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Out breeding for yield and horticultural attributes in indigenous eggplant germplasm

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Heterotic effects and genetic components of variation for qualitative and quantitative characters were estimated in eggplant (*Solanum melongena* L.). Forty hybrids generated by crossing four testers (males) with ten lines (females) were studied along with parents for studying heterosis and gene action for calyx length, fruit pedicel length, shoot borer infestation, fruit borer infestation, little leaf incidence, ascorbic acid content, total phenols content, number of fruit per plant and fruit yield per plant during rainy season of 2010-2011. The crosses obtained by L × T method possessed variation in terms of growth, yield and quality traits. Mean fruit yield per plant ranged from 2.85 to 1.04 kg. Among the 40 hybrids, the ones obtained from the cross 'Alagarkovil Local' × 'Annamalai' ($L_4 \times T_1$), 'Palamedu Local' × 'Punjab Sadabahar' ($L_5 \times T_3$), 'Palamedu Local' × 'EP 65' ($L_5 \times T_4$) and 'Keerikai Local' × 'KKM 1' ($L_7 \times T_2$) were suitable for heterosis breeding. Average performance of parents indicated that lines 'Alavayal local' (L_1), 'Sedapatty local' (Green) (L_2) and the tester 'Annamalai' (T_1) were good parents for further breeding to exploit high yield and low pest and disease incidences. Performance of these hybrids needs to be further evaluated in multiple locations or on farm trial prior to commercial use.

Key words: Hybrid vigour, brinjal germplasm, selection, yield attributes.

INTRODUCTION

Eggplant (*Solanum melongena*) belongs to the family Solanaceae. Brinjal grows throughout the tropical and sub-tropical regions of the world. It is also widely grown and common vegetable crop in India. It is locally known as 'Kathirikkai' or Aubergine' or Badanekkai' and is popular among the rural people. India is the major producer of brinjal in the world and it is grown in an area of 0.61 million ha with an estimated annual production of 13.37 million tons with a productivity of 17.3 tons/ ha. In Tamilnadu the production was 8.5 lakh tonnes from 0.75 lakh ha of area (Anonymous, 2010). Immature fruits are used as vegetable and extensively used in various culinary preparations. Nutritive value of brinjal is well compared with tomato (Choudhary, 1976). They are also known to have alkaloid solanine in roots and leaves. Some medicinal uses of brinjal include treatment of diabetes, asthma, cholera, bronchitis and dysuria. Fruits and leaves are administered to lower blood cholesterol

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levels. Fruits are rich source of minerals like Ca, Mg, P and fatty acids (Dhankhar and Singh, 1984).

There are number of local cultivars with wide range of variability in size, shape and color of fruits available in India and for this we can easily fulfill the gap by developing high yielding hybrid variety (Prabakaran, 2010).

The productivity of local genotypes ranged from 10t/ha to 18t/ha. Though a fairly common crop, to-date there is only limited work has been done for evolving hybrids/hybrid derivatives of high yield potential and better quality in Tamil Nadu (India) by using local germplasm.

Furthermore, very limited attempt has been made for genetic improvement of available indigenous types in this crop. Heterosis or hybrid vigor can play a vital role in increasing the yield quality of eggplant. Identification of potential parents in brinjal on the basis of progeny performance requires a large number of crosses, which is very laborious. L × T 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).

The phenomenon of heterosis of F1 hybrids can also reflect specific combining ability (SCA) and general combining ability (GCA) of parental lines. The combining ability works as the basic tool for improved production of crops in the form of F1 hybrids (Dhillion, 1975).

Heterotic studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programs (Chowdhury et al., 2010). The combining ability and heterosis work as the principal methods for screening of germplasm and determination of the ability of the genotypes to be included or not in a breeding program on the basis of their GCA, SCA, reciprocal, and heterotic effects. Recently, it has been divulged that the utilization of hybrid vigor is most effective for the improvement of different characters and the combining ability is the fundamental tool for enhancing the productivity/yield of different crops in the form of F1 hybrids (Pachiyappan et al., 2012). Considering the above idea in mind the present investigation was undertaken with the objectives (i) to determine the magnitude of heterosis in the hybrids (ii) to study the gene action of different traits and (iii) development of hybrids for higher fruit yield and quality using indigenous genotypes.

MATERIALS AND METHODS

The experimental site

The experiment was conducted during *kharif* (rainy season) 2010-2011 at College Orchard, Agricultural College and Research Institute, Madurai, Tamil Nadu, India which is situated at 9°5 latitude and 78°5 longitude and at an elevation of 147 m above MSL.

Experimental materials

Genetic improvement in eggplant germplasm has been initiated in Department of Horticulture, Agricultural College and Research Institute, Madurai, Tamil Nadu, India during 2009-2011 using indigenous germplasm for increasing the overall production of eggplant and release of hybrids for commercial use. Around 33 eggplant germplasm were collected from in and around the Tamil Nadu state having wider range of diversity and variability and evaluated under field condition for yield, quality and other desirable traits. Among them, 10 germplasm were selected based on color (consumer preference), shape, size and yield and used as female parents for crossing programme. Ten lines (females) were crossed with four testers (males) through Line × Tester mating design to derive the 40 F_1 hybrids. The details of different parents used in the present study were narrated in Table 1.

Selfing

All the fourteen parents were maintained in a homozygous condition by continuous selfing. Hundred percent selfing was achieved by bagging the flowers with white butter paper covers, a day prior to anthesis. When the fruits have attained marble stage, the covers were removed and the fruits were tagged. Fully ripe labelled fruits were collected individually and seeds were extracted by fermentation method. Seed moisture content was reduced to eight per cent by shade drying and the seeds were stored in butter paper covers for further use.

Crossing technique

The fourteen parents were used for crossing to get 40 hybrids. A separate crossing block was maintained for the production of hybrid seeds.

In the female parent, healthy, long or medium styled flower buds, which were likely to open on the next day, were selected for emasculation. Emasculation was carried out between 3.00 and 5.00 pm and bagged with butter paper covers. Similarly, in the male parents, a few selected flower buds for collection of pollen grains were bagged without emasculation to avoid contamination by foreign pollen. Pollen from the bagged flowers of the pollen parents were collected between 7.00 and 8.00 am in the next day and dusted on to the stigma of the emasculated flowers of the respective ovule parents. The flowers were bagged with butter paper covers and then labelled. The covers were removed after ensuring proper fruit set. The crossed fruits were harvested at full ripe stage and seeds were extracted by fermentation method. The seeds were shade dried to eight percent moisture content and stored in butter paper covers for further breeding programme.

Experimental design

Forty hybrids along with 14 parents were raised in a Randomized Complete Block Design with three replications.

Nursery and cultivation aspects

Thirty days-old seedlings raised in the nursery beds were transplanted on the ridges adopting a spacing of 60 x 60 cm. Thirty plants were maintained for each hybrid and parent in each replication. Recommended cultural practices were followed uniformly to all the hybrids and parents as per the Tamilnadu Agricultural University Crop Production Guide (2005). Observations were recorded in five randomly selected plants in each replication.

Table 1. Brief description of the parental genotypes used in experiments.

S/N	Name of the types	Flower colour	Flower bearing	Fruit bearing	Fruit shape	Fruit colour	Calyx fleshness	Calyx type	Source	Symbol
Lines										
1.	Alavayal Local	Dark purple	Cluster	Cluster	Round	Light purple	Fleshy	Persistent	Alavayal, Madurai D.t ,Tamil Nadu	L_1
2.	Sedapatty Local (Green)	Purplish white	Cluster	Cluster	Oval	Purplish green	Fleshy	Persistent	Sedapatty, Madurai D.t, Tamil Nadu	L_2
3.	Kariapatty Local	Purplish white	Cluster	Cluster	Round	Green striped	Fleshy	Persistent	Kariapatty, Virdhunagar D.t, Tamil Nadu	L_3
4.	Alagarkovil Local	Light purple	Cluster	Cluster	Round	Green striped	Fleshy	Persistent	Alagarkovil, Madurai D.t, Tamil Nadu	L_4
5.	Palamedu Local	Purplish white	Cluster	Cluster	Round	Light blue	Non fleshy	Persistent	Palamedu, Madurai D.t, Tamil Nadu	L_5
6.	Melur Local	Purplish white	Cluster	Cluster	Round	Purple	Fleshy	Persistent	Melur, Madurai D.t, Tamil Nadu	L_6
7.	Keerikai Local	Purplish white	Cluster	Cluster	Oval	Purplish green	Non fleshy	Persistent	Sempatty, Dindigul D.t, Tamil Nadu	L_7
8.	Nilakottai Local	White	Cluster	Cluster	Oblong	Green striped	Non fleshy	Persistent	Nilakottai, Dindigul D.t, Tamil Nadu	L_8
9.	Singampunari Local	Light purple	Cluster	Cluster	Round	Purplish green	Fleshy	Persistent	Singampunari, Sivagangai D.t, Tamil Nadu	L_9
10.	Sedapatty Local (Blue)	Purplish white	Cluster	Cluster	Round	Purple striped	Fleshy	Persistent	Sedapatty, Madurai D.t, Tamil Nadu	L_{10}
Testers										
1.	Annamalai	Purple	Cluster	Cluster	Long	Purple	Non fleshy	Non persistent	Vegetable Research Station, Palur, Tamil Nadu	T_1
2.	KKM 1	Purple	Cluster	Cluster	Egg shaped	White	Fleshy	Persistent	Agricultural College and Research Institute, Tuticorin, Tamil Nadu	T_2
3.	Punjab Sadabahar	Purple	Cluster	Cluster	Long	Purple	Non fleshy	Non persistent	Tamil Nadu Agricultural University, Coimbatore	T_3
4.	EP 65	Purple	Cluster	Cluster	Oval	Dark purple	Non fleshy	Non persistent	Vegetable Research Station, Palur, Tamil Nadu	T_4

Data collected

The data recorded for nine biometrical traits *viz*., calyx length, fruit pedicel length, shoot borer infestation, fruit borer infestation, little leaf incidence, ascorbic acid content, total phenols content, number of fruits per plant and fruit yield per plant in 14 parents and forty hybrids were used for estimating heterosis.

Calyx length (cm)

The calyx length of five randomly selected fruits at vegetable maturity in the third harvest was recorded and the mean is expressed in centimeter (cm).

Fruit pedicle length (cm)

The pedicle length of five randomly selected fruits at vegetable maturity in the third harvest was recorded and the mean is expressed in centimeter (cm).

Shoot borer infestation (%)

The number of shoots affected by borer and total number of shoots per plant were recorded and the percent of shoot borer infestation was worked out.

Fruit borer infestation (%)

The numbers of fruits affected by borer and total number of fruits harvested were recorded and the percent of fruit borer infestation was worked out.

Little leaf incidence (%)

The number of plants affected by little leaf and total number plants available was recorded and the percent of little leaf incidence was worked out.

Number of fruits per plant

Fruits at vegetable maturity were harvested and counted at each harvest and the cumulative number of fruits per plant is expressed.

Fruit yield per plant (kg)

The weight of fruits in each plant was recorded at each harvest and the total weight of fruits over all the harvests were recorded as yield per plant and expressed in kilogram (kg).

Table 2. Estimates of variance (L×T) components, rainy season 2010-2011.

Character	GCA variance	SCA variance	δ^2 A	δ^2 D	Ratio of δ^2 A: δ^2 D
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 phenols 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

GCA-General combining ability; SCA-specific combining ability; δ^2 A-additive variance; δ^2 D-dominance variance.

Quality traits

Ascorbic acid (mg/100 g): Ascorbic acid content was estimated by volumetric method as suggested by AOAC (2001).

$$\text{Ascorbic acid} = \frac{0.5\text{ mg}}{V_1\text{ ml}} \times \frac{V_2\text{ ml}}{5\text{ ml}} \times \frac{100\text{ ml}}{\text{weight of the sample}} \times 100$$

Total phenols (mg/100 g): Folin ciocalteau reagent method was followed for estimating the total phenols (Bray and Thrope, 1954).

Selection of hybrids

The selections were made in the F_1 hybrids based on fruit shape, colour, size and fruit yield per plant. The superior hybrids were selected and selfed. The seeds were collected from the selfed fruits and stored for further breeding programme.

Data analysis

Line x tester analysis was carried out to test parents and hybrids with respect to their general and specific combining ability, respectively. The line x tester analysis of combining ability gives useful information regarding the choice of parents and elucidates the nature and magnitude of various types of gene action for the expression of yield and yield attributing characters. The data on the hybrids and parents were subjected to L × T analysis. The assumption of null hypothesis was tested for differences among the genotypes as detailed by Panse and Sukhatme (1967). The general combining ability effects of the parents and specific combining ability effects of the crosses were worked out as suggested by Kempthorne (1957).

The magnitude of heterosis in hybrids was expressed as percentage of increase or decrease of a character over mid parent (d_i), better parent (d_{ii}) and standard hybrid (d_{iii}) and was estimated following the formula of Fonseca and Patterson (1968). The significance of magnitude of the relative heterosis, heterobeltiosis and standard heterosis was tested at error degrees of freedom by the formula as suggested by Turner (1953). It is estimated as follows:

$$\text{Standard heterosis } (d_{iii}) = \frac{\overline{F1} - \overline{SV}}{\overline{SV}} \times 100$$

RESULTS

Line × tester analysis

Line × tester analysis was carried out to detect the gene action of different traits. The significance level and mean square value of all the investigated traits are shown in Table 2. The total variance is further partitioned into several components, like variance due to lines, testers and their interactions. We observed a significant genetic variation among lines and testers for all traits. Heterosis is the superiority of an F1 hybrid produced through crossing of two genetically different individuals over the mean of its parents or the better parent. Standard heterosis was estimated for fruit pedicel length, calyx length, shoot borer infestation, fruit borer infestation, number of fruits per plant, ascorbic acid content, total phenols content and fruit yield per plant. Heterosis was obvious in different crosses for all the characters and the magnitude varied significantly for traits and crosses. The hybrid vigor can help to increase the yield by several times than open pollinated variety.

Performance of germplasm and hybrids

In any statistical analysis of data, average performance is

the true realized mean of the recorded data and this is a direct estimate based on the observation and not on assumption. Among parents, line L_8 produced the longest fruit pedicel followed by L_2. Testor T_2 had the shortest fruit pedicel. The parents L_1, L_2, L_4, L_8 and T_4 exceeded the mean value. The longest calyx was for parent L_7 followed by L_6 and the shortest was for L_8. Among testers, T_3 had the longest calyx. Nine parents had significant values for this character. The fewest fruit per plant was for L_5 and the most was for T_1 followed by L_9 among parents. The parents L_2, L_3, L_6, L_9, T_1, T_2 and T_3 exceeded the mean value. Parents T_2 and L_8 had the highest and lowest borer infestation, respectively. The females L_1, L_2, L_5, L_6, L_7, L_9, and L_{10} and males T_3 and T_4 had higher values over the mean. Fruit borer infestation was highest in T_2 and lowest in T_4 among testers. Seven parents had significant little leaf incidence values for this trait. Among parents, the highest ascorbic acid content was for T_1 and the lowest was for L_{10}. The parents L_1, L_3, L_4, L_6, L_8, T_1, T_3 and T_4 had high values for ascorbic acid content. Six parents had significant mean values for total phenol. The line L_5 had the highest yield per plan followed by L_2, while the lowest yield was in L_9. Six of 14 parents had higher fruit yield per plant over the grand mean. The hybrid $L_3 \times T_4$ produced the longest fruit pedicel length followed by $L_6 \times T_1$. The hybrid $L_7 \times T_4$ had the shortest fruit pedicel length. Of 40 hybrids, 13 had significantly higher values than the grand mean. The longest calyx was in the hybrid $L_3 \times T_4$ followed by $L_5 \times T_3$. Thirty one hybrids had significant values for this trait.

Of 40 hybrids, 16 crosses had higher mean values than the grand mean of fruit per plant. Among hybrids, the $L_3 \times T_3$ had the least borer infestation, followed by $L_1 \times T_3$. Twenty-four hybrids had significant mean values for this trait. The hybrid $L_8 \times T_1$ had the lowest and $L_8 \times T_3$ the highest borer infestation. Twenty-eight hybrids had lower borer infestation than the mean. Little leaf incidence was highest in the hybrid $L_{10} \times T_2$. The hybrid $L_5 \times T_3$ had the minimum little leaf incidence. The hybrid, $L_{10} \times T_2$ had the highest little leaf incidence. Twenty-three hybrids had lower values than the grand mean. The hybrid $L_1 \times T_3$ had the highest, followed by $L_1 \times T_1$; $L_{10} \times T_1$ (9.63 mg 100 g^{-1}) had the lowest ascorbic acid content. Among the 40 hybrids, 17 had higher values than the grand mean. Hybrid $L_7 \times T_2$ had the highest value and $L_2 \times T_4$ the lowest value for this trait. Nineteen hybrids exceeded the mean value. The highest fruit yield was for $L_7 \times T_2$ followed by $L_1 \times T_1$, $L_4 \times T_1$ and the lowest was in $L_3 \times T_4$ for this trait. Fourteen hybrids had values than the grand mean.

For fruit pedicel length standard heterosis over the standard variety. In 26 hybrids there was positive significant heterosis over the standard variety. Ten hybrids did not have heterosis and 3 ($L_7 \times T_3$, $L_7 \times T_4$ and $L_8 \times T_3$) had significant negative heterosis. For fruit circumference standard heterosis varied. Thirty-one hybrids had significant, positive, heterosis over the standard variety. Four hybrids had no heterosis. For calyx length standard heterosis was negative, and significant, in all hybrids except $L_5 \times T_3$ which had no heterosis over the standard variety. For numbers of fruit per plant significant heterosis over the standard variety occurred in 33 hybrids; 9 had positive and 23 had negative heterosis. For shoot borer infestation, fifteen hybrids had significant negative heterosis. For fruit borer infestation, the highest significant negative standard heterosis was for the hybrid $L_8 \times T_1$. Seventeen hybrids had significant negative heterosis and 7 had significant positive heterosis over the standard variety. For little leaf incidence, negative heterosis is a beneficial for this trait. Of 40 hybrids, 2, 7 and 16 hybrids had significant negative heterosis over mid-, and better parent and the standard check, respectively. For ascorbic acid content positive standard heterosis was highest for $L_1 \times T_3$. Seven hybrids had significant and positive d_{iii}. For total phenol content of 40 hybrids, 19 had positive and significant d_{iii} values with the highest in $L_7 \times T_2$. For fruit yield per plant, there was an appreciable amount of heterosis in F_1s over the standard check. Expression of superiority over the standard check occurred in 7 crosses. More hybrids had economic heterosis in crosses involving the tester T_2.

DISCUSSION

Knowledge of the relative importance of additive and non-additive gene action is essential to breeders for development of efficient hybridization. Panse (1942) stated that if additive genetic variance is greater, the chance of fixing superior genotypes in early segregating generation would be greater; if dominant and epistatic interactions are predominant, selection should be postponed to later generations and appropriate breeding should be adopted to obtain useful genotypes. The analysis of combining ability estimates (Table 2) indicated that non-additive gene action was operating for all characters studied because variance due to GCA and SCA were significant. Variance due to SCA was higher in magnitude than GCA for all traits. This supports the predominance of non-additive gene effects on governing expression of most characters.

The parents had significant differences for all characters. Variance due to lines were significant for all traits indicating existence of enormous amount of genetic variability for growth and yield attributes among the lines (females). Similarly, testers (males) had significant differences for all traits. The interaction between lines x testers was also significant for yield, quality and other traits studied (Table 3).

The hybrids chosen for heterosis breeding based on significant mean value, SCA effects and standard heterosis are shown in the Tables 4a, b and c. Mean performance and heterosis are important parameters to assess potential of F_1 hybrids. Among these, mean

Table 3. Analysis of variance for parents and hybrids with respect to 9 characters, rainy season 2010-2011.

Source	df	FPL	CL	NF/P	SBI	FBI	LLI	ACC	TPC	FY/P
Hybrids	39	1.4005*	1.0970*	161.9557*	54.4746*	63.3535*	69.4393*	12.9752*	533.5026*	0.6288*
Lines	9	2.1125*	2.5695*	197.8137*	104.8571*	80.0248*	128.8896*	24.3787*	998.8697*	0.9020*
Testers	3	0.4415*	0.5407*	234.2205*	41.9781*	34.1338*	70.4679*	33.1344*	55.7529*	0.4214*
Line × Testers	27	1.2698*	0.6680*	141.9736*	39.0689*	61.0430*	49.5083*	6.9342*	431.4635*	0.5608*
Errors	78	0.0216	0.0424	1.8176	0.9524	2.1378	0.8543	0.1632	4.1422	0.0100

Significant at 5% level, CL – Calyx length (cm); FPL – Fruit pedicel length (cm); NF/P – Number of fruits per plant; SBI – Shoot borer infestation (%); FBI – Fruit borer infestation (%); LLI – Little leaf incidence (%); ACC – Ascorbic acid content (mg/100g); TPC – Total phenols content (mg/100g); FY/P – Fruit yield per plant (kg).

Table 4a. Mean performance and standard heterosis for various quantitative and qualitative characters in eggplant, rainy season 2010-2011.

Entry	Calyx length (cm)		Fruit pedicel length (cm)		Number of fruits per plant		Shoot borer infestation (%)	
	Mean value	SH	Mean value	SH	Mean value	SH	Mean value	SH
Alavayal Local	2.45*		5.57*		25.89		22.86*	
Sedapatty Local (Green)	3.45*		6.03*		33.06*		20.65*	
Kariapatty Local	3.72*		4.58		30.85*		27.31	
Alagarkovil Local	3.84*		5.42*		27.43		25.47	
Palamedu Local	4.65		5.11		23.42		19.34*	
Melur Local	4.76		4.76		31.49*		22.14*	
Keerikai Local	5.54		4.19		27.37		21.40*	
Nilakottai Local	2.42*		7.04*		25.44		17.89	
Singampunari Local	3.34*		5.37		33.34*		22.66*	
Sedapatty Local (Blue)	3.54*		4.98		25.17		21.58*	
Annamalai	3.96		4.12		37.92*		26.67	
KKM 1	3.28*		3.44		31.07*		27.87	
Punjab Sadabahar	4.41		4.75		30.94*		23.09*	
EP 65	3.28*		5.44*		26.99		21.68*	
$L_1 \times T_1$	1.74*	-56.14**	4.40	6.88*	35.60*	-6.12	22.86*	6.85*
$L_1 \times T_2$	1.88*	-52.53**	4.03	-2.11	24.65	-35.00**	20.65*	-19.11**
$L_1 \times T_3$	2.84	-28.37**	5.35*	30.04**	20.52	-45.88**	27.31	-30.21**
$L_1 \times T_4$	2.20*	-44.44**	4.38	6.32*	28.04	-26.05**	25.47	-11.60**
$L_2 \times T_1$	2.02*	-48.99**	3.88	-5.83	43.02*	13.45**	19.34*	-0.11
$L_2 \times T_2$	2.10*	-46.97**	3.98	-3.40	26.22	-30.85**	22.14*	26.21**
$L_2 \times T_3$	2.25*	-43.18**	4.10	-0.32	36.92*	-2.63	21.40*	-9.07**
$L_2 \times T_4$	1.74*	-56.06**	4.96*	20.49**	29.97	-20.97**	17.89	-15.35**
$L_3 \times T_1$	2.20*	-44.44**	4.25	3.32	33.29	-12.21**	22.66*	-15.84**

Table 4a. Contd.

$L_3 \times T_2$	2.52*	-36.36**	4.46	8.34**	22.30	-41.19**	21.58*	-27.70**
$L_3 \times T_3$	3.14	-20.79**	4.90*	19.03**	28.10	-25.90**	26.67	-33.43**
$L_3 \times T_4$	3.88	-2.02	6.50*	57.89**	19.55	-48.44**	27.87	-15.82**
$L_4 \times T_1$	3.15	-20.37**	4.75	15.30**	41.00*	8.11*	23.09*	-22.41**
$L_4 \times T_2$	2.90	-26.77**	4.25	3.16	43.93*	15.85**	21.68*	2.66
$L_4 \times T_3$	2.48*	-37.37**	4.95*	20.24**	28.03	-26.09**	28.50	20.96**
$L_4 \times T_4$	3.36	-15.15**	5.80*	40.89**	32.92	-13.19**	21.57*	6.86*
$L_5 \times T_1$	2.44*	-38.30**	5.00*	21.46**	30.19	-20.39**	18.61*	-4.46
$L_5 \times T_2$	2.10*	-46.97**	4.58	11.26**	44.47*	17.27**	23.58*	4.91
$L_5 \times T_3$	3.76	-5.13	5.05*	22.67**	42.24*	11.39**	26.64*	-4.35
$L_5 \times T_4$	2.58*	-34.93**	5.53*	34.33**	43.36*	14.35**	33.66	-10.24**
$L_6 \times T_1$	2.42*	-38.97**	6.00*	45.75**	28.60	-24.58**	24.25*	7.62**
$L_6 \times T_2$	3.16	-20.20**	5.58*	35.63**	40.00*	5.49	22.58*	-16.69**
$L_6 \times T_3$	3.09	-22.05**	4.43	7.69*	25.46	-32.85**	22.45*	6.15*
$L_6 \times T_4$	2.26*	-42.93**	4.22	2.43	32.84	-13.40**	19.28*	-19.22**
$L_7 \times T_1$	2.10*	-46.97**	4.00	-2.83	19.98	-47.32**	17.75*	8.66**
$L_7 \times T_2$	1.54*	-61.20**	4.44	7.85*	41.04*	8.22*	22.45*	8.75**
$L_7 \times T_3$	1.56*	-60.61**	3.62	-12.06**	26.36	-30.49**	20.69*	-4.92
$L_7 \times T_4$	2.32*	-41.41**	3.36	-18.38**	30.09	-20.65**	27.38*	-7.85**
$L_8 \times T_1$	1.76*	-55.64**	4.58	11.26**	39.52*	4.23	32.26	30.07**
$L_8 \times T_2$	1.40*	-64.65**	4.68	13.68**	38.87*	2.51	28.50	17.17**
$L_8 \times T_3$	1.60*	-59.68**	3.42	-16.92**	25.61	-32.45**	25.48*	4.69
$L_8 \times T_4$	1.90*	-52.02**	4.30	4.45	41.62*	9.76**	27.98	-10.82**
$L_9 \times T_1$	2.44*	-38.47**	4.60	11.74**	42.96 *	13.29**	25.51*	-2.51
$L_9 \times T_2$	1.92*	-51.52**	4.74	15.14**	36.84*	-2.85	23.94*	29.25**
$L_9 \times T_3$	1.64*	-58.59**	5.74*	39.51**	21.61	-43.01**	28.70	18.75**
$L_9 \times T_4$	2.28*	-42.42**	4.44	7.85*	27.98	-26.21**	22.22*	4.69
$L_{10} \times T_1$	2.46*	-37.96**	4.86	17.98**	19.63	-48.24**	28.31	1.55
$L_{10} \times T_2$	2.42*	-38.80**	4.30	4.53	35.31*	-6.88*	21.54*	12.56**
$L_{10} \times T_3$	2.52*	-36.28**	5.12*	24.45**	23.14	-38.98**	28.98	8.31**
$L_{10} \times T_4$	1.70*	-57.07**	4.50	9.39**	25.56	-32.60**	29.00	14.16**
SEd	2.34	-	0.12	-	1.12		0.79	-
CD at 5%	4.69	0.15	0.23	0.13	2.22	1.30	1.56	0.72

SH-standard heterosis; *Significance at 5% level; ** Significance at 1% level.

performance is the most important criterion for evaluating hybrids and parents. Selection based on phenotypic expression is easy when the required character is controlled by a few genes and inherited simply. Continuously varying traits of yield and its components, which are under

Table 4b. Mean performance and standard heterosis for various quantitative and qualitative characters in eggplant, rainy season 2010-2011.

Entry	Fruit borer infestation (%)		Little leaf incidence (%)		Ascorbic acid (mg/100 g)		Total phenol content (mg/100 g)	
	Mean value	SH	Mean value	SH	Mean value	SH	Mean value	SH
Alavayal Local	33.75*		18.92		13.37*		67.28*	
Sedapatty Local (Green)	37.58*		20.74		12.03		51.77	
Kariapatty Local	38.08*		17.83*		12.86*		50.54	
Alagarkovil Local	40.41		15.58*		13.34*		46.04	
Palamedu Local	35.38*		10.42*		11.23		58.36	
Melur Local	39.54		24.75		13.58*		82.62*	
Keerikai Local	41.29		25.63		12.13		61.47*	
Nilakottai Local	38.42*		16.68*		13.55*		40.37	
Singampunari Local	39.58		12.45*		10.58		72.23*	
Sedapatty Local (Blue)	40.02		13.86*		9.88		48.28	
Annamalai	38.18*		24.08		14.65*		77.27*	
KKM 1	44.57		19.55		12.49		45.33	
Punjab Sadabahar	42.61		19.76		13.83*		29.46	
EP 65	28.89*		10.05*		13.87*		56.05*	
$L_1 \times T_1$	35.17*	-7.88**	20.74	20.16**	16.47*	12.42**	67.28*	-4.68*
$L_1 \times T_2$	37.96*	-0.58	17.83*	-5.97	15.42*	5.28*	51.77	-9.08**
$L_1 \times T_3$	40.28	5.50	15.58*	-11.78**	16.74*	14.29**	50.54	-4.09*
$L_1 \times T_4$	35.36*	-7.39*	10.42*	34.65**	14.15*	-3.39	46.04	-6.51**
$L_2 \times T_1$	38.48*	0.79	24.75	17.28**	13.61*	-7.10**	58.36	-20.53**
$L_2 \times T_2$	34.29*	-10.20**	25.63	5.69	13.95*	-4.78*	82.62*	19.16**
$L_2 \times T_3$	35.74*	-6.38*	16.68*	-18.05**	12.48	-14.81**	61.47*	10.05**
$L_2 \times T_4$	32.05*	-16.06**	12.45*	21.54**	12.53	-14.47**	40.37	-31.50**
$L_3 \times T_1$	36.98*	-3.14	13.86*	-6.80*	14.47*	-1.23	72.23*	14.29**
$L_3 \times T_2$	42.38	11.00**	18.92	-9.25**	11.22	-23.41**	48.28	-8.89**
$L_3 \times T_3$	36.47*	-4.48	24.08	-32.56**	14.33*	-2.16	77.27*	10.88**
$L_3 \times T_4$	39.56*	3.62	19.55	17.33**	13.18	-10.01**	45.33	-4.97*
$L_4 \times T_1$	38.82*	1.67	19.76	-22.23**	12.74	-13.06**	29.46	16.58**
$L_4 \times T_2$	36.76*	-3.71	10.05*	-22.58**	13.95*	-4.78*	56.05*	12.25**
$L_4 \times T_3$	34.40*	-9.91**	28.93	-6.45*	12.22	-16.59**	73.65	4.51*
$L_4 \times T_4$	32.96*	-13.67**	22.64*	-12.82**	10.62	-27.51**	70.25	14.33**
$L_5 \times T_1$	30.33*	-20.56**	21.24*	5.65	15.57*	6.28**	74.11	-11.42**
$L_5 \times T_2$	36.65*	-4.01	32.42	6.52*	11.56	-21.07**	72.24	7.76**
$L_5 \times T_3$	34.78*	-8.91**	28.24	-34.61**	11.60	-20.80**	61.40	-8.20**
$L_5 \times T_4$	45.57	19.36**	25.45*	-23.33**	10.61	-27.58**	92.07*	16.48**
$L_6 \times T_1$	39.98	4.71	19.73*	-31.80**	16.46*	12.33**	85.03*	-14.15**

Table 4b. Contd.

$L_6 \times T_2$	31.28*	-18.07**	29.26	-7.50*	11.40	-22.16**	52.93	9.45**
$L_6 \times T_3$	45.58	19.37**	22.44*	3.21	11.78	-19.59**	88.31*	10.25**
$L_6 \times T_4$	34.52*	-9.59**	21.85*	4.25	10.87	-25.80**	70.40	26.10**
$L_7 \times T_1$	38.90*	1.89	16.24*	18.59**	14.12*	-3.62	85.67*	28.68**
$L_7 \times T_2$	34.62*	-9.33**	28.25	-7.57*	11.27	-23.07**	73.42	30.96**
$L_7 \times T_3$	36.05*	-5.59	18.72*	29.35**	15.28*	4.30*	90.08*	8.91**
$L_7 \times T_4$	35.69*	-6.52*	18.64*	1.50	11.27	-23.07**	86.73*	27.35**
$L_8 \times T_1$	29.58*	-22.52**	22.52*	10.22**	10.31	-29.60**	80.75*	-10.31**
$L_8 \times T_2$	45.27	18.56**	20.99*	18.58**	14.18*	-3.21	88.34*	-24.38**
$L_8 \times T_3$	48.86	27.97**	25.44*	-7.59*	10.62	-27.49**	68.44	-8.27**
$L_8 \times T_4$	40.09	5.00	25.65*	33.50**	9.77	-33.31**	83.26*	-13.00**
$L_9 \times T_1$	44.28	15.97**	15.74*	26.43**	16.00*	9.22**	70.93	-28.81**
$L_9 \times T_2$	40.35	5.68	18.46*	10.23**	14.23*	-2.87	90.00*	-19.34**
$L_9 \times T_3$	45.63	19.51*	16.42*	18.58**	14.47*	-1.21	66.33	-16.44**
$L_9 \times T_4$	40.21	5.32	22.27*	-7.59*	10.52	-28.17**	84.57*	12.84**
$L_{10} \times T_1$	36.58*	-4.19	24.85*	21.03**	9.63	-34.24**	85.19*	27.35**
$L_{10} \times T_2$	31.28*	-18.07**	25.10*	43.04**	10.02	-31.60**	97.43*	-10.31**
$L_{10} \times T_3$	34.02*	-10.90**	28.55	10.25**	11.50	-21.50**	99.43*	-24.37**
$L_{10} \times T_4$	35.82*	-6.17*	22.25*	32.45**	10.61	-27.55**	101.19*	-16.08**
SEd	1.19	-	0.75	-	0.32	-	3.29	-
CD at 5%	2.36	1.14	1.49	0.71	0.65	0.31	7.01	1.56

SH-standard heterosis; *Significance at 5% level; ** Significance at 1% level.

Table 4c. Mean performance and standard heterosis for various quantitative and qualitative characters in eggplant, rainy season 2010-2011.

Entry	Fruit yield per plant (kg)	
	Mean value	SH
Alavayal Local	1.72*	
Sedapatty Local (Green)	1.86*	
Kariapatty Local	1.27	
Alagarkovil Local	1.26	
Palamedu Local	1.91*	
Melur Local	1.75*	
Keerikai Local	1.79*	
Nilakottai Local	1.27	

Table 4c. Contd.

Singampunari Local	1.16	
Sedapatty Local (Blue)	1.37	
Annamalai	2.12*	
KKM 1	1.46	
Punjab Sadabahar	1.56	
EP 65	1.36	
$L_1 \times T_1$	2.47*	16.33**
$L_1 \times T_2$	1.35	-36.58**
$L_1 \times T_3$	1.35	-36.42**
$L_1 \times T_4$	1.45	-31.55**
$L_2 \times T_1$	2.07*	-2.67
$L_2 \times T_2$	1.42	-32.97**
$L_2 \times T_3$	2.14*	0.63
$L_2 \times T_4$	1.56	-26.37**
$L_3 \times T_1$	1.45	-31.71**
$L_3 \times T_2$	0.99	-53.22**
$L_3 \times T_3$	1.74	-18.05**
$L_3 \times T_4$	0.93	-56.36**
$L_4 \times T_1$	2.40*	13.03**
$L_4 \times T_2$	2.32*	9.11*
$L_4 \times T_3$	1.49	-29.67**
$L_4 \times T_4$	1.92*	-9.73*
$L_5 \times T_1$	1.71	-19.62**
$L_5 \times T_2$	2.34*	10.20**
$L_5 \times T_3$	2.36*	11.30**
$L_5 \times T_4$	2.21*	4.08
$L_6 \times T_1$	1.48	-30.30**
$L_6 \times T_2$	2.24*	5.49
$L_6 \times T_3$	1.35	-36.26**
$L_6 \times T_4$	1.68	-21.04**
$L_7 \times T_1$	1.13	-46.78**
$L_7 \times T_2$	2.85*	34.07**
$L_7 \times T_3$	1.43	-32.50**
$L_7 \times T_4$	1.74	-18.21**
$L_8 \times T_1$	2.26*	6.28
$L_8 \times T_2$	1.66	-21.82**
$L_8 \times T_3$	1.04	-50.86**

Table 4c. Contd.

$L_8 \times T_4$	2.06*	-2.83
$L_9 \times T_1$	2.29*	7.69*
$L_9 \times T_2$	1.73	-18.68**
$L_9 \times T_3$	1.22	-42.54**
$L_9 \times T_4$	1.42	-33.28**
$L_{10} \times T_1$	1.12	-47.25**
$L_{10} \times T_2$	1.85	-13.03**
$L_{10} \times T_3$	1.43	-32.81**
$L_{10} \times T_4$	1.45	-31.55**
SEd	0.07	-
CD at 5%	0.15	0.08

SH-standard heterosis; *Significance at 5% level; ** Significance at 1% level.

influence of polygenes, require selection based on mean performance. It is essential to eliminate undesirable types, which can be achieved by studying mean performance of genotypes as an initial step in the evaluation procedure. Heterosis is a direct property of heterozygosity and due to superior gene content possible in a hybrid contributed by both parents (Mather, 1955). When performance of a hybrid is assessed based on significance of mean performance and heterosis, its superiority over other hybrids could be easily determined.

Evaluation of parents based on mean might result in identification of different sets of promising parents. Chandra et al. (1970) reported that parents with high mean may be able to transmit superior traits to hybrids and the need for combining ability of parents. On the basis of mean values, the line 'Alavayal Local' (L_1) had high mean values for fruit pedicel length, calyx length, shoot borer infestation, little leaf incidence, ascorbic acid content, total phenols and fruit yield per plant, and 'Sedapatty local' (Green) (L_2) had high mean values for fruit pedicel length, calyx length, number of fruit per plant, shoot borer infestation, fruit borer infestation and fruit yield per plant. Among testers, 'Annamalai' (T_1) was the best parent since it had high mean for number of fruit per plant, fruit borer infestation, ascorbic acid content and fruit yield per plant. An analysis of average performance of parents for fruit yield per plant, and other desirable traits, indicated that production of elite hybrids with the correct parents will led to fixes for heterotic effects through isolation of high yielding homozygous lines with better quality and lesser incidence of pest and disease in advance generation.

Chaudhary and Malhotra (2000) reported production of hybrids in crosses involving parents with high average values for yield and its component traits in eggplant. Das and Barua (2001) indicated crosses with two good general combiners to have particular merit in eggplant breeding and suggested bi-parental mating among F_2 progenies to evolve better genotypes through combination of desirable attributes. An overview of average performance of parents indicated that lines 'Alavayal local' (L_1), 'Sedapatty local' (Green) (L_2) and the tester 'Annamalai' (T_1) were good parents for further breeding to exploit high yield and low incidence of pest and diseases. The hybrid L_4xT_1 had favorable mean values for the characters numbers of fruit per plant, shoot borer infestation, fruit borer infestation, little leaf incidence, total phenol content and fruit yield per plant. This was followed by $L_7 \times T_2$ which had favorable mean performance for yield and quality traits calyx length, number of fruit per plant, fruit borer infestation, total phenols content and fruit yield per plant. The above hybrids could be outstanding for improving growth, yield and quality traits and lower incidence of pest and diseases.

Another important criterion to assess hybrids for heterosis breeding was through standard heterosis. Though, the bases of heterosis are important, Kadambavanasundaram (1980) indicated that heterotic expression over the standard variety should alone be given importance for commercial exploitation of hybrid vigor and the crosses, which showed significantly high value of standard heterosis over 'Annamalai' (T_1) for yield and yield components, quality, pest

and disease. None of the hybrids expressed favorable standard heterosis for all characters. The hybrids $L_7 \times T_2$ had significant standard heterosis over its parents for calyx length, total phenol content and fruit yield per plant. The hybrid and $L_6 \times T_1$ had better heterosis values for fruit pedicel length, ascorbic acid content and little leaf incidence. For shoot borer infestation and little leaf incidence hybrid $L_3 \times T_3$ can be chosen for reduced pest and disease incidence. The hybrid $L_8 \times T_1$ had superior standard heterosis for fruit borer infestation and these hybrids can be used for heterosis breeding. Hybrids were selected for heterosis breeding based on average performance and standard heterosis for fruit yield per plant. The hybrid $L_4 \times T_1$ was suitable for heterosis breeding since it expressed high values for numbers of fruit per plant, shoot borer infestation, little leaf incidence, total phenols content and fruit yield per plant. Hybrids $L_5 \times T_3$, $L_5 \times T_4$ and $L_7 \times T_2$ could be the next best for high values under those 3 criteria for 4 and 3 traits, respectively. For hybrids based on average performance, SCA effects and standard heterosis, hybrids 'Alagarkovil Local' × 'Annamalai' ($L_4 \times T_1$), 'Palamedu Local' × 'Punjab Sadabahar' ($L_5 \times T_3$), 'Palamedu Local' × 'EP 65' ($L_5 \times T_4$) and 'Keerikai Local' × 'KKM 1' ($L_7 \times T_2$) were suitable for heterosis breeding.

The F1 hybrids 'Keerikai Local' × 'KKM 1' ($L_7 \times T_2$) and 'Alavayal Local' × 'Annamalai' ($L_1 \times T_1$) had the highest yield, respectively; higher than performance of other hybrids, male parent, female parent and commercial varieties. The F1 hybrid 'Keerikai Local' × 'KKM 1' had positive heterosis for calyx length, total phenol content and fruit yield per plant; F1 hybrid 'Alavayal Local' × 'Annamalai' had positive heterosis for fruit pedicel length, ascorbic acid content and fruit yield per plant. Although there were no parental varieties which showed good appearance in all traits, some parents had a high mean value in some characteristics. These are useful in breeding to improve fruit yield and qualities of commercial varieties.

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REFERENCES

Abhinav S, Nandan M (2010). Heterosis in relation to combining ability for yield and quality attributes in Brinjal (*Solanum melongena* L.). Elect. J. Plant Breed. 1(4):783-788.

AOAC (2001). Official methods of analysis. Association of Official Analytical Chemists, Washington D.C., U.S.A

Anonymous (2010).Area, production and productivity of brinjal in India during 2009-2010, www.indiastat.com.

Bray HG, Thrope WV (1954). Analysis of phenolic compounds of interest in metabolism. Meth. Biochem. Anal. 1:27-52.

Dhankhar BS, Singh K (1984). Path analysis for fruit yield and its components in brinjal (*Solanum melongena* L.). Haryana J. Hort. Sci., 12: 38-41.

Chandra V, Singh B, Singh A, Kapoor LD (1970). Variation in the solasodine content of fruits of *Solanum khasianum* at different stages of development in Lucknow. Indian For. 96:352-360.

Chaudhary B (1976).Vegetables (4th Edn.), National Book Trust, New Delhi, pp. 50-58.

Chaudhary DR, Malhotra SK (2000). Combining ability of physiological and growth parameters in eggplant (*Solanum melongena* L.). Indian J. Agric. Res. 34(1):55-58.

Chowdhury MJ, Ahmad S, Nazim UM, Quamruzzaman AKM, Patwary MMA (2010). Expression of heterosis for productive traits in F1 brinjal (*Solanum melongena* L.) hybrids. Agriculturists 8(2):8-13.

Das G, Barua NS (2001). Heterosis and combining ability for yield and its components in eggplant. Ann. Agric. New Series. 22(3):399-403.

Dhillion BS (1975). The application of partial diallel crosses in plant breeding – A review. Crop Improv. 2:17.

Fonseca S, Patterson FL (1968). Hybrid vigour in a seven parent diallel crosses in common winter wheat (*Triticum aestivum* L.). Crop Sci. 8:85-88.

Kadambavanasundaram M (1980). Heterotic system in cultivated species of *Gossypium*. An appraisal (Abst). Genetic and crop improvement of heterotic systems. In: Pre-congress scientific meeting of XV international congress of genetics, TNAU, Coimbatore. P. 20.

Pachiyappan R, Saravanan K, Kumar R (2012). Heterosis is yield and yield components in eggplant (*Solanum melongena* L.). Int. J. Curr. Agric. Sci. 2(6):17-19.

Panse and Sukhatme (1967).Statistical methods for Agricultural workers.

Panse VG (1942).The inheritance of quatitative characters and plant breeding:http://www.ias.ac.in/jarch/jgenet/40/283.pdf pp. 284-302.

Prabakaran S (2010). Evaluation of local types of brinjal (*Solanum melongena* L.). M.Sc., (Hort.) Thesis, Agricultural College and Research Institute, TNAU, Madurai.

Turner JR (1953). A study on heterosis in upland cotton II. Combining ability and inbreeding effects. Agron. J. 45:487-490.