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Studies on Combining Ability in Eggplant (*Solanum melongena* L.) for Yield and Its Component

Pramila[1*], M. L. Kushwaha[2], Udit Kumar[1], Ramesh Kumar Gupta[1] and Bishwa Mitra Sinha[1]

[1]Department of Horticulture, Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur, Bihar, 848125, India.
[2]Department of Vegetable Science, G.B. Pant University and Technology, Pantnagar, 263145, Uttarakhand, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author Pramila designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MLK and UK managed the analyses of the study. Authors RKG and BMS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Present investigation was carried out during autumn winter season 2013-14 and 2014-15 at the Vegetable Research Centre of GBPUA&T, Pantnagar with 43 genotypes including 10 lines, 3 testers and 30 F_1s of brinjal. The experiment was laid out in Randomized Block Design with three replications. The observations were recorded for 11 characters. Variances due to testers were greater than variances due to lines for most of the characters. The estimates of General Combining Ability (GCA) effect indicated that PB71, BB85, PB66, Swarn Syamli and DBL02 were best general combiner for earliness (days to 50% flowering), whereas the best specific cross was BRLVAR6 × DBL02. For weight of marketable fruits per plant PB66, SMB115, LC7, BRLVAR6 were best general combiners and SMB115 × DBL02, PB66 × Pant Samrat and IBWL 2001-1 × Pant Rituraj were best specific combiners. Pant Rituraj was found best general combining effect for plant height, fruit diameter, weight of marketable fruits per plant, number of unmarketable fruits per plant, total yield per plant and total yield per hectare. Pant Samrat showed good General Combining Ability (GCA)

**Corresponding author: E-mail: prmtca@gmail.com;*

effects for number of primary branches per plant, number of marketable fruits per plant, weight of unmarketable fruits per plant and total number of fruits per plant. DBL02 was recorded best general combiner for earliness and fruit length. SMB115 and PB 66 were best general combiners for most of the yield characters. SMB115 × DBL02, PB66 × Pant Samrat and IBWL2001-1 × Pant Rituraj were showed highest Specific Combining Ability (SCA) effect for most of the characters. Therefore, these cross combinations could be commercially exploited for higher yield.

Keywords: Eggplant; General Combining Ability (GCA); Specific Combining Ability (SCA); line x tester.

1. INTRODUCTION

Brinjal (*Solanum melongena* L.) is one of the important Solanaceous vegetable crops. It is widely cultivated in both temperate and tropical region of the world. Its immature fruits are generally used as vegetable and other culinary preparations. Brinjal cultivated extensively in different parts of India and considered to be one of the most remunerative vegetables [1]. It is popular among people of all social strata and hence it is rightly called as vegetable of masses [2]. Eggplant contains a higher content of free reducing sugars, anthocyanin, phenols, glycoalkaloids (solasodine) and amide proteins. Bitterness in eggplant is due to the presence of saponins and glycoalkaloids) [3]. Eggplant is well known for its medicinal properties and has also been recommended as an excellent remedy for liver complaints and diabetic patients [4]. Due to the multiple health benefits of eggplant, which include anti-oxidant, anti-diabetic, hypotensive, cardio protective and hepatoprotective effects, the demand for eggplant has been on a rapid and steady rise in the recent years [5]. Combining ability of brinjal was studied by several worker of India. Combining ability is pre-requisite in any plant breeding programme either for varietal improvement or for evolving a hybrid. The knowledge of general combining ability and specific combining ability help to choose better parents and better hybrids respectively. Line × Tester analysis is proved to be useful technique for screening large number of genotypes. The present investigation formulated to investigate the combining ability effects by using ten lines and three testers analysis in brinjal as suggested by [6]. In this investigation we have to identify potential parental combination in order to have superior hybrids with high yield potential.

2. MATERIALS AND METHODS

The present investigation is carried out at Vegetable Research Centre of Govind Ballabh Pant University of Agriculture and Technology (G.B.P.U.A&T) Pantnagar, Udham Singh Nagar (Uttarakhand), India during autumn-winter season, 2013-14 and 2014-15.Thirteen diverse genotypes of brinjal including ten lines and three testers and thirty hybrids produced from these parents were used as a plant material for study. The genotypes were Swarn Syamli, PB71, BARI, SMB115, BB85, BRLVAR6, IBWL2001-1, PB66, LC7 and PB70 is used as female parents whereas, Pant Rituraj, Pant Samrat and DBL02 were used as male parents. The hybrids and parents were evaluated in Randomized Block Design with three replications for eleven fruit yield and yield component characters viz. day's to 50% flowering, number of primary branches per plant, Plant height (cm), Fruit length(cm), Fruit diameter (mm), number of marketable fruits per plant, weight of marketable fruits per plant (kg), number of unmarketable fruits per plant, weight of unmarketable fruits per plant (kg), total number of fruits per plant and total weight of fruits per plant (kg).

The seed of thirteen parents and thirty hybrids were sown in nursery on 14.6.2013 and transplanted on 20.7.2013 for 1st year evaluation and 2nd in 2014-15, nursery was sown on 16.6.2014 and transplanted on 16.7.2014. Each genotype were transplanted in single row plot of 6 meter length, with spacing 75×60 cm and crop was raised following recommended packages of practices.

Data was recorded on five random plant tagged for each entry in each replication and average values were computed. The analysis of general and specific combining ability for eleven characters was done as per model suggested by [6] pooled data of analysis of variance for combining ability, general combining ability and specific combining ability were also calculated.

3. RESULTS AND DISCUSSION

Analysis of variance for combining ability was done for all the eleven characters for both the years respectively and pooled results are presented in Table 1.

Table 1. Analysis of variance (Mean sum square) for combining ability pooled

Source of variations	df	Days to 50% flowering	No. of primary branches/plant	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of Marketable fruits/plant	No. of Unmarketable fruits/plant	Wt. of Marketable fruits/plant (Kg)	Wt. of Unmarketable fruits/plant (Kg)	Total number of fruits/plant	Total yield/plant (Kg)
Replicates	2.00	0.05	0.01	56.55	2.03	22.94	13.83	0.26	0.04	0.00	6.4080	0.0301
Treatments	42.00	210.90**	2.84**	295.58**	88.56**	1362.33**	248.62**	19.52**	0.91**	0.18**	368.0721**	1.7462**
Parents	12.00	289.65**	3.00**	483.86**	149.23**	2094.45**	147.12**	13.02**	0.45**	0.18**	226.7243**	1.0808**
Parent vs Crosses	1.00	169.11**	5.09**	1455.30**	107.48**	896.55**	1066.85**	40.21**	10.28**	1.22**	1521.3169**	18.5910**
Crosses	29.00	179.76**	2.70**	177.68**	62.80**	1075.45**	262.40**	21.50**	0.78**	0.15**	386.7937**	1.4406**
Line effect	9.00	362.67**	4.67*	233.29	93.18**	581.80	377.45*	39.57*	1.02	0.17	629.5616*	1.7802
Tester effect	2.00	780.00**	4.11	557.68*	294.63**	10231.47**	800.70*	18.08	0.97	0.26	1007.0502*	2.0587
Line × Tester effect	18.00	21.60**	1.56**	107.65**	21.84**	304.94**	145.07**	12.84**	0.64**	0.12**	196.4924**	1.2022**
Error	168.00	4.39	0.12	30.64	2.42	19.94	4.48	0.04	0.03	0.00	4.8195	0.0268

** indicates level of significance at 5%, ** indicates level of significance at 1%*

Table 2. Genetic components of variance

Characters	Season	σ^2gca (lines)	σ^2gca (testers)	σ^2gca (average)	σ^2sca	σ^2gca/ σ^2sca
Days to 50% Flowering	pooled	19.89	12.92	14.53	2.82	5.15
Number of primary branches/plant	Pooled	0.25	0.07	0.11	0.24	0.46
Plant height (cm)	Pooled	11.38	8.82	9.41	13.20	0.71
Fruit length (cm)	Pooled	5.09	4.88	4.93	3.38	1.46
Fruit diameter (mm)	Pooled	31.51	170.28	138.26	48.39	2.86
No. of marketable fruits/plant	Pooled	20.71	13.27	14.98	23.39	0.64
No. of unmarketable fruits/plant	pooled	2.19	0.30	0.74	2.13	0.35
Wt. of marketable fruits/plant (Kg)	pooled	0.05	0.02	0.02	0.10	0.20
Wt. of unmarketable fruits/plant (Kg)	pooled	0.01	0.00	0.01	0.02	0.50
Total numbers of fruits/plant	pooled	34.71	16.71	20.86	31.96	0.65
Total yield /plant (Kg)	pooled	0.10	0.03	0.05	0.19	0.26

The analysis of variance revealed that mean sum square due to lines was recorded highest for total number of fruits per plant, number of marketable fruits per plant, days to 5% flowering, fruit length, number of unmarketable fruits per plant and number of primary branches per plant. Variance due to tester was significant in fruit diameter followed by total number of fruits per plant, number of marketable fruits per plant, days to 50% flowering, plant height and fruit length. Variance due to line × tester effect was significant for all the characters, indicating importance of additive component of genetic variance in the inheritance of these characters. The genetic component of variance presented in Table 2. Which depicted that the gca/sca variance ratio being less than unity for most of the characters except day's to 50% flowering, fruit length and fruit diameter indicating the greater role of non additive genetic variance in the inheritance of these traits. Thus these traits might be governed by dominance, additive × dominance and/or dominance ×dominance epistatis. Similar results have been obtained by [7-15].

3.1 General Combining Ability

The estimates of gca of ten lines & three testers for all eleven characters were presented Table 3. This table is also indicates the pooled data over the season in which females lines PB71 followed by BB85, PB 66 and Swarn Syamli considered desirable for days to 50% flowering among lines and DBL02 among testers. As earliness is desirable character therefore, negative gca effect is desirable to days to 50% flowering. The general combining ability includes both additive, additive × additive types of gene action [16] which is fixable in nature. Additive parental effect measured by gca effect are practical importance where as non allelic interaction cannot manipulated easily. Rank wise gca performance of genotypes for different characters were depicted in Table 5.

It was found that out of thirteen parental lines, nine line except IVWL2001-1 and two testers Pant Rituraj and DBL02 were good general combiners for eight to ten characters , the result in agreement with the work of [17,7,8,18,9,10, 19,20,13].

The basic idea of hybridization is to combine favourable gene present in different parents into a single genotype. To get out standing recombinants in segregating generations the parents of the hybrid must be good general combiners for the characters for which improvement is required. In case of hybrids with significant sca effects reflected in early segregating generation is likely to fail as the sca effect mask the true performance of the selected plant. Therefore, it will be useful to select those hybrids with parents showing significant gca and non significant sca effect for recombination breeding. Since it is likely to get segregants with fevourable genes derived from both parents [21,10]. Parents with high gca were found to produce high yielding cross combination [22,23,10].

Table 3. General combining ability effects of the parents pooled

Sl. no.	Treatments	Days to 50% flowering	No. of primary branches/plant	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits/plant	No. of unmarketable fruits/plant	Wt. of marketable fruits/plant (Kg)	Wt. of unmarketable fruits/plant (Kg)	Total number of fruits/ plant	Total yield/plant (Kg)
	Lines											
1	SwarnSyamli	-0.08	-0.20	-0.01	-3.21**	5.47**	2.98**	-0.28**	-0.22**	-0.12**	2.70**	-0.34**
2	PB71	-5.58**	0.31**	3.99**	-0.46	-1.30	-1.128*	-0.75**	-0.19**	-0.02**	-1.87**	-0.21**
3	BARI	6.31**	-0.31**	-0.32	4.74**	-10.45**	-1.99**	0.27**	-0.34**	-0.12**	-1.73**	-0.46**
4	SMB115	1.69**	-0.17	-1.97	-1.67**	-3.40**	5.94**	1.08**	0.28**	0.04**	7.02**	0.32**
5	BB85	-4.86**	-0.39**	-0.52	-1.85**	1.30	3.40**	0.81**	-0.08	-0.03**	4.21**	-0.10*
6	BRLVAR6	5.03**	0.89**	5.29**	-0.63*	-0.04	-1.14*	-0.26**	0.15**	0.04**	-1.40**	0.18**
7	IBWL2001-1	-4.03**	-0.77**	-0.63	1.51**	-5.03**	-0.11	0.83**	-0.04	0.10**	0.72	0.06
8	PB 66	-4.53**	-0.01	-4.23**	2.01**	-1.36	5.56**	2.65**	0.37**	0.19**	8.21**	0.56**
9	LC7	4.36**	-0.09	-5.74**	-0.78**	7.33**	-5.32**	-2.13**	0.21**	-0.06**	-7.45**	0.15**
10	PB70	1.69**	0.73**	4.15**	0.34	7.48**	-8.20**	-2.22**	-0.15**	-0.03**	-10.42**	-0.18**
	SE (gi)	0.72	0.12	1.77	.42	1.27	0.72	0.06	0.06	0.00	0.73	0.06
	Tester											
1	Pant Samrat	-1.00	0.28**	1.23	0.31	-8.46**	4.22**	0.50**	-0.07**	-0.07**	4.719**	-0.134
2	Pant Rituraj	4.00**	-0.23**	2.24**	-2.35**	15.04**	-2.06**	-0.59**	0.15**	0.06**	-2.651**	0.211**
3	DBL02	-3.00**	-0.05	-3.47**	2.05**	-6.58**	-2.15**	0.09**	-0.08**	0.00	-2.067**	-0.078**
	SE(gj)	0.40	0.06	0.97	0.23	0.70	0.40	0.03	0.03	0.00	0.40	0.03

** indicates level of significance at 5%, ** indicates level of significance at 1%*

Table 4. Specific combining ability effects of the crosses pooled

Treatments	Days to 50% flowering	No. of primary branches/ Plant	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits/plant	No. of unmarketable fruits/plant	Wt. of marketable fruits/plant (Kg)	Wt. of unmarketable fruits/plant (Kg)	Total no. of fruits/plant	Total yield/plant (Kg)
SwarnSyamli × Pant Samrat	1.17	0.67**	1.99	-0.40	-8.25**	3.08**	-2.49**	-0.34**	-0.21**	0.59	-0.55**
SwarnSyamli × Pant Rituraj	0.33	-0.04	1.88	0.75	7.13**	-1.69	-0.46**	0.02	-0.06**	-2.15*	-0.04
SwarnSyamli × DBL02	-1.50	-0.63**	-3.87	-0.34	1.12	-1.39	2.95**	0.32**	0.27**	1.56	0.59**
PB71 Pant × Samrat	1.33	0.20	4.66*	-0.77	2.47	1.33	-0.02	0.21**	0.12**	1.32	0.33**
PB71 × Pant Rituraj	-1.17	0.15	1.51	-1.03*	-4.88**	4.39**	0.70**	0.17*	0.04**	5.09**	0.22**
PB71 × DBL 02	-0.17	-0.34*	-6.17**	1.80**	2.41	-5.72*8	-0.69**	-0.38**	-0.16**	-6.41**	-0.55**

Treatments	Days to 50% flowering	No. of primary branches/ Plant	Plant height (cm)	Fruit length (cm)	Fruit diameter (mm)	No. of marketable fruits/plant	No. of unmarketable fruits/plant	Wt. of marketable fruits/plant (Kg)	Wt. of unmarketable fruits/plant (Kg)	Total no. of fruits/plant	Total yield/plant (Kg)
BARI × Pant Samrat	-0.72	-0.12	-2.50	-2.51**	10.99**	-1.72	-0.56**	-0.03	0.05**	-2.28*	0.03
BARI × Pant Rituraj	-0.56	0.07	-1.08	0.97	-12.46**	-0.51	-0.10	-0.08	-0.04**	-0.60	-0.12
BARI × DBL02	1.28	0.05	3.57	1.55**	1.47	2.23*	0.66**	0.10	-0.02**	2.88**	0.09
SMB115 × Pant Samrat	1.06	0.24	5.82**	-0.17	-2.93	-7.94**	0.33**	-0.25**	0.09**	-7.61**	-0.16*
SMB115 × Pant Rituraj	-1.11	0.49**	-6.50**	-1.38**	2.26	-1.89*	-1.38**	-0.45**	-0.18**	-3.27**	-0.63**
SMB115 × DBL02	0.06	-0.73**	0.68	1.54**	0.68	9.83**	1.05**	0.70**	0.09**	10.88**	0.79**
BB85 × Pant Samrat	-1.22	-0.24	-5.03*	-0.20	0.08	1.73	0.29**	0.07	0.01	2.02*	0.07
BB85 × Pant Rituraj	0.61	-0.15	0.66	-0.49	1.42	-4.60**	-0.06	-0.17*	-0.04**	-4.66**	-0.21**
BB85 × DBL02	0.61	0.39**	4.37*	0.70	-1.50	2.87**	-0.23**	0.10	0.03**	2.64**	0.13
BRLVAR6 × Pant Samrat	2.56**	0.12	-2.64	1.33*	4.41**	-1.37	-0.56**	0.01	-0.01	-1.93*	0.00
BRLVAR6 × Pant Rituraj	1.22	0.13	2.45	1.34**	6.76**	1.20	0.40**	0.27**	0.09**	1.60	0.35**
BRLVAR6 ×DBL02	-3.78**	-0.25	0.19	-2.67**	-11.17**	0.17	0.16*	-0.28**	-0.08**	0.33	-0.36**
IBWL2001-1 × Pant Samrat	-1.56	-0.09	3.12	-2.21**	-4.32**	-0.76	0.68**	-0.05	-0.08**	-0.08	-0.13
IBWL2001-1 × Pant Rituraj	-0.89	-0.04	-1.63	0.81	8.47**	2.06*	-0.36**	0.36**	0.19**	1.70	0.55**
IBWL2001-1 × DBL02	2.44**	0.14	-1.48	1.40**	-4.15**	-1.30	-0.32**	-0.31**	-0.11**	-1.62	-0.42**
PB66 × Pant Samrat	0.11	0.15	0.92	1.15*	-0.15	9.09**	2.93**	0.40**	0.12**	12.02**	0.52**
PB66 × PantRituraj	-1.39	-0.20	-0.53	1.28*	-6.38**	-1.79*	-0.49**	-0.27**	-0.16**	-2.28*	-0.43**
PB66 × DBL02	1.28	0.05	-0.38	-2.44**	6.54**	-7.30**	-2.44**	-0.13	0.03**	-9.74**	-0.10
LC7 ×Pant Samrat	-1.61	0.10	-4.74*	0.48	3.50*	-1.06	-0.11	0.04	0.00	-1.17	0.04
LC7× Pant Rituraj	0.22	-0.39*	-0.35	-0.92	-3.90*	1.94*	0.69**	0.01	-0.01	2.63**	0.00
LC7 × DBL02	1.39	0.29	5.09*	0.44	0.40	-0.88	-0.58**	-0.05	0.01	-1.46	-0.05
PB70× Pant Samrat	-1.11	-1.03**	-1.60	3.31**	-5.79**	-2.38**	-0.50**	-0.06	-0.10**	-2.88**	-0.16*
PB70× Pant Rituraj	2.72**	-0.01	3.60	-1.33*	1.59	0.89	1.06**	0.14	0.17**	1.94*	0.31**
PB70 × DBL02	-1.61	1.04**	-2.00	-1.98**	4.21**	1.50	-0.56**	-0.08	-0.07**	0.94	-0.15
CD 95% SCA	1.75	0.29	4.31	1.01	3.09	1.76	0.15	0.15	0.01	1.76	0.15

** indicates level of significance at 5%, ** indicates level of significance at 1%*

Table 5. Ranking of genotypes as per GCA and SCA performance

S. no.	Characters	Best general combiners	Best specific combiners
1.	Days to 50% flowering	PB71, BB85, PB66, DBL02	BRLVAR6 ×DBL02, PB70 × DBL02
2.	Number of primary branches/ plant	BRLVAR6, PB70, PB71, Pant Samrat	PB70 × DBL02, SwarnSyamli × Pant Samrat
3.	Plant height (cm)	BRLVAR6, PB70, PB71, Pant Rituraj	SMB115 × Pant Samrat, LC7 × DBL02
4.	Fruit length (cm)	BARI, PB66, IBWL2001-1,DBL02	PB70 × Pant Samrat, PB 71 × DBL02
5.	Fruit diameter (mm)	PB70, LC7, SwarnSyamli,PantRituraj	BARI × Pant Samrat, IBWL 2001-1 × Pant Rituraj
6.	Number of marketable fruits/plant	SMB115, PB66, BB85, Pant Samrat	SMB115 × DBL02, PB66 × Pant Samrat
7.	Weight of marketable fruits/plant(Kg)	PB66, SMB115, LC7, Pant Rituraj	SMB115 × DBL02, PB66 × Pant Samrat
8.	Number of unmarketable fruits/plant	PB70, LC7,PB71, Pant Rituraj	SwarnSyamli × Pant Samrat, PB66 × DBL02
9.	Weight of unmarketable fruits/plant (Kg)	SwarnSyamli, BARI, LC7, Pant Samrat	SwarnSyamli × Pant samrat,SMB115 × Pant Rituraj
10.	Total number of fruits/plant	PB66, SMB115, BB85, Pant Samrat	PB66 × Pant Samrat, SMB115 × DBL02
11.	Total yield/plant (Kg)	PB66, SMB115, BRLVAR6, Pant Rituraj	SMB115 × DBL02, IBWL2001-1 × Pant Rituraj, PB66 × Pant Samrat

For many of the characters studied the lines PB66, SMB115, PB70, PB71 and BRLVAR6 and among tester Pant Samrat and Pant Rituraj were found good general combiners on the basis of more than eight to ten yield attributing characters and magnitude of their gca effect. Therefore, these parents may be used for hybridization for producing promising recombination's.

3.2 Specific Combing Ability

The sca effect of all the 30 hybrids pertaining to different characters are given in Table 4 that indicates that predominance of non additive gene action which is non fixable and it is a major component that may utilize in heterosis breeding. sca effect represents dominance variance and additive × dominance and dominance × dominance type of epistasis.

The cross BRLVAR6 × DBL02 and PB70×DBL02 exhibited best sca effect for days to 50% flowering. Heterosis in this cross due to low × high combiner might be due to dominant × additive type of interaction which is partially fixable. Best performing crosses on the basis of sca effect for different characters were shown in Table 5.

SMB115× DBL02 is best specific combiners for the characters, number of fruit per plant, weight of marketable fruits per plant and total yield per plant .Other hybrids such as IBWL2001-1× Pant Rituraj, PB66×Pant Smart, PB71 × Pant Rituraj, BRLVAR6 × Pant Rituraj and PB70 × Pant Rituraj were best specific combiner for total yield per plant and more than five yield attributing characters.

Evaluation of hybrids on the basis of sca effect is second most important criteria because sca of hybrids has been attributed to the combination of positive favourable gene from different parents or might be due to the presence of linkage in repulsion phase [24]. Hence selection of hybrids based on sca effects would excel in their heterotic effect. These crosses exhibited significant sca effect indicating the presence of dominance and epistatis type of gene action these findings were similar with the findings of [25,21,7,18,9,10,19,20,11,14,13]. The three promising hybrids are SMB115× DBL02 IBWL2001-1× Pant Rituraj and PB66×Pant Smart could be included for exploitation of hybrid vigour in brinjal. However, it need further testing before recommendation these combinations for exploitation on large scale.

4. CONCLUSION

The present study concluded that PB66, SMB115, PB70, PB71 and BRLVAR6 among ten lines and Pant Samrat and Pant Rituraj were best among three testers as it showed desirable effect of gca for most of the yield attributing characters. Therefore these genotypes could be used extensively in hybrid breeding programme with view to increase yield of brinjal. Furthermore based on sca effect the three hybrids viz. SMB115× DBL02 IBWL2001-1× Pant Rituraj and PB66×Pant Smart were found suitable for yield of brinjal. For varietal improvement these crosses could be utilized for exploiting promising recombinants after multi location testing.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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