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Heterosis studies for yield and yield attributing traits in brinjal (*Solanum melongena* L.)

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Abstract
The magnitude of heterosis in different hybrids is the basic prerequisite for the identification of hybrid combinations that exhibit a high level of exploitable heterosis. The analysis of variance due to genotypes is highly significant for all the characters except for the plant spread. Heterosis was assessed for yield and yield attributing traits and the top five hybrids *viz*., Bili Chandu Badane x Mullugai Badane, Bili Udda Badane x Mullugai Badane, 40 A Badane x Mullugai Badane, Desi Jawari Badane x Mullugai Badane, and Nati Badane x Mullugai Badane exhibited significant positive heterosis for yield per plant over the standard check. Among twenty-one hybrids, eight hybrids over the mid parent, four hybrids over the better parent, and nine hybrids over standard check recorded positive significant heterosis.

Keywords: Dominant-gene, heterosis, heterozygosis, hybrid, productivity

Introduction
Eggplant (*Solanum melongena* L.) is also known as Brinjal, which is a nutritionally and commercially important vegetable of the Solanaceous family. It has a wide range of variability in the world and has originated from India. It is grown in all the parts of India in all seasons throughout the year. Brinjal is widely grown for immature fruits and used as vegetables in both subtropical and tropical regions of the world. Brinjal is called as a "vegetable of masses" as it is popularly grown by people of different cultures. In India based on consumer preferences different cultivars with different fruit colors, sizes, shapes, tastes, are being grown.

Crop improvement includes different strategies to enhance the yield potentiality and quality components. The selecting of parents on it's per se performance basis is a very common approach and will not yield fruit full results. The phenomenon of heterosis in plants is well known today and we exploit it to increase yield in crop plants and is an efficient approach for the improvement of vegetable crops. Heterosis refers to the superiority of F_1 hybrids in one or more characters over its parents and also refers to an increase in vigour and fitness over the parental values in F_1 hybrids. Heterosis was coined by Shull (1908) and referred to this phenomenon as the stimulus of heterozygosis. The harmful recessive genes are masked by the dominant genes thus recessive mutants are not expressed.

Breeding for higher heterosis in many crops for yield characters depends on the choice of parents and the genetic distance between the two parents which are used for developing the hybrids. For self-pollinated crop improvement, breeding methods should be based on the nature and magnitude of genetic variance that governs the inheritance of quantitative characters as per Joshi and Dhawan (1966). After the crossing program, the Line x Tester mating design can be used precisely to identify the best cross combinations based on the heterosis.

The basic requirement for identifying crosses that exhibit a high amount of exploitable heterosis in different cross combinations is the magnitude of heterosis. India is the centre of origin for Brinjal, which has a huge genetic divergence and this offers higher scope for improvement through heterosis breeding. Because of the characters of Brinjal, like a large number of seeds that can be obtained in a single act of pollination, the larger size of flowers, and also hardy nature, it has become a crop of interest for heterosis exploitation. With this background, the present study has been conducted during the season *Kharif* 2016-17.

Material and Methods
The research work has been conducted at ZAHRS, Navile, Shivamogga. In the proposed research work, among the 80 germplasm lines collected from OFRC material, 30 superior germplasm lines were identified.

During the first season in *Kharif* 2016, the seeds were sown in the trays and 35 days old seedlings were transplanted to the polyhouse. The crossed progenies were developed by the line x tester method. To develop the crosses three testers were selected based on the different types of thorns like tester1 (T1) purple thorns everywhere, tester2 (T2) green thorns everywhere, tester3 (T3) Green thorns on the calyx. Ten lines were selected based on general fruit characters and were named L1, L2, L3, L4, L5, L6, and L7. The evaluation of 21 F_1 hybrids was conducted during the season Rabi - 2016-17. This research has been conducted in 3 replications in Randomized Complete Block Design. The observations of parents and F_1 hybrids was recorded for the characters like days to first flowering, days to 50 percent flowering, days to maturity, plant height (cm), plant spread (cm), number of branches, leaf length (cm), leaf width (cm), flowers per cluster, fruits per cluster, fruit length (cm), fruit diameter (cm), fruit length to diameter ratio, fruit weight (g), number of fruits per plant, fruit yield per plant (kg), fruit yield per hectare (q). The details about the material used in the research work are mentioned below:

S. No.	Lines	Name of the genotypes	Source
1	L1	Bili Udda Badane	OFRC, UAHS, Shivamogga
2	L2	40 A Badane	OFRC, UAHS, Shivamogga
3	L3	Nati Badane	OFRC, UAHS, Shivamogga
4	L4	Thailand Badane	OFRC, UAHS, Shivamogga
5	L5	Sakleshpur Badane	OFRC, UAHS, Shivamogga
6	L6	Bili Chandu Badane	OFRC, UAHS, Shivamogga
7	L7	Desi Jawari Badane	OFRC, UAHS, Shivamogga
	Testers		
1	T1	Dodda Mullina Badane	OFRC, UAHS, Shivamogga
2	T2	Mullugai Badane	OFRC, UAHS, Shivamogga
3	T3	Doral Badane	OFRC, UAHS, Shivamogga
	Check		
1	C1	Private Company Seeds	Local market

Results and Discussion

The analysis of variance for seventeen different yield and yield attributing traits is presented in Table 1. The variance due to genotypes and parents was highly significant for all the characters under study except for plant spread. The variance due to parents vs. crosses was significant for all the characters except for plant spread, number of branches, number of fruits, leaf length, leaf width, and flowers per cluster. Variance due to crosses was non-significant for plant height, plant spread, and number of branches whereas variance due to line x tester effect showed a non-significant difference for plant height, plant spread, number of branches, and leaf length. The variance due to the line effect observed a significant difference in fruit length, fruit length to fruit diameter ratio, and the number of fruits per plant. The variance due to the tester effect observed a non-significant difference for all the yield and yield attributing traits under the study. The results obtained were in accordance with Abhinav and Nandan (2010) [1], Leena Biswas *et al.* (2013) [6], Paramappa *et al.* (2014) [7], Raghvendra dubey *et al.* (2014) [8], Ramesh Kumar *et al.* (2012) [9], Reddy and Patel (2014) [10], Shafeeq *et al.* (2007) [11], Shanmugapriya *et al.* (2009) [12], Suneetha *et al.* (2008) [13], VenkataNaresh *et al.* (2014) [14].

The analysis by line x tester design revealed that there is highly significant heterosis both in the positive direction and negative direction due to variation between the parents. In the present study, the heterosis over the mid parent, better parent, and the standard check was found to be highly variable in desirable direction and magnitude among hybrids, for all the characters except plant spread over better parent and number of branches over the standard check.

The heterosis over standard check was beneficial and the range of useful heterosis in percent for days to first flowering is from 11.57 to -14.36, days to fifty percent flowering is from 6.07 to -21.44, days to maturity is from 9.85 to -9.14, plant height is with the range from 18.27 to 64.36, plant spread is from -3.34 to 40.92, the number of branches ranges from 0.93 to 50, leaf length is between -3.11 to 38, leaf width is from -10.99 to 66.39, flowers per cluster were observed in between -37.21 to 20.93, fruits per cluster -28 to 56, fruit length is from -35.6 to 90.03, fruit diameter is from -22.47 to 35.86, the ratio of fruit length to diameter is between -40.51 to 97.21, Fruit weight is from -43.28 to 194.03, the number of fruits ranges between -49.04 to 27.88, fruit yield per plant ranges between -32.59 to 65.75 and fruit yield per hectare was from -32.59 to 65.75.

The *perse* performance and heterosis was found superior over standard check in five cross combinations *i.e.*, Bili Chandu badane x Mullugai badane, Bili Udda badane x Mullugai badane, 40 A badane x Mullugai badane, Desi Jawari badane x Mullugai badane and Nati badane x Mullugai badane with respect to yield per plant. Among twenty-one hybrids, eight hybrids over the mid parent, four hybrids over the better parent, and nine hybrids over standard check recorded positive significant heterosis. Three hybrids over the mid parent, six hybrids over the better parent, and one hybrid over standard check recorded significant negative heterosis for yield per plant as mentioned in Table 2, similar results *i.e* the positive heterosis for yield and yield attributing traits was observed by Chowdhury *et al.* (2010) [2], Desai *et al.* (2016) [3], Makani *et al.* (2013) [4], Nalini *et al.* (2011) [5], Raghvendra dubey *et al.* (2014) [8], Ramesh Kumar *et al.* (2012) [9], Reddy and Patel (2014) [10], Shafeeq *et al.* (2007) [11], Suneetha *et al.* (2008) [13], VenkataNaresh *et al.* (2014) [14].

Table 1: Analysis of variance (mean sum of squares) for 21 hybrids and 10 parents in line x tester for 17 different yield and yield attributing traits in brinjal

	df	DTFF	DTFIF	DTM	PH	PS	NOB	LL	LW	Flo/C
Replicates	2	1.25688	6.533	8.82267	71.89389	107.30045	2.58968	10.12238	0.92349	0.11742
Genotypes	30	59.46364**	98.91688**	88.93820**	134.01367*	131.44051	10.90196**	4.93956**	4.41969**	0.55662**
Parents	9	79.77200**	141.176**	131.354**	191.80484*	119.51292	28.10133**	7.16416**	3.76427**	0.59793*
Parents vs. crosses	1	88.89246**	297.34433**	87.36085**	590.33714**	10.34562	0.93042	0.04372	1.35942	0.23399
Crosses	20	48.85343**	69.979**	69.930**	85.191	142.863	3.661	4.183*	4.868**	0.554*
Line Effect	6	24.933	20.700	17.451	86.668	39.718	4.929	7.048	5.343	0.573
Tester Effect	2	14.792	77.855	10.763	145.111	351.419	1.566	3.449	3.508	0.256
Line x Tester Effect	12	66.491**	93.305**	106.031**	74.467	159.676	3.376	2.873	4.857**	0.594*
Error	60	12.37221	15.653	9.83413	73.38178	84.63183	4.07857	2.15441	0.93753	0.26320
Total	92	27.48648	42.606	35.60695	93.12070	100.38833	6.27122	3.23583	2.07271	0.35571

*, ** indicate the level of significance at 5% and 1% respectively

DTFF: Days to first flowering
DTFIF: Days to fifty per cent flowering
DTM: Days to maturity
PH: Plant height (cm)
PS: Plant spread (cm)
NOB: Number of branches
LL: Leaf length (cm)
LW: Leaf width (cm)
Flo/C: Flowers per cluster

Table 1: Cont.…...

	df	F/C	FL	FD	FL/FD	FW	NOF	FY/P	Y/H
Replicates	2	0.17720	0.52785	0.37776	0.03198	62.46237	1.67742	0.12331	39.952
Genotypes	30	0.50887**	21.85098**	1.79608**	2.68599**	2018.64158**	187.85376**	0.48650**	157.62447**
Parents	9	0.78459**	31.72647**	3.11511**	6.62602**	1365.18889**	132.94815**	0.34238**	110.92975**
Parents vs. crosses	1	0.92490*	15.43947**	0.68141*	2.14147**	1458.45207**	28.19068	1.43911**	466.27215**
Crosses	20	0.364*	17.728**	1.258**	0.940**	2340.705**	220.544**	0.504**	163.205**
Line Effect	6	0.652	49.898**	0.688	2.701**	3754.460	474.852*	0.331	107.188
Tester Effect	2	0.036	0.746	1.646	0.090	3099.190	146.016	1.269	411.285
Line x Tester Effect	12	0.275*	4.473**	1.479**	0.202**	1507.413**	105.812**	0.463**	149.866**
Error	60	0.19365	0.59446	0.14665	0.01665	27.55125	8.44409	0.03066	9.93319
Total	92	0.29608	7.52449	0.68953	0.88742	677.57878	66.80014	0.18131	58.74598

*, ** indicate the level of significance at 5% and 1% respectively

F/C: Fruits per cluster
FL: Fruit length (cm)
FD: Fruit diameter (cm)
FL/FD: Fruit length to diameter ratio
FW: Fruit weight (g)
NOF: Number of fruits
FY/P: Fruit yield per plant (kg)
Y/H: Fruit yield per hectare (q)

Table 2: Heterosis (%) range over mid parent, better parent and standard checks for yield and yield attributing characters in hybrids of brinjal

S. No.	Characters	MP	BP	SC
1	Days to first flowering	9.68 to -22.85	-0.83 to -23.12	11.57 to -14.36
2	Days to fifty per cent flowering	5.54 to -25.64	-2.33 to -29.02	6.07 to -21.44
3	Days to maturity	6.7 to -19.59	2.21 to -22.31	9.85 to -9.14
4	Plant height (cm)	-25.82 to 13.52	-28.81 to 11.02	18.27 to 64.36
5	Plant spread (cm)	-19.2 to 27.55	-19.66 to 21.84	-3.34 to 40.92
6	Number of branches	-38.59 to 67.39	-50.68 to 39.25	0.93 to 50
7	Leaf length (cm)	-15.59 to 25.25	-18.2 to 21.81	-3.11 to 38
8	Leaf width (cm)	-21.96 to 44.21	-30.94 to 40.63	-10.99 to 66.39
9	Flowers per cluster	-37.93 to 31.65	-42.55 to 25	-37.21 to 20.93
10	Fruits per cluster	-35.38 to 77.27	-50 to 69.57	-28 to 56
11	Fruit length (cm)	-49.48 to 16.02	-60.87 to -9.13	-35.6 to 90.03
12	Fruit diameter (cm)	-33.37 to 27.43	-38.24 to 12.56	-22.47 to 35.86
13	Ratio of fruit length to diameter	-47.81 to 27.49	-58.13 to 6.32	-40.51 to 97.21
14	Fruit weight (g)	-57.85 to 179.81	-65.45 to 173.39	-43.28 to 194.03
15	Number of fruits	-46.15 to 69.33	-55.08 to 45.98	-49.04 to 27.88
16	Fruit yield per plant (kg)	-30.8 to 73.23	-47.53 to 48.11	-32.59 to 65.75
17	Fruit yield per hectare (q)	-30.8 to 73.23	-47.53 to 48.11	-32.59 to 65.75

MP: Mid parent, BP: Better parent and, SC: Standard check

Conclusion

Hybrids offer opportunities for improvement in earliness, uniformity, productivity, quality, wider adaptability, and rapid deployment of dominant genes for resistance to disease and pests. Hence, these hybrids were evaluated, and combining ability was estimated. Heterosis was recorded for yield and yield attributing traits and the top five hybrids *viz*., Bili Chandu Badane x Mullugai Badane, Bili Udda Badane x Mullugai Badane, 40 A Badane x Mullugai Badane, Desi Jawari Badane x Mullugai Badane and Nati Badane x Mullugai Badane exhibited significant positive heterosis for yield per plant over the standard check.

The five hybrids Bili Chandu Badane x Mullugai Badane, Bili Udda Badane x Mullugai Badane, 40 A Badane x Mullugai Badane, Desi Jawari Badane x Mullugai Badane and Nati Badane x Mullugai Badane were superior for the yielding character over standard check-in positive significant direction and can be said as a productive cross combination. These

superior hybrids can be forwarded to the next generation to obtain superior segregants. The superior hybrids can be tested in multi-location trials to confirm their potentiality over different environmental conditions.

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