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Combining ability and gene action for structural and economical traits in brinjal (*Solanum melongena*)

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ABSTRACT

An experiment was undertaken to estimate GCA for 8 parents and SCA for 15 hybrids in brinjal (*Solanum melongena* L.) through line × tester analysis. The combining ability analysis revealed highly significant differences among the treatments for all the characters. The *gca* reveals that, parental lines L_2 (IC- 433678), L_5 (Raidurg Local) and T_3 (Pusa Purple Cluster) were identified as good general combiners for fruit yield per plant. These lines and testers were also best combiner for yield component characters like number of primary branches per plant, days to first flower, medium and long styled flowers, fruits per plant and fruit length. The estimates of specific combining ability effects indicated that cross combinations, viz. IC-433678 × IC-89986, Tiptur Local × Vellayani Local, Jagaluru Local × Vellayani Local, IC-345271 × Pusa Purple Cluster and Raidurg Local × Pusa Purple Cluster were most promising for fruit yield per plant and its component attributes. Gene action analysis revealed preponderance of both additive and nonadditive gene actions for yield and its contributing characters.

Keywords: Brinjal, GCA, Gene action, SCA

Brinjal (*Solanum melongena* L.) belongs to the family *Solanaceae,* has chromosome number of 2n=24. It is an important crop in the tropical regions of world and being grown extensively in India, Bangladesh, Pakistan, China and Philippines. It is also popular in Egypt, France, Italy and United States. In India, it is one of the most common, popular and principal vegetable crop grown throughout the country. It is a versatile crop adapted to different agro-climatic regions and can be grown throughout the year. It is a perennial but grown commercially as an annual crop. Brinjal has several ayurvedic medicinal properties and is good for diabetic patients. It has also been recommended as an excellent remedy for those suffering from liver complaints (Shukla and Naik 1993). In brinjal, preference of colour and shape of the fruits varies from one region to another region, it is quite impossible to have one common cultivar to suit different localities and local preferences. Therefore, it is very important to breed a variety or hybrid with preferable shape, colour along with high yield and adaption to different agro-climatic conditions. Now, these fruit characteristics are most desirable objectives for the brinjal breeders in our country as well as world.

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General and specific combining ability effects and variances obtained from a set of F_1's would enable a breeder to select desirable parents and crosses for each of the quantitative components. Line × Tester is a mating design whereby the selected parents are crossed in a certain order to predict the combining ability of the parents and elucidate the nature of gene action involved in the inheritance of the traits (Abhinav and Nandan 2010). Nature of gene action as measured by GCA and SCA variances is particularly useful in deciding the inheritance of character and thereby selection of a suitable breeding programme. Therefore, the present study was undertaken to find out gene action as well the best general combiners and specific combiners for yield and yield contributing traits by using the line × tester mating design.

MATERIALS AND METHODS

The experiment was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram (KAU, Thrissur) during 2017. The experimental site (Vellayani) was located at 8° 5' N latitude and 77° 1' E longitude at an altitude of 29 m amsl. The experimental material consisted of 8 parental lines (five lines as a female and three lines as testers). A total of 15 F_1 hybrids were developed by crossing eight parents in Line × Tester fashion. The experiment was laid out in randomized block design with 23 treatments and one standard check (Haritha) in three replications. Thirty five days old seedlings having 8-10 cm height were transplanted

Table 1 Analysis of variance for combining ability (L × T) for yield and yield components in brinjal

Source of variation	DF	Plant height (cm)	Primary branches/ plant	Days to first flower	Medium styled flower (%)	Long styled flowers (%)	Short styled flowers (%)	No. of fruits/ plant	Length of fruit (cm)	Girth of fruit (cm)	Fruit weight (g)	Days to first harvest	Days to last harvest	Fruit yield/ plant (kg)
Analysis of variance for combining ability (L x T)														
Replicates	2	6.346*	0.12	0.353	2.37	2.7	0.45	1.16	0.001	0.22	3.2	0.12	2.36	0.015
Treatments	22	665.2**	6.63**	64.1**	65.5**	70.6**	16.4**	276**	51.6**	39.5**	2753**	103.6**	161**	3.47**
Parents	7	560.9**	2.70**	46.4**	25.1**	33.3**	3.99*	67.9**	65.3**	59.3**	4709**	24.2**	32.6**	0.59**
Parents (line)	4	291.1**	0.95**	60.8**	28.0**	41.4	4.96*	43.3**	19.7**	26.6**	2489**	35.0**	33.1**	0.04
Parents (Testers)	2	1248**	5.67**	3.87**	24.1**	15.3*	1.08	147**	138**	152**	11241**	1.21	33.9**	0.11**
Parents (L vs T)	1	264.9**	3.78**	73.9**	15.6*	36.8**	5.93	7.02**	102**	4.5**	528**	26.7**	28.1**	3.77**
Parents vs Crosses	1	4939**	37.26**	251**	298.2**	1.3	274.6**	1560**	46.7**	30.6**	5254**	467.0**	1263**	11.11**
Crosses	14	412.0**	6.40**	59.7**	69.1**	94.2**	4.27**	289**	45.0**	30.2**	1597**	117.4**	146**	4.37**
Line effect	4	883.53	8.93	36.1	100.1	160.7	8.17	452.7	97.6**	25.6	3779*	103.6	143.4	3.97
Tester effect	2	72.04	8.79	287**	132.9	157.6	2.36	426.3	75.0*	122**	1271.3	468.6**	485.4*	13.50*
Line × Tester effect	8	261.3**	4.54**	14.5**	37.6**	45.2**	2.8	174**	11.2**	9.5**	587**	36.5**	63.4**	2.28**
Error	44	1.792	0.11	0.39	2.7	3.5	1.58	0.61	0.13	0.1	2.8	0.41	1.13	0.019
Total	68	216.57	2.22	21	23	25.2	6.36	90	16.7	12.9	892.9	33.81	52.9	1.13
Combining ability variances														
σ^2gca		39.67	0.73	13.46	9.48	12.97	0.31	36.58	7.19	6.15	161.40	23.81	26.11	0.73
σ^2sca		86.52	1.48	4.71	11.64	13.88	0.41	57.80	3.71	3.11	194.97	12.05	20.78	0.76
σ^2gca/σ^2sca		0.46	0.49	2.85	0.82	0.93	0.76	0.63	1.94	1.98	0.83	1.98	1.26	0.96

Table 2 Estimates of combining ability effects of parents and hybrids

Parents	Plant height (cm)	Primary branches/ plant	Days to first flower	Medium styled flower (%)	Long styled flowers (%)	Short styled flowers (%)	No. of fruits/ plant	Length of fruit (cm)	Girth of fruit (cm)	Fruit weight (g)	Days to first harvest	Days to last harvest	Fruit yield/ plant (kg)
General combining ability effects parents													
$Line_1$	-13.81**	-0.993**	2.080**	0.078	-0.547	0.469	-8.42**	-4.40**	-0.90**	-29.44**	2.811**	3.438**	-0.63**
$Line_2$	11.83**	1.518**	-1.631**	-3.356**	4.587**	-1.23**	9.120**	4.573**	-2.29**	-0.551	-4.67**	-4.65**	0.771**
$Line_3$	-4.169**	-0.793**	2.302**	3.322	-3.74**	0.424	-3.59**	0.518**	-0.049	-5.662**	3.733**	4.571**	-0.73**
$Line_4$	-0.502	0.051	-1.364**	3.311**	-4.39**	1.080*	-2.42**	-1.48**	1.773**	9.304**	-0.389	-0.307	0.144**
$Line_5$	6.653**	0.218	-1.387**	-3.356**	4.098**	-0.742	5.320**	0.796**	1.473**	26.349**	-1.47**	-3.05**	0.456**
$Tester_1$	-0.698	-0.331**	0.429*	2.758**	-2.77**	0.020	-0.122	-1.96**	3.271**	10.629**	0.300	0.191	-0.54**
$Tester_2$	2.456**	-0.544**	4.149**	0.398	-0.784	0.387	-5.26**	2.436**	-1.99**	-5.144**	5.433**	5.591**	-0.55**
$Tester_3$	-1.758**	0.876**	-4.578**	-3.156**	3.562**	-0.407	5.391**	-0.47**	-1.27**	-5.484**	-5.73**	-5.78**	1.096**
Specific combining ability effects of hybrids													
$L_1 \times T_1$	13.453**	0.420*	1.427**	2.909**	-3.06**	0.158	0.844	2.598**	-1.01**	10.493**	1.389**	2.009**	0.020
$L_1 \times T_2$	-13.03**	-0.200	-0.560	-1.064	1.073	-0.009	0.658	-2.93**	0.618**	-7.333**	-0.978*	-1.158	-0.65**
$L_1 \times T_3$	-0.420	-0.220	-0.867*	-1.844	1.993	-0.149	-1.502**	0.338	0.398	-3.160**	-0.411	-0.851	0.630**
$L_2 \times T_1$	-2.858**	0.909**	-2.829**	-6.624**	6.933**	-0.309	10.500**	-0.380	-1.56**	-11.42**	-5.35**	-6.23**	1.352**
$L_2 \times T_2$	2.322**	-1.078**	2.251**	3.869**	-5.26**	1.391	-9.087**	0.520*	0.240	7.211**	4.944**	5.864**	-1.06**
$L_2 \times T_3$	0.536	0.169	0.578	2.756**	-1.673	-1.082	-1.413**	-0.140	1.320**	4.218**	0.411	0.371	-0.29**
$L_3 \times T_1$	-12.05**	-0.547	2.738**	1.731	-1.767	0.036	-2.689**	-2.59**	-1.43**	-17.01**	3.433**	4.142**	-0.53**
$L_3 \times T_2$	7.856**	0.767**	-1.216**	-0.909	1.673	-0.764	4.824**	2.076**	0.496	9.656**	-2.50**	-2.92**	0.737**
$L_3 \times T_3$	4.202**	-0.220	-1.522**	-0.822	0.093	0.729	-2.136**	0.516*	0.942**	7.362**	-0.933*	-1.218	-0.204*
$L_4 \times T_1$	-2.191**	-0.491*	-0.229	-1.058	0.978	0.080	-1.922**	-0.024	1.740**	-1.518	0.156	0.320	-0.67**
$L_4 \times T_2$	6.989**	1.756**	-1.849**	-0.064	1.218	-1.153	6.858**	1.042**	0.407	7.256**	-2.94**	-4.88**	0.906**
$L_4 \times T_3$	-4.798**	-1.264**	2.078**	1.122	-2.196	1.073	-4.936**	-1.01**	-2.14**	-5.738**	2.789**	4.560**	-0.23**
$L_5 \times T_1$	3.653**	-0.291	-1.107**	3.042**	-3.07**	0.036	-6.733**	0.398	2.273**	19.471**	0.378	-0.236	-0.164
$L_5 \times T_2$	-4.133**	-1.244**	1.373**	-1.831	1.296	0.536	-3.253**	-0.70**	-1.76**	-16.78**	1.478**	3.098**	0.067
$L_5 \times T_3$	0.480	1.536**	-0.267	-1.211	1.782	-0.571	9.987**	0.304	-0.513*	-2.682*	-1.85**	-2.86**	0.096

$L_1 \times T_1$: IC-345271 × IC-89986 (Purple); $L_1 \times T_2$: IC-345271 ×Vellayani Local (Green with white stripes); $L_1 \times T_3$: IC-345271 ×Pusa Purple Cluster (Pale Purple); $L_2 \times T_1$: IC-433678 × IC-89986 (Deep Purple); $L_2 \times T_2$: IC-433678 ×Vellayani Local (Pale Purple); $L_2 \times T_3$: IC-433678 ×Pusa Purple Cluster (Purple); $L_3 \times T_1$: Jagaluru Local × IC-89986 (Deep Purple); $L_3 \times T_2$: Jagaluru Local ×Vellayani Local (Pale Purple); $L_3 \times T_3$: Jagaluru Local ×Pusa Purple Cluster (Purple); $L_4 \times T_1$: Tiptur Local × IC-89986 (Green with white stripes); $L_4 \times T_2$: Tiptur Local ×Vellayani Local (Green with white stripes); $L_4 \times T_3$: Tiptur Local ×Pusa Purple Cluster (Green with white stripes); $L_5 \times T_1$: Raidurg Local × IC-89986 (Purple); $L_5 \times T_2$: Raidurg Local ×Vellayani Local (Pale Purple); $L_5 \times T_3$: Raidurg Local ×Pusa Purple Cluster (Purple).

into the main field at a spacing of 60 cm × 75 cm. The crop received timely management practices as per package of practices recommendations of Kerala Agricultural University (KAU 2011). In brinjal, anthesis occurs between 8 to 12 AM matured flower-buds likely to open next morning were emasculated during evening hours and bagged. On the next day morning (between 7 to 10 AM) emasculated buds were pollinated by the respective male parents. The pollinated buds were again bagged with paper bags and labelled. The mature crossed fruits were harvested and the seeds were collected separately from each cross. For maintenance of parental lines, flower buds of different parents were selfed by bagging the individual buds and properly tagged and later the seeds were collected from the mature fruits accordingly. Observation on five plants from each replication were recorded on plant height, number of primary branches/plant, days to first flower, percentage of medium styled flowers, percentage of long styled flowers, percentage of short styled flowers, number of fruits/plant, length of fruit, girth of fruit, fruit weight, days to first harvest, days to last harvest and fruit yield/plant. The combining ability analysis of parents and crosses was calculated for different characters using the L × T model as given by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance (Table 1) showed significant differences among all parents as well as hybrids for all the traits studied, indicating the presence of considerable amount of genetic variability. Variance due to lines was highly significant for all the traits except for long styled flowers and fruit yield per plant. Variance due to tester was highly significant for all the traits except for short styled flowers and days to first harvest. These results indicate the involvement of both additive and non-additive type of gene actions for expression of the characters.

In the present study (Table 1) variance due to gca was higher than sca as evidenced by the ratio being greater than one, for days to first flower, fruit length, fruit girth, days to first harvest, days to last harvest indicating that, preponderance of additive gene action for expression of these characters. This suggested that, simple selection would be enough to make desirable improvements of the character as it as fixable. Variance due to sca was higher than gca as evidenced by the ratio being less than one for the characters like plant height, primary branches, medium styled flowers, long styled flowers, short styled flowers, number of fruits per plant, fruit weight and fruit yield per plant, indicates significant role of non-additive gene action like dominance, epistasis and other interaction effects in expression of these characters. This suggested that, heterosis breeding may be rewarding or selection has to be postponed to later generations for the improvement of these characters. The similar results were reported in brinjal by Peter and Singh (1974), Das *et al.* (2010), Sane *et al.* (2011) and Dishri and Mishra (2017).

Estimates of general combining ability for various traits have been presented in Table 2. The parental lines L_5 (Raidurg Local) and L_2 (IC- 433678) were good general combiners (high gca effects) for length of fruit, number of fruits per plant, long styled flowers, days to first flower, plant height, days to first harvest and days to last harvest. The parental line L_4 (Tiptur Local) was an average combiner for days to first flower, girth of fruit, fruit weight and fruit yield per plant but L_1 (IC- 345271) was poor combiner for all characters. Among the testers, T_3 (Pusa Purple Cluster) was good general combiner for number of fruits per plant, long styled flowers, days to first flower and number of primary branches per plant, days to first harvest and last harvest, whereas T_1 (IC-89986) and T_2 (Vellayani Local) were poor combiners. The parental lines L_5 (Raidurg Local), L_2 (IC- 433678), L_4 (Tiptur Local) and T_3 (Pusa Purple Cluster) were the best general combiner (high gca effects) for fruit yield and yield attributing characters. Therefore, it would be worthwhile to use these parental lines in hybridization programme as a good source of favourable genes for increasing fruit yield and yield attributes. The potentiality of a parent in hybridization may be assessed by its *per se* performance and gca effects. The results revealed that most of the characters had relatively high degree of correspondence between *per se* performance and gca effects. This could be ascribed to the predominant role of additive and additive × additive type of gene action for the inheritance of these traits. Similar results were reported in brinjal by Narendrakumar and Ram (1987), Das *et al.* (2010), Rai and Asati (2011) and Dishri and Mishra (2017).

The estimates of specific combining ability effects (Table 2) revealed that the cross combinations $L_1 \times T_3$ (IC-345271 × Pusa Purple Cluster), $L_2 \times T_1$ (IC-433678 × IC-89986), $L_3 \times T_2$ (Jagaluru Local × Vellayani Local) and $L_4 \times T_2$ (Tiptur Local × Vellayani Local) exhibited significant and positive sca effects for fruit yield per plant. The cross combination L_2 x T_1 (IC-433678 × IC-89986) had the highest sca effects for fruit yield (1.35), which also recorded significant sca effects in desired direction for number of fruits per plant, long styled flowers and number of primary branches per plant. In another hybrid $L_4 \times T_2$ (Tiptur Local × Vellayani Local) also manifested significant sca effects for plant height, number of fruits per plant, days to first flower, length of fruit and fruit yield per plant in desired direction. The cross $L_5 \times T_3$ (Raidurg Local × Pusa Purple Cluster) exhibited high significant sca effects for number of fruits per plant, number of primary branches per plant and days to first harvest. Similar finding have been reported in brinjal by Peter and Singh (1974), Abhinav and Nandan (2010), Rai and Asati (2011), Sane *et al.* (2011) and Dishri and Mishra (2017). Earliness is an important trait in vegetables like brinjal. Earliness is required in such crops for realizing the potential economic yield in as less time as possible to catch early market. The crosses that exhibited significant sca effects for earliness like days to first flower and days to first harvest were $L_1 \times T_3$ (IC-345271 × Pusa Purple Cluster), $L_2 \times T_1$ (IC-433678 × IC-89986), $L_3 \times T_2$ (Jagaluru Local × Vellayani Local) and $L_4 \times T_2$ (Tiptur Local × Vellayani Local) $L_3 \times T_3$ (Jagaluru Local × Pusa

Purple Cluster) and $L_5 \times T_3$ (Raidurg Local × Pusa Purple Cluster). Similar findings in brinjal have been reported by Peter and Singh (1974), Shanmugapriya *et al.* (2009), Sane *et al.* (2011) and Dishri and Mishra (2017).

In the present study, top three crosses $L_2 \times T_1$ (IC-433678 × IC-89986), $L_4 \times T_2$ (Tiptur Local × Vellayani Local) and $L_5 \times T_3$ (Raidurg Local × Pusa Purple Cluster) which exhibited high sca effects for yield per plant involved at least one good general combiners. The two crosses $L_3 \times T_2$ (Jagaluru Local × Vellayani Local) and $L_1 \times T_3$ (IC-345271 × Pusa Purple Cluster) had high sca effects for yield per plant in which poor × poor ($L_3 \times T_2$) and poor × good ($L_1 \times T_3$) general combiners was involved which clearly indicated that, the parental contribution to the heterosis is mainly through non-additive gene effects. Hence, exploitation of heterosis appeared to be an appropriate strategy for improvement in brinjal. These crosses could also be improved through recurrent selection schemes. These results were in accordance with the findings of Narendrakumar and Ram (1987), Chowdhury *et al.* (2010), Sane *et al.* (2011), Makani (2013) and Dishri and Mishra (2017). If a cross combination exhibited high sca effects as well as *per se* performance having at least one parent as good general combiner for a particular trait, it is expected that such cross combinations would throw desirable transgressive segregants in later generations. Significant sca effects of those combinations involving good × good combiners showed the major role of additive type of gene effects, which is fixable. However, two good general combiners may not necessarily throw good segregants. Similarly, in the case of superior crosses involving both the poor × poor general combiners, very little gain is expected from such crosses because high sca effects may dissipate with the progress towards homozygosity.

Thus, on the basis of combining ability, the parents L_5 (Raidurg Local), L_2 (IC- 433678), L_4 (Tiptur Local) and T_3 (Pusa Purple Cluster) was good general combiner for yield and yield contributing characters. Considering mean performance and combining ability, the hybrid $L_2 \times T_1$ (IC-433678 × IC-89986) and L4 × T2 (Tiptur Local × Vellayani Local) followed by $L_5 \times T_3$ (Raidurg Local × Pusa Purple Cluster) was found promising for commercial exploitation. It is evident that both additive and non-additive gene effects are involved in the genetic control of the traits. So both gene effects should be considered when developing superior lines. The identified hybrids could be effectively used for heterosis breeding to exploit maximum hybrid vigour.

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