence desirable for higher total fruits yield per plant. The results obtained in the present study are in conformity with the earlier findings of Bhakta et al. [1]. Singh et al. [5] and Choudhary and Didel [6]. All the crosses were ranked on the basis of their SCA effects and *per se* performance for individual character. The revealed that top four crosses selected on the basis of their SCA effects also had, in general, high *per se* performance in most of the cases. These results are in agreement with Mishra et al. [14]

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