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Short communication

Gene action and combining ability analysis in brinjal (*Solanum melongena* L.)

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ABSTRACT

Combining ability analysis in brinjal genotypes indicated significant genotypic and environmental variations for all the 15 characters studied. Both general combining ability (GCA) and specific combining ability (SCA) variances showed significant interactions. Genotypes Palamedu Local (L_5), Alagarkovil Local (L_4), Melur Local (L_6) and Annamalai (T_1) were found to be good general combiners, and the crosses L_3 x T_3 (Kariapatty Local x Punjab Sadabahar), L_8 x T_1 (Nilakottai Local x Annamalai), L_4 x T_1 (Alagarkovil Local x Annamalai), L_6 x T_2 (Melur Local x KKM 1), L_7 x T_3 (Keerikai Local x Punjab Sadabahar) and L_7 x T_2 (Keerikai Local x KKM 1) were identified as good specific combiners for fruit yield and other related traits. These hybrid combinations can be used for commercial exploitation for fruit yield in brinjal.

Key words: Brinjal, gene action, combining ability, GCA and SCA

Egg plant or brinjal (*Solanum melongena* L.) is an important, highly productive vegetable crop and is often referred to as the poor man's crop (Bindu *et al*, 2004). Heterosis breeding is an efficient approach in crop improvement, and selection of parental lines is very important in developing hybrids for commercialization. A knowledge of combining ability helps identify the best combiners, aids heterosis breeding or to accumulate fixable genes through selection. Such information forms the backbone of any breeding programme. Among the various methods, Line X Tester analysis provides information on the combining ability of genotypes.

Combining ability effects rank among the important parameters commonly used by plant breeders to evaluate genetic potential of the material being handled by them. Dhillion (1975) opined that combining ability of parents gave useful information on making the choice of parents in terms of expected performance of their hybrids and progenies. The *gca* effect is considered as an intrinsic genetic value of the parent for a trait, which is due to additive genetic effects and is fixable (Simmonds, 1979). Singh and Hari Singh (1985) suggested that parents with high *gca* tend to produce transgressive segregants in F_2 or later generations. Gravios and McNew (1993) reported that if additive gene action was predominant in a self-pollinated species, the breeder could effectively select various levels of inbreeding, because additive effects are readily transmissible from one generation to another. In view of this, we undertook combining ability analysis using ten lines and four testers.

The experimental material comprised of 40 F_1s and 14 parents (10 lines and 4 testers) which were evaluated, during 2010-2011 in RBD, with three replications, at College Orchard, Agricultural College and Research Institute, Madurai which is situated at 9°5 latitude and 78°5 longitude and at an elevation of 147m above MSL. Cultural practices were followed as per the package of practices in TNAU Crop Production Guide (2005) with plants spaced at 60cm x 60cm. Observations were recorded in five plants selected randomly in each genotype. Data were recorded for 15 biometrical traits viz., plant height, days to first flowering, number of branches per plant, fruit length, fruit pedicel length, fruit circumference, calyx length, number of fruits per plant, average fruit weight, shoot borer infestation, fruit borer infestation, little leaf incidence, ascorbic acid content, total phenol content and fruit yield per plant in 14 parents and 40 hybrids. This data was used for estimating combining ability. Combining ability analysis was computed as per Kempthorne (1957). Parents/hybrids that showed negative and significant *gca* effects were considered for days to first flowering, fruit length, calyx length, shoot and fruit borer

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Table 1. Analysis of Variance for parents and hybrids for 15 characters

Source	df	PH	DFF	NB/ P	FL	FPL	FC	CL
Hybrids	39	346.5306*	54.8730*	17.4039*	5.4570*	1.4005*	9.9952*	1.0970*
Lines	9	973.0851*	76.5412*	40.2728*	4.9768*	2.1125*	20.0498*	2.5695*
Testers	3	66.6626*	17.7451*	12.1612*	9.7032*	0.4415*	16.6776*	0.5407*
Line x Testers	27	168.7756*	51.7756*	10.3635*	5.1453*	1.2698*	5.9011*	0.6680*
Errors	78	85.0412	3.3519	4.3914*	0.0933	0.0216	0.4478	0.0424

Source	df	NF/P	AFW	SBI	FBI	LLI	ACC	TPC	FY/P
Hybrids	39	161.9557*	149.5525*	54.4746*	63.3535*	69.4393*	12.9752*	533.5026*	0.6288*
Lines	9	197.8137*	328.0857*	104.8571*	80.0248*	128.8896*	24.3787*	998.8697*	0.9020*
Testers	3	234.2205*	72.4168*	41.9781*	34.1338*	70.4679*	33.1344*	55.7529*	0.4214*
Line x Testers	27	141.9736*	98.6121*	39.0689*	61.0430*	49.5083*	6.9342*	431.4635*	0.5608*
Errors	78	1.8176	4.0138	0.9524	2.1378	0.8543	0.1632	4.1422	0.0100

*Significant at 5% level

PH - Plant height (cm)
DFF - Days to first flowering
NB/P - Number of branches per plant
FL - Fruit length (cm)
FPL - Fruit pedicel length (cm)
FC - Fruit circumference (cm)
CL - Calyx length (cm)
NF/P - Number of fruits per plant
AFW - Average fruit weight (g)
SBI - Shoot borer infestation (%)
FBI - Fruit borer infestation (%)
LLI - Little leaf incidence (%)
ACC - Ascorbic acid content (mg/100g)
TPC - Total phenol content (mg/100g)
FY/P - Fruit yield per plant (kg)

infestation and little leaf incidence; while, for the other traits, parents /hybrids with positively significant *gca* effects were taken into consideration. Combining ability analysis was carried out using TNAUSTAT software package.

Analysis of Variance revealed highly significant differences among all parents and hybrids for all the characters studied, indicating the presence of considerable amount of genetic variability (Table 1). Hybrids vs Parents comparison was significant for all the traits, revealing occurrence of heterotic effects. Knowledge of relative importance of additive and non-additive gene action is essential to the plant breeder for developing an efficient hybridization programme. Panse (1942) suggested that if additive genetic variance was greater, the chance of fixing superior genotypes in early-segregating generation would be greater; whereas, if dominant and epistatic interactions were predominant, selection should be postponed to a later generation, and appropriate breeding techniques should be applied to obtain a useful genotype. From an analysis of the combining ability estimates, it was seen that non-additive gene action operated for all the characters in our study, as, variance due to general combining ability (GCA) and specific combining ability (SCA) was highly significant (Table 2). Further, it was observed that variance due to SCA was higher in magnitude than GCA for all the traits studied. Thus, it supports predominance of non-additive gene effects on governing the expression of most of the characters.

These results are in accordance with Prabhu (2005), Muthulakshmi (2007) and Prakash (2008) for plant height; Indiresh *et al* (2005) for days to first flowering; Prakash (2008) for number of branches per plant; Suneetha (2006), Muthulakshmi (2007) and Prakash (2008) for number of fruits per plant; Muthulakshmi (2007) for average fruit

Table 2. Magnitude of Variance for yield components

Character	*GCA* variance	*SCA* variance	δ^2A	δ^2D	Ratio of δ^2A: δ^2D
Plant height (cm)	67.02	98.15	2.91	98.15	0.02
Days to first flowering	2.06	14.97	0.20	14.97	0.01
Number of branches per plant	4.52	17.34	0.26	17.34	0.01
Fruit length (cm)	-0.01	2.15	0.05	2.15	0.02
Fruit pedicel length (cm)	0.07	0.41	0.03	0.41	0.07
Fruit circumference (cm)	1.17	4.40	0.06	4.40	0.01
Calyx length (cm)	0.15	0.38	0.007	0.38	0.01
Number of fruits per plant	11.80	62.29	0.75	62.29	0.01
Average fruit weight (g)	19.12	51.88	0.83	51.88	0.01
Shoot borer infestation (%)	5.48	19.66	0.25	19.66	0.01
Fruit borer infestation (%)	1.58	18.65	0.03	18.65	1.60
Little leaf) incidence (%	6.61	26.49	0.32	26.49	0.01
Ascorbic acid content (mg/100g)	1.45	6.84	0.09	6.84	0.01
Total phenol content (mg/100g)	47.28	159.27	1.67	159.27	0.01
Fruit yield per plant (kg)	0.02	0.20	0.02	0.20	0.10

Table 3. General combining ability effects of parents

Parent	Plant height (cm)	Days to first flowering	Number of branches per plant	Fruit length (cm)	Fruit pedicel length (cm)	Fruit circum-ference (cm)	Calyx length (cm)	Number of fruits per plant	Average fruit weight (g)	Shoot borer infestation (%)	Fruit borer infestation (%)	Little leaf incidence (%)	Ascorbic acid content (mg/100g)	Total phenols content (mg/100g)	Fruit yield per plant (kg)
								LINES							
L_1	11.29**	1.30*	0.24	0.31**	-0.11*	1.78**	-0.18**	-4.73**	6.34**	-3.33**	-0.40	1.38**	2.90**	-4.95**	-0.07*
L_2	13.92**	3.14**	-2.87**	0.25**	-0.42**	-0.48*	-0.32**	2.10**	-0.98	0.38	-2.45**	0.74**	0.35**	-4.66**	0.07*
L_3	6.51*	3.19**	-2.23**	-0.27**	0.38**	-2.08**	0.59**	-6.12**	-4.74**	-5.91**	1.26**	-2.73**	0.51**	1.94**	-0.45**
L_4	1.14	-3.16**	-0.35	0.53**	0.28**	-1.31**	0.63**	4.53**	2.20**	0.81**	-1.86**	-4.71**	-0.41**	8.96**	0.30**
L_5	-7.68**	-2.16**	3.53**	-0.07	0.39**	1.79**	0.38**	8.13**	4.17**	-0.67*	-0.76	-3.61**	-0.46**	0.64	0.43**
L_6	-9.69**	-3.48**	3.03**	-0.25**	0.41**	0.69**	0.39**	-0.21	-1.05	-1.20**	0.25	-2.77**	-0.17	5.87**	-0.04
L_7	5.36*	-1.03	2.26**	-0.04	-0.80**	-0.55**	-0.46**	-2.57**	5.48**	0.58*	-1.28**	1.67**	0.19	18.28**	0.06*
L_8	-2.20	1.52**	-0.12	1.26**	-0.41**	-0.91**	-0.68**	4.47**	-10.28**	3.01**	3.36**	2.44**	-1.57**	-11.06**	0.03
L_9	-7.83**	-1.29*	0.66	-0.64**	0.23**	0.16	-0.27**	0.41	-3.95**	3.62**	5.03**	2.02**	1.01**	-10.24**	-0.06*
L_{10}	-10.83**	1.97**	-4.13**	-1.08**	0.05	0.89**	-0.07	-6.03**	2.80**	2.71**	-3.16**	5.57**	-2.35**	-4.77**	-0.27**
SE	2.66	0.52	0.49	0.08	0.04	0.19	0.05	0.39	0.57	0.28	0.42	0.26	0.11	0.58	0.02
								TESTERS							
T_1	1.54	-0.96**	1.32**	-0.71**	-0.02	0.86**	-0.07	1.44**	0.11	0.52**	-0.68*	0.56**	1.14**	-0.48	0.11**
T_2	-2.01	-0.17	1.34**	0.08	-0.15**	-0.05	-0.15**	3.43**	-0.78*	1.29**	-0.51	-0.10	-0.07	0.34	0.15**
T_3	0.48	0.26	-1.05**	-0.05	0.02	-0.95**	0.14**	-4.13**	2.12**	-0.34	1.59**	-2.05**	0.31**	-1.54**	-0.17**
T_4	-0.01	0.86*	-1.61**	0.68**	0.15**	0.14	0.08*	-0.74**	-1.46**	-1.47**	-0.41	1.59**	-1.38**	1.69**	-0.09**
SE	1.68	0.33	0.31	0.05	0.02	0.12	0.03	0.25	0.36	0.17	0.26	0.16	0.07	0.37	0.01

** Significant at 1% level   * Significant at 5% level

Table 4. Specific combining ability effects of hybrids

Hybrid	PH	DFF	NB/ P	FL	FPL	FC	CL	NF/P	AFW	SBI	FBI	LLI	ACC	TPC	FY/P
$L_1 \times T_1$	-13.03*	-2.80**	2.62*	0.17	-0.12	-1.46**	-0.36**	6.95**	8.88**	4.91**	-1.34	2.07**	-0.37	1.57	0.71**
$L_1 \times T_2$	-2.48	-0.08	-0.07	-0.29	-0.36**	1.02**	-0.13	-5.98**	-5.01**	-2.78**	1.27	-3.57**	-0.20	-2.65*	-0.46**
$L_1 \times T_3$	-2.68	1.58	-1.36	-0.25	0.79**	0.96*	0.53**	-2.55**	3.25**	-4.11**	1.50	-3.02**	0.74**	3.09*	-0.13*
$L_1 \times T_4$	18.19**	1.30	-1.19	0.37*	-0.31**	-0.52	-0.04	1.58*	-7.12**	1.98**	-1.43	4.52**	-0.16	-2.01	-0.12*
$L_2 \times T_1$	13.08*	2.82**	-1.51	1.42**	-0.33**	2.28**	0.06	7.54**	-5.21**	-0.67	4.02**	2.01**	-0.68**	10.98**	0.16**
$L_2 \times T_2$	-5.44	-2.98**	-0.91	-1.29**	-0.11	-0.62	0.22	-11.26**	2.01	5.59**	-0.35	-0.12	0.88**	18.87**	-0.52**
$L_2 \times T_3$	0.13	4.10**	0.54	-0.39*	-0.14	-0.82*	0.08	7.02**	2.60*	-2.19**	-0.99	-3.89**	-0.97**	13.72**	0.51**
$L_2 \times T_4$	-7.77	-3.94**	1.88	0.26	0.58**	-0.83*	-0.37**	-3.32**	0.60	-2.74**	-2.69**	2.00**	0.77**	-21.61**	-0.15**
$L_3 \times T_1$	8.55	4.48**	1.59	0.32	-0.76**	0.53	-0.66**	6.03**	-5.95**	1.44*	-1.19	-0.31	0.02	9.34**	0.06
$L_3 \times T_2$	0.34	5.67**	-0.58	-0.11	-0.42**	-0.04	-0.26*	-6.94**	-4.12**	-2.49**	4.04**	-0.24	-2.01**	-9.39**	-0.43**
$L_3 \times T_3$	-3.44	-4.44**	-2.11*	0.47**	-0.15	-0.21	0.06	6.42**	10.53**	-2.39**	-3.97**	-3.91**	0.72 **	7.77**	0.63**
$L_3 \times T_4$	-5.46	-5.71**	1.11	-0.68**	1.32**	-0.28	0.87**	-5.52**	-0.47	3.43 **	1.12	4.46**	1.26**	-7.72**	-0.27**
$L_4 \times T_1$	1.83	-1.28	3.37**	-0.30	-0.17*	1.79**	0.25*	3.08**	4.52**	-7.04 **	3.76**	-2.05**	-0.79**	4.09**	0.26**
$L_4 \times T_2$	-3.15	-1.31	2.32*	-0.09	-0.54**	0.75	0.08	4.03**	-2.86*	-1.11	1.54	-1.48**	1.64**	-0.08	0.14*
$L_4 \times T_3$	3.92	1.76	-3.52**	-1.43**	-0.00	-0.69	-0.64**	-4.31**	-5.02**	5.40 **	-2.93**	4.35**	-0.47 *	-4.18**	-0.37**
$L_4 \times T_4$	-2.59	0.83	-2.15*	1.81**	0.72**	-1.85**	0.31*	-2.81**	3.36**	2.76 **	-2.37**	-0.82	-0.38	0.18	-0.03
$L_5 \times T_1$	-2.62	-2.13*	-3.90**	-0.05	-0.02	-0.50	-0.20	-11.37**	7.78**	-0.77	-5.82**	3.56**	2.09**	-9.24**	-0.56**
$L_5 \times T_2$	-0.44	0.44	0.03	-0.42*	-0.31**	-0.95*	-0.47**	0.98	2.17	0.97	0.32	4.43**	-0.70**	4.76**	0.04
$L_5 \times T_3$	7.13	3.88**	2.11*	0.03	-0.01	1.12**	0.89**	6.31**	-4.33**	0.13	-3.64**	-3.53**	-1.04**	-5.68**	0.38**
$L_5 \times T_4$	-4.07	-2.20*	1.81	0.43*	0.34**	0.33	-0.22	4.04**	-5.62**	-0.32	9.14**	-4.45**	-0.35	10.16**	0.14*
$L_6 \times T_1$	4.25	2.59*	-3.47**	-1.49**	0.96**	-0.46	-0.24*	-4.57**	-1.49	2.99**	2.82**	-6.30**	2.63**	-16.57**	-0.32**
$L_6 \times T_2$	1.94	-1.56	1.97*	3.50**	0.67**	-0.90*	0.58**	4.85**	3.72**	-4.26**	-6.05**	0.21	-1.15**	0.85	0.41**
$L_6 \times T_3$	-14.13**	-1.06	0.91	-0.20	-0.64**	-0.80*	0.21	-2.13**	-1.67	3.46 **	6.15**	4.74**	-1.12**	3.35**	-0.16**
$L_6 \times T_4$	7.94	0.03	0.59	-1.81**	-0.99**	2.17**	-0.55**	1.85*	-0.56	-2.18**	-2.91**	1.35*	-0.38	12.37**	0.07
$L_7 \times T_1$	-5.83	4.52**	-2.08 *	-0.48**	0.16	-0.23	0.29*	-10.8**	-3.11**	1.48 *	3.27**	1.40*	-0.01	4.12**	-0.77**
$L_7 \times T_2$	4.19	1.11	1.74	1.03**	0.73**	1.69**	-0.19	8.24**	10.71**	0.74	-1.19	-4.24**	-1.64**	5.06**	0.91**
$L_7 \times T_3$	5.42	-6.12**	-0.66	-0.99**	-0.25**	0.96*	-0.46**	1.13	-7.17**	-1.28 *	-1.86*	6.59**	1.99**	-10.10**	-0.18**
$L_7 \times T_4$	-3.78	0.48	1.00	0.45*	-0.64**	-2.42**	0.36**	1.46	-0.43	-0.94	-0.22	-3.75**	-0.34	0.92	0.04
$L_8 \times T_1$	-1.24	-8.00**	3.45**	-0.50**	0.35**	-0.74	0.16	1.67*	-1.86	4.76 **	10.69**	-1.39*	-2.05**	3.32**	0.39**
$L_8 \times T_2$	-4.85	1.00	-0.39	-2.26**	0.58**	-1.10**	-0.11	4.86**	-0.27	0.55	4.82**	1.28*	3.03**	-8.37**	-0.24**
$L_8 \times T_3$	2.72	-2.46*	1.20	2.67**	-0.84**	0.10	-0.21	-0.97	-5.07**	-1.15 *	6.32**	-3.07**	-0.91 **	5.97**	-0.54**
$L_8 \times T_4$	3.38	9.46**	-4.26**	0.08	-0.09	1.74**	0.16	-6.66**	7.20**	-4.16 **	-0.45	3.18**	-0.07	-0.92	0.39**
$L_9 \times T_1$	-2.85	1.63	4.08**	0.03	-0.26**	-1.19**	0.44**	5.95**	-3.58**	-4.54**	2.34**	2.94**	1.05**	-11.79**	0.51**
$L_9 \times T_2$	7.38	-0.74	-4.69**	-0.56**	0.01	-1.26**	0.00	9.17**	-2.48*	3.17**	-1.76*	-0.30	0.50 *	-5.28**	-0.08
$L_9 \times T_3$	-1.04	2.59*	1.11	0.65**	0.84**	0.69	-0.57**	1.06	4.18**	2.00 **	1.42	3.65**	0.36	-1.16	-0.27**
$L_9 \times T_4$	-3.49	-3.49**	-0.49	-0.12	-0.59**	1.76**	0.13	-6.60**	1.87	-0.63	-2.00*	-6.29**	-1.90**	18.23**	-0.16**
$L_{10} \times T_1$	-2.13	-1.84	-4.09**	0.88**	0.18*	-0.01	0.25*	-3.63**	0.02	-2.55**	2.83**	-1.92**	-1.95**	26.14**	-0.45**
$L_{10} \times T_2$	2.51	-1.56	0.58	0.48**	-0.25**	1.43**	0.30*	-7.73**	-3.89**	-0.38	-2.64**	4.04**	-0.35	-3.78**	0.24**
$L_{10} \times T_3$	1.95	0.16	1.81	-0.57**	0.41**	-1.32**	0.10	5.97**	2.70*	0.12	-2.00*	-1.91**	0.75**	-12.77**	0.14*
$L_{10} \times T_4$	-2.33	3.23**	1.70	-0.79**	-0.34**	-0.10	-0.65**	1.37	1.17	2.80 **	1.80*	-0.21	1.55**	-9.59**	0.08
SE	5.32	1.05	1.20	0.17	0.08	0.38	0.11	0.77	1.15	0.56	0.84	0.53	0.23	1.17	0.05

*Significant at 5% level, **Significant at 1% level

NF/P - Number of fruits per plant
AFW - Average fruit weight (g)
SBI - Shoot borer incidence (%)
FBI - Fruit borer incidence (%)
LLI - Little leaf incidence (%)
ACC - Ascorbic acid content (mg/100g)
TPC - Total phenol content
FY/P - Fruit yield per plant (kg) (mg/100g)
PH - Plant height (cm)
DFF - Days to first flowering
NB/P - Number of branches per plant
FL - Fruit length (cm)
FPL - Fruit pedicel length (cm)
FC - Fruit circumference (cm)
CL - Calyx length (cm)

weight; Prasath (1997) for ascorbic acid content; and, Jerard (1996) and Suneetha (2006) for fruit yield per plant.

General combining ability estimates are presented in Table 3. In the present study, the line L_5 (Palamedu Local) was adjudged as the best general combiner, since, it expressed significant GCA effects for nine traits, viz., days to first flowering, number of branches per plant, fruit pedicel length, fruit circumference, number of fruits per plant, average fruit weight, shoot borer infestation, little leaf incidence and fruit yield per plant. This was followed by L_4 (Alagarkovil Local) which showed good general combining ability for the traits days to first flowering, fruit pedicel length, number of fruits per plant, average fruit weight, fruit borer infestation, little leaf incidence, total phenol content and fruit yield per plant. Among the lines, Alavayal Local (L_1) and Sedapatty Local Green (L_2) were also good general combiners, because of having high GCA values for seven characters.

Among the testers, T_1 (Annamalai) was adjudged as a good general combiner, as, it showed significantly favourable *gca* effect for days to first flowering, number of branches per plant, fruit length, fruit circumference, number of fruits per plant, fruit borer infestation, ascorbic acid content and fruit yield per plant. From the above information, it is inferred that Palamedu Local (L_5), Alagarkovil Local (L_4), Melur Local (L_6) and Annamalai (T_1), among parents, were found to be the best general combiners, since these expressed good GCA effects for a majority of the traits (including growth, yield and quality characters).

Estimates for specific combining ability are given in Table 3. Sprague and Tatum (1942) reported that specific combining ability was due to non-additive gene action. SCA effect of hybrids have been attributed to a combination of positive, favourable genes from different parents or due to presence of linkage in repulsion phase (Sarsar *et al*, 1986). Therefore, selection of hybrids based on SCA effects would excel in heterotic effect. In the present study, hybrid L_3xT_3 (Kariapatty Local x Punjab Sadabahar) excelled, with superior SCA effect for nine characters, viz., days to first flowering, number of fruits per plant, average fruit weight, shoot and fruit borer infestation, little leaf incidence, ascorbic acid content, total phenol content and fruit yield per plant.

The crosses, L_8 x T_1 and L_4 x T_1, were the next best specific combiners for eight traits each. These were followed by L_6 x T_2, L_{10} x T_3, L_7 x T_3 and L_7 x T_2, which were identified as specific combiners for seven traits each. In general, among the 40 hybrids studied, hybrids L_3 x T_3 (Kariapatty Local x Punjab Sadabahar), L_8 x T_1, (Nilakottai Local x Annamalai), L_4 x T_1 (Alagarkovil Local x Annamalai), L_6 x T_2 (Melur Local x KKM 1), L_7 x T_3 (Keerikai Local x Punjab Sadabahar) and L_7 x T_2 (Keerikai Local x KKM 1) were good specific combiners for a majority of growth and yield attributing characters, including fruit yield.

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