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Diallel analysis for multiple traits in eggplant (*Solanum melongena* L.)

SK Dhaka and RA Kaushik

Abstract

An investigation was carried out to assess the combining ability in eggplant genotypes using a diallel mating design (without reciprocal crosses) using 10 genetically diverse eggplant genotypes namely, Pusa Purple Long, Pusa Uttam, Punjab Sadabahar, Selection-2, Mukta Shree, Type -3, Pusa Upkar, BR-112, Azad-331 and Udaipur Local. The experiment was set up in a randomized complete block design (RCBD) with 3 replications during autumn-winter season of 2011-12. General combining ability studies revealed that Pusa Purple Long was the best combiner for major flowering contributing characters including days to anthesis of first flower, days to 50 per cent flowering and days to first fruit picking and Pusa Uttam was best combiner for yield and yield attributing traits including fruit yield per plant, fruit weight and number of fruits per cluster in all the environments. However, the estimates of specific combining ability showed the desirable SCA effects in crosses Pusa Purple Long x Pusa Uttam was suitable for heterosis breeding since it expressed desirable values for six important characters in all the environments. The hybrids Pusa Upkar x Azad-331 and Pusa Uttam x Selection-2 could be considered as next best hybrid suitable for heterosis breeding.

Keywords: General combining ability, specific combining ability, diallel analysis, eggplant

Introduction

Eggplant (*Solanum melongena* L.) is widely cultivated as one of the most important vegetables in both subtropical and tropical areas of India as well as abroad, therefore, can play a vital role in achieving the nutritional security (Sarker *et al.* 2006) [4]. Earlier, eggplant breeding was relied both on mass selection and pureline selection from the land races for the development of improved varieties. It is a fact that selection of parents on the basis of their performance does not necessarily lead to desired results (Rai and Asati 2011 and Dhasarathan *et al.* 2015) [1, 6]. Therefore, devising a sound breeding strategy to improve the yield of this crop is of paramount importance. The combining ability analysis help breeders in choosing suitable genotypes as parents for hybridization and superior cross combinations through GCA and SCA studies, respectively (Rodrigues and Silva 2002) [7]. In order to select superior parents, it is imperative to study the relative ability of the parents to transfer economic traits in the hybrid combination. Combining ability is one of the important and powerful tools in identifying the best combiner that may be used in crosses to exploit heterosis (Sharaf Uddin *et al.* 2015) [5]. It helps to know the genetic architecture of various characters that enables the breeder to design effective breeding plan for future improvement of the existing materials. This information is also useful to the breeder for selection of diverse parents and hybrid combinations. It is possible to develop high yielding variety through genetic manipulation and selection of superior parents. Hence, it is necessary to have knowledge about genetic makeup of yield and yield contributing characters. Diallel cross analysis provides the estimates of genetic parameters regarding combining ability as well as a rapid overall picture of the dominance relationship of the parents studied using the first filial generations (F₁) with or without reciprocals, Diallel analysis involving parents give the additional information as presence or absence of average degree of dominance, distribution of dominant and recessive genes in the parents. Application of diallel technique in a self-pollinated crop like eggplant for this purpose may be appropriate (Griffing, 1956) [3].

Although eggplant is the major vegetable in Rajasthan, yet an organized and systematic attention has not been given for its improvement from a breeding point of view. Considering the above facts the present study was undertaken to determine the GCA of the selected parents and SCA of crosses and to generate information on the nature and magnitude of some gene actions involved in the inheritance of yield and yield contributing characters.

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Materials and methods

Experimental material

The present experiment was carried out at Hi-Tech Horticulture Unit, Department of Horticulture, Udaipur and KVK, Chittorgarh, Maharana Pratap University of Agricultural and Technology, Rajasthan, by involving 10 genetically diverse eggplant genotypes viz., Pusa Purple Long, Pusa Uttam, Punjab Sadabahar, Selection-2, Mukta Shree, Type -3, Pusa Upkar, BR-112, Azad-331 and Udaipur Local were used as parents (Table 1) and crossed in diallel mating design following Model-I, Method-II of Griffing (1956) [3]. This method of combining analysis includes one way crosses and their parents. This method is used when reciprocal differences are not significant. This is most commonly used method of combining ability analysis from a diallel cross (Singh and Narayanan, 1993) [21].

Experimental methods

The parents and their resulting 45 F₁s were raised in a randomized complete block design (RCBD) with 3 replications in four different environments during autumn-winter season of 2011-12. Each genotype consisted of 1 rows plot of 7.20 m length and spacing between rows and plants adopted were 75 and 60 cm respectively. Twelve plant per plot was maintained and recommended package of practices was followed to raise a healthy crop. Observations on eggplant yield and its component traits including days to anthesis of first flower, days to 50 per cent flowering, days to first fruit picking, leaf area (cm²), plant height (cm), number of branches per plant, fruit length (cm), fruit width (cm), number of fruits per plant, number of fruits per cluster, fruit weight (g) and fruit yield per plant (kg) were recorded on 5 randomly selected plants from each plot. Mean data was subjected for analysis of general combining ability (GCA) and specific combining ability (SCA) as per method given by Griffing (1956) [3].

Results and discussion

Analysis of variance for GCA and SCA presented in Table 2 revealed that mean sum of squares of combining ability for various yield and yield contributing characters were highly significant for all the characters in all the environments, indicating a wide range of variability among the genotypes. The magnitudes of GCA and SCA effects are indicative of the relative importance of additive and non-additive gene actions in the inheritance of a trait, respectively. The mean squares of GCA were larger than those of SCA in all the characters, indicating the preponderance of additive gene action in the control of most of the characters. This suggested that simple selection would be effective to make desirable improvements of the characters under study. Involvement of additive gene action for the characters in present investigation is also in consonance with the findings of Chezhian *et al.* (2000) [16], Sao and Mehta (2010) [12], Rai and Asati (2011) [1] and Sharaf Uddin *et al.* (2015) [5]. The large GCA: SCA variance ratio suggests the importance of additive gene effects, while a low ratio signifies presence of dominant and/or epistatic gene effects. The GCA/SCA variance ratio being more than unity indicates that the predominance of additive (dominance or epistasis) gene action is important for all the characters. A very few researchers reported the gene action in eggplant. They reported that days to flowering, plant height, branches per plant, fruits per plant and yield per plant have the additive

gene effect (Das and Barua 2001 and Singh *et al.* 2003) [15, 19]. Estimates of general combining ability for various traits have been presented in Table 3. An overall appraisal of general combining ability (GCA) effects revealed that none of the parents were found good general combiner for all the characters in all the four environments. The estimates of GCA effects exhibited that the parents Pusa Purple long, Pusa Uttam, Pusa Upkar and BR-112 were the best general combiners for most earliness characters *i.e.* days to anthesis of first flower, days to 50 per cent flowering and days to first fruit picking in all the four environments. Among the parents the highest significant negative GCA effect was provided by Pusa Purple long in all the environments. Earliness is one of the important characters in vegetable crop like eggplant as early harvest fetches higher price in the market and early hybrids fit well in multiple cropping system. In the present study, Pusa Purple long was found to be early parent in all the four environments.

Fruit yield, a complex character, is contributed by the number of fruits per plant, fruit weight and fruit size. Among the parents studied Pusa Uttam and Pusa Upkar in all the environment exhibited significant positive GCA effects for fruit yield per plant. The parent Pusa Uttam was also having high GCA effects for days to anthesis of first flower, days to 50 per cent flowering, days to first fruit picking, plant height, number of branches per plant, fruit width, number of fruits per plant, number of fruits per cluster and fruit weight in all the four environments and for leaf area in E₁, E₂ and E₄. Parent Pusa Upkar was also having good GCA effects for days to anthesis of first flower, days to first fruit picking, plant spread, fruit width, number of fruits per plant, number of fruits per cluster and fruit weight in all the four environments and for days to 50 per cent flowering in E₁ and E₄, for leaf area in E₂ and E₃ and for plant height in E₁, E₂ and E₃. Similarly, parent Mukta Shree was also good general combiner for one or other component characters in one or more environments. The other good general combiner (best three) for different characters is shown in Table 4. As reported earlier high GCA effects are related primarily to additive or additive x additive interaction, which are fixable genetic component of variation. Hence, the parents Pusa Uttam, Pusa Upkar and Mukta Shree are recommended to utilize as donors in cross breeding programme. In present investigation, it was observed that the parents which showed high GCA effects for different characters also exhibited good performance with respect to other characters, such results has been earlier reported by Chaudhary and Malhotra (2000), Singh *et al.* (2002) [20], Kumar *et al.* (2004) [17], Kamalakkannan *et al.* (2007) [9] and Rai and Asati (2011) [11]. It is clear from above results that parents exhibited good general combining ability for fruit yield per plant were always not good general combiner for all the component characters. Therefore, high GCA effects for fruit yield per plant was due to buffering action of one or another component traits. Further, parents with high GCA effects for fruit yield also exhibited high GCA effects for one or more attributes, whereas high GCA effects for component characters may not always lead to high GCA effects for fruit yield.

The second important criterion for the evaluation of hybrids is the SCA effects (Table 5 to 7). Sarsar *et al.* (1986) [18] reported the SCA effect of hybrids has been attributed to the combination of positive favourable genes from different parents or might be due to the presence of linkage in repulsion

phase. Hence, it can be utilization in F₁ generation only for development of hybrid varieties. Hybrids with significantly favourable SCA effects in the present investigation are discussed here under.

Specific combining ability effects for fruit yield per plant were significant and positive for 14 crosses in all the environments. The 18 crosses in E₁, 17 each in E₂ and E₃ and 15 in E₄ manifested significant positive SCA effect. The crosses had significant and positive SCA effects for fruit yield per plant in more than one environment were Pusa Purple Long x Type-3 and Pusa Uttam x Azad-331 in E₁, E₂ and E₃, Pusa Uttam x Udaipur Local in E₁, E₂ and E₄ and Mukta Shree x Pusa Upkar in E₂, E₃ and E₄. All these crosses were also having significant SCA effects for one or more components and these, crosses were also having economic heterosis for yield and its components characters (Table 8). The crosses with significant SCA effect for fruit yield and its component traits were also identified by Ashwani and Khandelwal (2005) [13], Keskar *et al.* (2006) [8], Kamalakkannan *et al.* (2007) [9] and Rai and Asati (2011) [11]

and Patel *et al.* (2013) [10].

The significant SCA effects might be due to the presence of intra or inter allelic interaction and can be easily exploited in cross pollinated crops and in self pollinated crops where commercial hybrid seed production is possible. However, if its parents are good general combiners the high SCA might be due to accumulation of dominant alleles from both the parents, if so it can be easily exploited in self pollinated crops by selecting transgressive segregants in segregating generations. In present investigation, crosses Pusa Uttam x Azad-331 in E₁, E₂ and E₃ and Pusa Purple Long x Pusa Uttam, Pusa Uttam x Selection-2, Pusa Uttam x Type-3, Type-3 x Pusa Upkar, Pusa Upkar x BR-112 and Pusa Upkar x Azad-331 depicted high economic heterosis along with at least one good general combiner parent and high SCA effects in all the environments whereas, crosses Pusa Uttam x Udaipur Local in E₂ and Mukta Shree x Pusa Upkar in E₂, E₃ and E₄ exhibited significant economic heterosis involved at least one good general combiner parent and high SCA effects.

Table 1: Salient features of ten selected parental eggplant genotypes grown in 2010-11.

Parents	Parent symbol	Origin/Source	Main features/Characteristics
Pusa Purple Long	P ₁	IARI, New Delhi	It is an extra early variety, becomes ready for picking in about 75-80 days after sowing. Fruits are long, slender, purple and glossy, 20-25 cm long tend to drop down and touch the ground.
Pusa Uttam	P ₂	IARI, New Delhi	Plants are semi-upright, vigorous, well branched and free from spines. Fruits are solitary, pendent, oval-round, medium, large sized and glossy with dark purple skin and green peduncle. Single fruit weight about 250- 300 g. It takes 85-90 days for first harvest after seed sowing.
Punjab Sadabahar	P ₃	PAU, Ludhiana	Plants are dwarf, erect and thorn less. The fruits are long, thin and deep purple in colour. It takes about 60-65 days from transplanting to the first harvesting.
Selection-2	P ₄	APAU, Hyderabad	Plants are non- spiny with semi-spreading growth habit. Leaves are green-violet in colour, fruits are round, dark purple in colour. It takes 90-100 days for first fruit picking after sowing the seeds in nursery.
Mukta Shree	P ₅	NBPGR, New Delhi	Plants are tall, non-spiny with large spreading growth habit. Fruits are medium round, glossy and dark purple coloured. Single fruit weights 150-200 g. It takes 100-110 days for harvest after sowing the seed in the nursery.
Type-3	P ₆	CSAUA&T, Kanpur	Plants are spreading, well branched and free from spines fruits are round, light purple with whitish green colour at stigmatic end. Average fruit weight 200 g.
Pusa Upkar	P ₇	IARI, New Delhi	Plants are semi upright, medium to tall (70 cm) with 5-6 moderate branching and free from spines. Fruits are solitary, pendent round (9 cm diameter), glossy, dark purple and medium large sized. Single fruit weight 200 g. It takes 90-95 days for first picking.
BR-112	P ₈	CCSHAU, Hisar	Plants are medium tall bushy and non- spiny with semi- upright growth habit. Fruits are round with bright purple colour and fleshy. It required 85-95 days for first picking after sowing the seed.
Azad-331	P ₉	CSAUA&T, Kanpur	Plants are medium-tall compact with erect growth habit, well branched and free of spines. Fruits are long with light purple in colour. Average fruit weight is 70-80 g. First picking starts 90-100 days after sowing.
Udaipur Local	P ₁₀	Udaipur, Rajasthan	Plants are hardy, small, well branched with spreading growth habit. Stem, leaves and leaf peduncle bears spine profusely. Fruits are solitary, medium to large, light green colour with green shiny calyx. Fruits are round in shape and green calyx bears spines densely. Single fruits weights 200-225 g and takes about 70-80 days from transplanting to the first harvesting.

Table 2: Analysis of variance for combining ability in each environment for different characters in eggplant.

Source of variation	D.f.	Days to anthesis of first flower	Days to 50 per cent flowering	Days to first fruit picking	Leaf area (cm ²)	Plant height (cm)	Number of branches per plant	Fruit length (cm)	Fruit width (cm)	Number of fruits per plant	Number of fruits per cluster	Fruit weight (g)	Fruit yield per plant (kg)	
GCA	9													
		E ₁	57.86**	96.90**	136.56**	337.36**	444.13**	9.46**	69.36**	16.49**	180.32**	3.35**	7259.61**	4.27**
		E ₂	90.10**	80.34**	134.03**	228.63**	280.95**	7.99**	48.16**	13.27**	168.08**	2.74**	6357.85**	3.82**
		E ₃	79.75**	52.55**	56.93**	323.35**	356.63**	9.67**	52.56**	17.45**	170.44**	3.12**	6914.47**	4.37**
SCA	45													
		E ₁	65.59**	55.82**	79.68**	183.70**	173.26**	4.04**	35.14**	12.35**	135.55**	2.23**	5253.05**	3.37**
		E ₂	22.04**	16.95**	18.17**	32.79**	51.65**	0.96**	4.19**	0.97**	22.26**	0.27**	638.04**	0.45**
		E ₃	20.69**	21.01**	25.79**	58.09**	68.79**	0.96**	3.86**	1.10**	19.84**	0.25**	553.34**	0.44**
Error	108													
		E ₁	18.89**	16.64**	19.97**	25.48**	47.20**	0.90**	4.43**	1.23**	19.88**	0.26**	629.08**	0.42**
		E ₂	28.01**	19.58**	22.32**	62.91**	36.36**	0.71**	6.84**	1.47**	17.56**	0.23**	618.82**	0.37**
		E ₃	4.13	3.45	4.94	17.89	6.90	0.12	0.33	0.06	0.84	0.009	24.65	0.018
		E ₂	4.00	4.99	5.40	15.75	5.08	0.08	0.28	0.07	0.54	0.007	15.08	0.015
		E ₃	4.50	4.11	6.19	16.76	7.09	0.09	0.28	0.09	0.62	0.008	21.15	0.013

SCA ratio	E ₁	4.55	3.20	3.83	11.55	4.82	0.06	0.19	0.07	0.41	0.0047	16.18	0.009
	E ₂	2.63	5.72	7.52	10.29	8.60	9.85	16.55	17.00	8.10	12.41	2.63	5.72
	E ₃	4.35	3.82	5.20	3.94	4.08	8.32	12.48	12.06	8.47	10.96	4.35	3.82
	E ₄	4.22	3.16	2.85	12.69	7.56	10.74	11.86	14.19	8.57	12.00	4.22	3.16
	E ₅	2.34	2.85	3.57	2.92	4.77	5.69	5.14	8.40	7.72	9.70	2.34	2.85

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

Table 3: Estimates of general combining ability effects for different characters

Parents	Days to anthesis of first flower				Days to 50 per cent flowering				Days to first fruit picking				Leaf area (cm ²)			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
P1	-3.51**	-4.88**	-4.62**	-3.37**	-4.20**	-4.89**	-3.43**	-3.26**	-5.22**	-4.96**	-2.87**	-4.08**	-4.29**	-3.02**	-2.79*	-0.60
P2	-2.60**	-3.05**	-1.66**	-1.69**	-4.02**	-2.76**	-1.85**	-1.22*	-3.92**	-3.02**	-2.57**	-1.81**	2.42*	1.24	4.14**	2.49**
P3	0.13	-0.69	-0.65	-1.09	-0.78	-0.82	-1.20*	-1.09*	-1.77**	-1.60*	-1.83**	-2.16**	-3.78**	-2.47*	-3.23**	0.37
P4	1.10	1.01	0.74	0.06	0.74	1.09	0.80	-0.21	1.61**	0.73	1.56*	1.17*	2.39*	1.74	0.18	-1.13
P5	1.94**	3.11**	3.40**	4.32**	4.11**	2.81**	3.17**	3.87**	4.61**	4.75**	1.91**	2.97**	11.03**	10.76**	12.10**	8.29**
P6	0.97	2.96**	3.19**	2.46**	2.19**	2.08**	2.00**	2.15**	1.64**	1.53*	1.57*	1.58**	5.09**	1.88	2.83*	3.41**
P7	-1.60**	-1.13*	-2.03**	-1.75**	-1.02*	-0.73	-1.03	-1.21*	-1.29*	-2.02**	-1.43*	-1.19*	-0.12	-2.22*	-2.26*	-1.50
P8	-0.74	-1.42*	-1.58**	-1.44*	-1.41**	-1.25*	-1.38*	-1.75**	-2.14**	-2.42**	-0.73	-1.51**	-3.00*	-3.07**	-3.40**	-2.30*
P9	0.43	0.83	0.83	0.61	0.92	1.12	0.79	0.78	2.04**	2.07**	0.82	0.76	-6.42**	-4.19**	-5.70**	-5.24**
P10	3.88**	3.25**	2.39**	1.89**	3.47**	3.36**	2.13**	1.95**	4.45**	4.96**	3.56**	4.27**	-3.31**	-0.65	-1.87	-3.80**
SE (gi)	0.56	0.55	0.58	0.58	0.51	0.61	0.56	0.49	0.61	0.64	0.68	0.54	1.16	1.09	1.12	0.93
SE (gi-gj)	0.83	0.82	0.87	0.87	0.76	0.91	0.83	0.73	0.91	0.95	1.02	0.80	1.73	1.62	1.67	1.39

Parents	Plant height (cm)				Number of branches per plant				Fruit length (cm)				Fruit width (cm)			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
P1	2.09**	2.60**	2.38**	3.39**	2.12**	1.84**	2.10**	1.10**	3.70**	2.75**	3.25**	2.34**	-1.98**	-1.40**	-1.65**	-1.54**
P2	2.13**	3.16**	2.35**	2.72**	0.40**	0.58**	0.44**	0.33**	0.06	-0.13	0.09	0.20	1.15**	1.38**	1.36**	1.21**
P3	-2.29**	-2.45**	-2.63**	-2.55**	-0.37**	-0.36**	-0.30**	-0.18**	1.94**	1.66**	1.72**	1.64**	-1.22**	-1.15**	-1.55**	-1.22**
P4	-4.81**	0.41	-3.56**	-1.34*	-0.81**	-0.50**	-0.76**	-0.53**	-2.06**	-1.90**	-2.10**	-1.49**	0.49**	0.80**	0.39**	0.42**
P5	13.92**	9.50**	12.65**	8.50**	-0.13	0.39**	0.13	0.13	-1.00**	-0.54**	-0.50**	-1.01**	0.67**	0.61**	1.06**	0.48**
P6	-3.91**	-1.52*	-4.53**	-3.13**	-0.64**	-0.77**	-0.55**	-0.43**	-0.35*	-0.39**	-0.81**	-0.89**	-0.04	-0.37**	-0.46**	-0.37**
P7	5.53**	3.09**	3.87**	-0.13	-0.39**	-0.49**	-0.69**	-0.70**	-0.86**	-0.79**	-1.06**	-0.39**	0.44**	0.27**	0.44**	0.29**
P8	-5.14**	-7.61**	-4.76**	-3.52**	-0.85**	-0.92**	-0.98**	-0.56**	-3.67**	-2.69**	-2.45**	-2.29**	0.07	-0.02	0.20*	0.13
P9	-2.92**	-2.57**	-1.91*	-1.48*	0.61**	0.01	0.44**	0.29**	3.67**	3.45**	3.35**	2.81**	-1.32**	-1.39**	-1.37**	-0.96**
P10	-4.60**	-4.60**	-3.85**	-2.47**	0.06	0.23**	0.16	0.55**	-1.60**	-1.42**	-1.49**	-0.92**	1.73**	1.27**	1.59**	1.54**
SE (gi)	0.72	0.62	0.73	0.60	0.09	0.08	0.08	0.07	0.16	0.14	0.14	0.12	0.07	0.07	0.08	0.07
SE (gi-gj)	1.07	0.92	1.09	0.90	0.14	0.12	0.12	0.10	0.23	0.22	0.22	0.18	0.10	0.11	0.12	0.11

Parents	Number of fruits per plant				Number of fruits per cluster				Fruit weight (g)				Fruit yield per plant (kg)			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
P1	4.37**	4.32**	4.09**	4.05**	-0.25**	-0.22**	-0.24**	-0.19**	-33.73**	-32.06**	-32.45**	-25.57**	-0.40**	-0.46**	-0.45**	-0.42**
P2	2.89**	1.57**	1.75**	0.67**	0.85**	0.77**	0.78**	0.72**	29.69**	29.05**	29.93**	30.70**	1.22**	1.20**	1.29**	1.13**
P3	4.86**	5.37**	5.20**	4.85**	-0.48**	-0.41**	-0.39**	-0.34**	-24.13**	-19.37**	-21.82**	-20.34**	-0.31**	-0.24**	-0.30**	-0.28**
P4	-2.24**	-2.28**	-2.26**	-2.29**	-0.12**	-0.11**	-0.15**	-0.06**	-9.18**	-7.48**	-9.11**	-5.92**	-0.26**	-0.28**	-0.30**	-0.22**
P5	-4.00**	-3.32**	-3.34**	-3.18**	-0.55**	-0.47**	-0.53**	-0.34**	19.22**	21.12**	19.99**	15.86**	0.11**	0.13**	0.06	0.02
P6	-3.90**	-3.75**	-4.00**	-3.32**	-0.52**	-0.50**	-0.52**	-0.44**	16.80**	17.48**	16.60**	17.68**	-0.12**	-0.10**	-0.08*	-0.02
P7	2.58**	2.51**	2.77**	2.18**	0.74**	0.70**	0.78**	0.62**	17.46**	9.20**	15.39**	6.69**	0.89**	0.76**	0.85**	0.75**
P8	-1.46**	-1.60**	-1.56**	-1.54**	-0.32**	-0.30**	-0.34**	-0.43**	-22.69**	-22.21**	-23.84**	-21.05**	-0.51**	-0.49	-0.46**	-0.43**
P9	2.59**	2.65**	2.88**	2.95**	0.16**	0.14**	0.17**	0.13**	-21.87**	-21.60**	-19.53**	-19.53**	-0.05	-0.05	-0.05	-0.13**
P10	-5.70**	-5.47**	-5.51**	-4.37**	0.49**	0.40**	0.44**	0.33**	28.44**	25.86**	26.98**	21.49**	-0.56**	-0.47**	-0.54**	-0.41**
SE (gi)	0.25	0.20	0.22	0.18	0.03	0.02	0.02	0.02	1.36	1.06	1.26	1.10	0.04	0.03	0.03	0.03
SE (gi-gj)	0.37	0.30	0.32	0.26	0.04	0.03	0.04	0.03	2.03	1.59	1.88	1.64	0.05	0.05	0.05	0.04

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

Table 4: Promising general combiners (best three) based on GCA effects.

Characters	Environment											
	E ₁			E ₂			E ₃			E ₄		
Days to anthesis of first flower	Pusa Purple Long			Pusa Purple Long			Pusa Purple Long			Pusa Purple Long		
	Pusa Uttam			Pusa Uttam			Pusa Uttam			Pusa Uttam		
	Pusa Upkar			BR-112			Pusa Uttam			Pusa Uttam		
Days to 50 per cent flowering	Pusa Purple Long			Pusa Purple Long			Pusa Purple Long			Pusa Purple Long		
	Pusa Uttam			Pusa Uttam			Pusa Uttam			BR-112		
	BR-112			BR-112			BR-112			Pusa Uttam		
Days to first fruit picking	Pusa Purple Long			Pusa Purple Long			Pusa Purple Long			Pusa Purple Long		
	Pusa Uttam			Pusa Uttam			Pusa Uttam			Punjab Sadabahar		
	BR-112			BR-112			Punjab Sadabahar			Pusa Uttam		
Leaf area (cm ²)	Mukta Shree			Mukta Shree			Mukta Shree			Mukta Shree		
	Type-3			-			Pusa Uttam			Type-3		
	Pusa Uttam			-			Type-3			Pusa Uttam		
Plant height (cm)	Mukta Shree			Mukta Shree			Mukta Shree			Mukta Shree		
	Pusa Upkar			Pusa Uttam			Pusa Upkar			Pusa Purple Long		

	Pusa Uttam	2.13**	Pusa Upkar	3.09**	Pusa Purple Long	2.38**	Pusa Uttam	2.72**
Plant spread (m ²)	Mukta Shree	0.0955**	Mukta Shree	0.0800**	Mukta Shree	0.0923**	Mukta Shree	0.0697**
	Pusa Upkar	0.0402**	Pusa Upkar	0.0387**	Pusa Upkar	0.0501**	Pusa Upkar	0.0453**
	Pusa Uttam	0.0209**	Pusa Uttam	0.0230**	Pusa Uttam	0.0123**	Pusa Uttam	0.0264**
Number of branches per plant	Pusa Purple Long	2.12**	Pusa Purple Long	1.84**	Pusa Purple Long	2.10**	Pusa Purple Long	1.10**
	Azad-331	0.61**	Pusa Uttam	0.58**	Azad-331	0.44**	Pusa Purple Long	0.55**
	Pusa Uttam	0.40**	Mukta Shree	0.39**	Pusa Uttam	0.44**	Pusa Uttam	0.33**
Fruit length (cm)	Pusa Purple Long	3.70**	Azad-331	3.45**	Azad-331	3.35**	Azad-331	2.81**
	Azad-331	3.67**	Pusa Purple Long	2.75**	Pusa Purple Long	3.25**	Pusa Purple Long	2.34**
	Punjab Sadabahar	1.94**	Punjab Sadabahar	1.66**	Punjab Sadabahar	1.72**	Punjab Sadabahar	1.64**
Fruit width (cm)	Udaipur Local	1.73**	Pusa Uttam	1.38**	Udaipur Local	1.59**	Udaipur Local	1.54**
	Pusa Uttam	1.15**	Udaipur Local	1.27**	Pusa Uttam	1.36**	Pusa Uttam	1.21**
	Mukta Shree	0.67**	Selection-2	0.80**	Mukta Shree	1.06**	Mukta Shree	0.48**
Number of fruits per plant	Punjab Sadabahar	4.86**	Punjab Sadabahar	5.37**	Punjab Sadabahar	5.20**	Punjab Sadabahar	4.85**
	Pusa Purple Long	4.37**	Pusa Purple Long	4.32**	Pusa Purple Long	4.09**	Pusa Purple Long	4.05**
	Pusa Uttam	2.89**	Azad-331	2.65**	Azad-331	2.88**	Azad-331	2.95**
Number of fruits per cluster	Pusa Uttam	0.85**	Pusa Uttam	0.77**	Pusa Uttam	0.78**	Pusa Uttam	0.72**
	Pusa Upkar	0.74**	Pusa Upkar	0.70**	Pusa Upkar	0.78**	Pusa Upkar	0.62**
	Udaipur Local	0.49**	Udaipur Local	0.40**	Udaipur Local	0.44**	Udaipur Local	0.33**
Fruit weight (g)	Pusa Uttam	29.69**	Pusa Uttam	29.05**	Pusa Uttam	29.93**	Pusa Uttam	30.70**
	Udaipur Local	28.44**	Udaipur Local	25.86**	Udaipur Local	26.98**	Udaipur Local	21.49**
	Mukta Shree	19.22**	Mukta Shree	21.12**	Mukta Shree	19.99**	Type-3	17.68**
Fruit yield per plant (kg)	Pusa Uttam	1.22**	Pusa Uttam	1.20**	Pusa Uttam	1.29**	Pusa Uttam	1.13**
	Pusa Upkar	0.89**	Pusa Upkar	0.76**	Pusa Upkar	0.85**	Pusa Upkar	0.75**
	Mukta Shree	0.11**	Mukta Shree	0.13**	-	-	-	-

Table 5: Estimates of specific combining ability effects for days to anthesis of first flower, days to 50 per cent flowering, days to first fruit picking and leaf area

Crosses	Days to anthesis of first flower				Days to 50 per cent flowering				Days to first fruit picking				Leaf area (cm ²)			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
P1 x P2	-13.59**	-12.27**	-11.46**	-17.05**	-11.84**	-10.27**	-10.92**	-14.69**	-9.17**	-13.25**	-9.77**	-15.71**	8.35*	21.54**	9.61*	15.13**
P1 x P3	-4.37*	0.10	-2.80	-4.41*	-4.31*	0.52	-6.23**	-3.26	-2.32	-0.85	-4.21	-3.82*	-1.55	-7.31*	-0.08	-6.10
P1 x P4	3.01	5.27**	4.41*	7.43**	3.63*	4.93*	2.43	7.92**	-0.88	1.40	0.00	4.46*	-1.23	-2.52	-3.55	2.69
P1 x P5	3.75**	4.17*	-1.58	-1.80	2.29	2.80	5.49**	-2.85	3.28	4.18	5.75*	-1.87	-0.44	3.36	-0.31	-1.07
P1 x P6	5.60**	2.61	3.96*	2.92	3.95*	3.95	5.24**	2.59	-1.82	6.20**	4.51	5.19**	2.90	7.34*	2.90	-0.28
P1 x P7	3.99*	2.50	4.21*	3.34	3.53*	1.42	2.69	1.74	5.34*	0.85	2.32	2.94	-2.24	-0.27	-2.20	-4.94
P1 x P8	5.50**	7.07**	6.10**	2.30	-0.22	-4.78*	5.68**	2.87	2.03	-2.95	5.80*	5.26**	4.72	-2.42	-1.93	-10.43**
P1 x P9	2.74	5.45**	6.72**	6.89**	3.15	6.87**	4.52*	6.16**	3.01	2.36	1.80	5.41**	2.52	-2.68	-0.92	-3.49
P1 x P10	3.94*	2.78	2.89	6.73**	4.93**	3.31	3.51	5.71**	6.54**	6.77**	0.94	6.48**	3.42	6.16	2.99	6.94*
P2 x P3	1.43	2.28	0.97	1.00	1.49	2.39	3.26	-0.32	3.82	2.38	2.14	0.93	5.11	0.30	0.96	-5.95
P2 x P4	-3.45	-6.14**	-5.12*	-10.25**	-3.01	-7.62**	-7.02**	-6.67**	-6.75**	-9.84**	-10.39**	-7.80**	-5.80	10.23**	9.79*	15.15**
P2 x P5	-2.35	5.71**	3.19	4.87*	-3.83*	6.63**	1.86	3.95*	-4.99*	3.24	2.51	4.14*	-2.04	-1.04	-5.62	1.37
P2 x P6	4.10*	6.93**	5.13**	5.78**	3.05	9.81**	4.72*	4.53**	0.55	8.06**	7.09**	3.21	0.93	3.08	-1.11	-3.36
P2 x P7	4.82*	1.00	3.32	3.00	6.87**	-0.70	2.66	0.79	6.04**	0.01	6.79**	2.68	6.42	-2.20	-0.49	-4.06
P2 x P8	3.22	1.31	1.87	2.35	3.61*	3.11	3.03	2.33	2.41	0.66	-0.59	4.06*	-3.02	1.32	-4.97	2.41
P2 x P9	1.02	-0.30	0.49	1.58	0.62	1.42	3.13	-0.80	1.71	1.82	1.64	3.01	-1.08	-3.34	-6.42	-4.69
P2 x P10	-1.66	0.47	-0.83	0.19	-2.58	0.78	-0.51	-0.37	-1.18	3.63	0.72	-3.27	-2.30	-0.45	-4.27	-13.84**
P3 x P4	1.72	-0.55	0.13	1.53	2.97	-0.19	-0.72	-1.35	1.25	1.44	-0.94	-1.35	-1.62	-7.81*	-6.43	-4.30
P3 x P5	1.38	3.06	0.21	-1.10	-1.11	-1.30	1.81	-0.72	0.37	-3.10	3.61	0.22	-1.88	2.91	3.18	-4.72
P3 x P6	-2.05	-4.84**	-3.88*	-0.82	-2.61	-4.17*	-0.92	-0.30	0.94	-3.05	1.98	0.87	-4.18	-2.94	0.37	7.05*
P3 x P7	2.11	0.65	2.64	3.07	-0.53	1.34	2.33	0.16	1.48	2.48	2.00	0.77	-2.66	1.16	-2.06	-5.24
P3 x P8	-0.99	3.91*	0.20	2.05	-1.06	3.19	-1.32	2.23	-1.31	4.68*	-1.39	2.73	6.71	4.74	-0.43	2.45
P3 x P9	2.42	0.66	1.75	2.61	1.99	-0.19	1.24	1.12	-1.01	-3.21	-1.00	1.35	-3.93	3.48	-0.20	1.97
P3 x P10	-4.50*	-5.46**	-3.76	-7.39**	-5.29**	-6.70**	-4.68*	-3.48*	-7.89**	-10.50**	-8.88**	-6.42**	16.83**	14.61**	15.17**	11.28**
P4 x P5	-8.08**	2.28	0.49	0.19	-8.38**	2.23	-0.14	-0.27	-7.65**	0.21	-0.69	4.14*	0.90	-1.15	0.00	-0.16
P4 x P6	2.37	3.19	-0.30	-1.96	-0.14	0.63	-0.87	-2.18	2.52	0.51	-1.34	-1.38	-0.27	-10.58**	-1.26	-8.67**
P4 x P7	-0.51	-2.46	-3.11	0.92	-1.92	-2.25	0.04	-1.13	-0.62	1.76	-0.41	0.87	1.64	-3.80	-2.31	-3.65
P4 x P8	0.21	2.48	0.51	1.28	-0.60	7.27**	0.38	2.31	1.65	3.26	1.23	0.09	-3.74	9.47*	-2.39	3.97
P4 x P9	1.67	-1.44	1.06	1.90	1.61	0.47	2.21	-0.31	-1.05	-2.03	1.41	-2.88	4.42	-0.08	6.77	-3.89
P4 x P10	0.63	2.56	1.81	-1.95	0.32	2.68	3.29	1.31	3.06	0.28	4.01	3.45	2.14	0.26	0.85	-0.99
P5 x P6	3.50	0.43	0.11	1.43	-0.04	0.70	-0.56	0.34	1.03	-2.67	-0.63	-0.52	0.91	-0.92	0.30	-7.03*
P5 x P7	3.39	0.71	-1.44	-5.86**	0.96	1.93	-1.60	-0.30	-0.47	-1.08	-3.67	1.19	-2.27	-4.48	0.03	-12.24**
P5 x P8	0.38	-3.67*	-2.89	-2.98	-0.77	-2.45	-1.58	-4.66**	-2.25	-8.43**	-3.10	-7.82**	2.30	-9.72**	0.31	-7.10*
P5 x P9	-0.19	-3.09	-3.51	-4.80*	-2.74	-3.15	-3.15	-3.29*	1.05	-1.85	-0.83	-2.20	1.50	-0.02	2.23	-13.34**
P5 x P10	-0.64	-3.97*	-4.85*	-1.79	-1.00	-3.46	-3.09	-2.43	-3.27	-3.74	-2.69	1.08	1.25	1.14	-0.31	0.08
P6 x P7	-6.82**	-2.31	-2.19	-1.30	-3.30	-1.22	-1.09	1.51	-2.06	0.60	0.85	-0.30	5.51	7.50*	3.83	10.05**
P6 x P8	-6.47**	-10.13**	-11.97**	-9.71**	-2.01	-7.73**	-9.84**	-10.74**	-6.72**	-9.60**	-9.10**	-11.42**	3.21	11.54**	8.82*	8.32**
P6 x P9	2.48	0.95	-1.36	2.08	1.02	-1.36	-4.46*	-0.17	-1.38	-0.87	-6.60**	-0.58	4.95	-6.57	0.76	5.01
P6 x P10	-7.03**	0.19	1.93	-3.62	-4.74**	0.34	0.71	-4.33**	-4.26*	-3.02	-0.06	-0.66	-1.40	-7.58**	-9.10*	-4.66
P7 x P8	1.79	4.28*	-1.88	-1.57	0.36	5.82**	-0.76	-0.28	-0.22	3.46	-3.03	0.34	-1.47	-0.59	11.97**	-3.12
P7 x P9	-13.25**	-6.30**	-9.67**	-13.44**	-9.47**	-7.06**	-6.56**	-8.91**	-9.92**	-10.10**	-8.64**	-9.47**	12.13**	17.35**	4.04	15.19**
P7 x P10	0.84	4.58*	0.14	4.39*	1.48	4.37*	-1.22	2.01	-0.63	0.75	-1.39	-1.32	-1.76	-2.55	-2.97	0.85
P8 x P9	-3.51	-1.98	0.68	1.01	-0.58	-2.16	-0.64	0.33	-2.65	7.38**	3.70	0.83	2.80	4.41	-0.04	3.17
P8 x P10	-2.98	-4.34*	-0.90	0.41	-3.79*	-3.27	-3.18	1.91	0.96	0.66	-0.12	0.20	-3.03	-7.18	-2.18	-4.19

P ₉ x P ₁₀	-1.03	6.52**	-0.69	-2.51	0.22	7.96**	-0.74	0.66	2.93	5.66**	0.34	-0.34	-17.62**	-1.71	-1.35	-4.01
SE (S _{ij})	1.87	1.84	1.95	1.96	1.71	2.06	1.87	1.65	2.05	2.14	2.29	1.80	3.90	3.66	3.77	3.13
SE (S _{ij} -S _{ik})	2.75	2.71	2.87	2.89	2.51	3.02	2.74	2.42	3.01	3.15	3.37	2.65	5.73	5.37	5.54	4.60
SE (S _{ij} -S _{kl})	2.62	2.58	2.74	2.75	2.40	2.88	2.62	2.31	2.87	3.00	3.21	2.53	5.46	5.12	5.29	4.39

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

Table 6: Estimates of specific combining ability effects for plant height, number of branches, fruit length and fruit weight

Crosses	Plant height (cm)				Number of branches per plant				Fruit length (cm)				Fruit width (cm)			
	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄
P1 x P2	4.11	6.25**	3.18	4.55*	1.50**	1.71**	1.75**	2.04**	5.46**	4.72**	5.08**	6.45**	2.62**	2.37**	2.58**	3.05**
P1 x P3	2.77	1.14	3.32	-0.89	-0.36	0.13	-0.21	-0.12	-0.50	0.24	0.69	0.52	-0.24	-0.44	0.26	-0.13
P1 x P4	-2.76	-11.19**	-3.98	1.49	-0.11	0.77**	0.31	1.02**	1.29*	0.73	2.09**	-1.95**	-0.93**	0.83**	-0.58*	0.18
P1 x P5	2.05	-0.56	2.33	0.83	3.24**	2.78**	2.96**	0.24	1.21*	0.14	-0.47	-0.80*	0.42	-0.20	0.17	0.11
P1 x P6	8.39**	9.04**	9.27**	1.65	-0.13	-0.67*	-0.24	0.03	-0.07	0.36	-0.46	-2.36**	-0.77**	-0.28	-0.08	-0.40
P1 x P7	-6.10*	-4.38*	-4.96*	4.85*	0.55	0.76**	0.88**	-1.67**	-0.52	-2.56**	-2.51**	-2.20**	-0.95**	-0.41	-1.18**	-1.40**
P1 x P8	-1.78	-2.32	-4.99*	-7.29**	-1.21**	-0.51	-1.03**	-0.39	-1.45**	-1.59**	-0.79	-2.42**	0.27	-0.10	-0.37	-0.59*
P1 x P9	-2.33	-2.12	-1.30	-5.03*	-0.28	-1.45**	-0.70*	-1.40**	-5.09**	-0.18	-3.59**	-1.26**	-0.20	-0.10	-0.12	-0.12
P1 x P10	2.33	2.50	2.89	-0.34	-0.18	-1.06**	-0.29	-0.53*	-0.58	0.40	0.39	-1.06**	-0.14	-0.19	-0.53	-0.05
P2 x P3	3.39	5.67**	2.75	4.75*	0.37	0.24	0.50	-0.36	-0.70	-1.16*	-0.94	-3.39**	0.23	-0.74**	-0.20	-1.13**
P2 x P4	14.35**	11.97**	15.12**	10.67**	1.71**	1.35**	1.64**	0.34	3.28**	2.09**	2.53**	2.93**	0.57*	0.55*	0.75**	1.33**
P2 x P5	2.94	4.32*	1.02	3.92	0.30	-0.81**	0.07	-0.97**	0.12	0.72	0.53	2.16**	-0.98**	-0.42	-1.06**	-1.02**
P2 x P6	-3.09	0.42	-0.06	3.39	-0.69*	0.10	-0.41	-0.08	-1.69**	-0.63	-0.95	-1.04*	-0.10	-1.41**	-1.62**	-1.00**
P2 x P7	-4.60	-15.08**	-7.17**	-13.06**	-0.08	0.03	-0.11	0.54*	-1.60**	-0.60	-1.50**	-3.20**	-0.60**	-0.19	-0.28	-0.55*
P2 x P8	-3.61	-9.13**	-4.35	-6.92**	-0.45	0.05	-0.17	-0.11	0.45	0.13	2.15**	-0.15	0.55*	0.89**	0.61*	0.73**
P2 x P9	-0.34	2.10	0.85	2.64	-0.26	-0.18	-0.57*	-0.19	-1.09*	-1.55**	-2.39**	-1.66**	-1.08**	-0.42	0.30	-0.30
P2 x P10	0.54	-2.14	-0.62	1.68	-0.39	-0.39	-0.71*	-0.06	-0.24	-1.07*	-1.98**	-2.29**	0.21	0.81**	0.67*	0.21
P3 x P4	-0.02	-9.65**	-0.75	-6.21**	-0.43	-0.33	-0.35	-0.18	-0.88	-1.53**	-0.67	-1.25**	0.36	-1.59**	-0.68*	-1.25**
P3 x P5	4.47	-0.69	-0.60	-1.38	-0.59	-0.42	-0.63*	-0.13	0.94	0.37	0.21	0.39	-0.49*	0.22	-1.05**	-0.32
P3 x P6	4.41	4.50*	3.82	1.66	0.25	-0.56*	0.36	-0.31	-1.26*	-0.80	-2.57**	-4.51**	0.32	0.08	-0.51	-0.17
P3 x P7	-6.55**	-7.22**	-7.98**	-8.71**	-0.10	-0.74**	-0.82**	-0.27	-0.55	-1.47**	-1.22*	-1.34**	-1.09**	-0.40	-1.33**	-0.08
P3 x P8	-6.76**	-8.63**	-5.47*	1.76	0.31	0.54*	0.41	0.31	0.71	0.01	-0.72	0.97*	-0.43	-0.77**	-0.42	-1.07**
P3 x P9	-5.51*	1.07	-1.17	0.90	-0.26	-0.04	-0.24	-0.40	1.52**	1.23*	2.02**	1.56**	-0.40	0.26	0.53	0.23
P3 x P10	14.46**	16.17**	13.95**	10.78**	1.29**	1.59**	1.18**	1.94**	3.54**	4.77**	4.14**	5.41**	2.48**	3.57**	2.45**	3.52**
P4 x P5	7.03**	6.88**	6.82**	7.64**	-0.12	-0.32	-0.45	0.32	0.40	-0.85	-0.05	0.08	0.02	0.62*	-0.79**	-0.80**
P4 x P6	-5.11*	4.65*	0.11	1.38	-0.79*	-0.60*	-0.72**	-0.46*	-0.46	1.42**	0.46	-0.16	-0.69**	-0.32	0.23	-1.96**
P4 x P7	5.81*	9.51**	7.74**	2.60	1.41**	0.65*	0.65*	0.10	2.15**	3.95**	1.68**	0.67	-0.37	0.49*	0.49	0.94**
P4 x P8	-6.95**	-4.61*	-7.49**	0.72	-0.31	-0.17	-0.29	0.09	-1.92**	-2.06**	-2.51**	0.65	-0.32	-0.18	-0.87**	-0.60*
P4 x P9	-2.96	-5.69**	-1.24	-11.25**	-0.68*	-0.18	-0.40	0.09	-1.23*	-2.94**	-1.55**	-2.87**	1.42**	-0.56*	-0.07	-0.62*
P4 x P10	-2.22	-4.56**	-4.41	3.38	-0.06	0.18	-0.07	-0.47*	-1.18*	0.12	-1.96**	0.89*	0.69**	0.41	0.64*	1.28**
P5 x P6	-14.00**	-18.34**	-11.06**	-9.94**	0.11	-0.55*	-0.03	-0.20	2.05**	0.88	2.78**	0.32	-0.23	0.37	0.20	-0.72**
P5 x P7	3.83	8.50**	2.28	1.75	0.08	-0.14	-0.09	0.50*	1.02	0.56	-0.10	-0.69	0.06	-0.10	0.36	-0.82**
P5 x P8	4.29	4.02	5.99*	1.59	-0.91**	-0.81**	-0.61*	-0.32	-0.59	1.66**	0.90	-0.24	0.62**	0.65**	0.58*	-0.22
P5 x P9	6.67**	5.72**	6.80**	-2.22	0.51	-0.33	0.11	0.36	0.11	-0.28	-0.54	-1.18**	-0.10	0.51*	0.63*	-0.11
P5 x P10	-3.05	-2.95	-3.50	-6.05**	0.13	-0.06	-0.09	0.65**	-1.29*	-3.37**	-1.01*	-2.00**	1.16**	-0.08	0.85**	0.27
P6 x P7	2.02	0.79	0.42	-0.21	0.76*	-0.43	0.09	-0.72**	-0.55	-0.45	-1.11*	-0.25	-0.45*	-0.26	-0.84**	-0.28
P6 x P8	12.11**	15.67**	13.24**	10.66**	1.28**	0.90**	1.39**	0.81**	4.00**	3.38**	3.46**	5.27**	1.15**	-0.58*	1.32**	1.01**
P6 x P9	-12.09**	-10.03**	-9.66**	-2.79	0.26	0.86**	-0.02	0.72**	0.96	-0.66	-0.19	0.31	1.02**	-0.58*	-1.56**	0.64**
P6 x P10	-12.41**	-9.60**	-12.61**	-7.98**	-0.19	0.65*	0.18	0.47*	-0.53	-1.85**	-0.83	-1.71**	0.47*	-0.91**	-1.18**	-1.25**
P7 x P8	4.02	-2.82	0.29	3.70	0.75*	0.52*	0.88**	0.96**	-2.04**	-2.05**	-1.10*	-1.80**	0.78**	-0.68**	0.07	0.35
P7 x P9	15.56**	16.18**	15.88**	13.81**	1.55**	2.52**	1.98**	2.64**	5.34**	5.04**	6.82**	7.09**	2.54**	1.69**	3.01**	1.93**
P7 x P10	1.85	-5.33**	3.65	-1.83	-0.82*	-0.02	-0.38	-0.34	-0.68	-1.43**	0.17	1.19**	-0.20	-1.97**	-1.51**	-2.12**
P8 x P9	4.71	-2.88	4.07	5.96**	-0.93**	-0.98**	-1.37**	-1.27**	0.80	0.64	0.35	-3.32**	-1.52**	0.46	-1.36**	0.50*
P8 x P10	0.79	-2.49	1.98	-3.14	-0.32	-1.24**	-0.90**	-0.90**	-1.71**	0.58	-0.04	-0.39	-0.39	-0.69**	0.51	-1.03**
P9 x P10	-4.06	-12.39**	-5.12*	0.57	0.33	-0.78**	0.41	-0.56*	0.22	0.79	0.92	-2.98**	-0.59*	-1.84**	-1.35**	-1.08**
SE (S _{ij})	2.42	2.08	2.45	2.02	0.32	0.26	0.28	0.23	0.53	0.49	0.49	0.40	0.23	0.24	0.28	0.24
SE (S _{ij} -S _{ik})	3.56	3.05	3.61	2.97	0.47	0.38	0.41	0.33	0.78	0.72	0.72	0.59	0.33	0.36	0.41	0.36
SE (S _{ij} -S _{kl})	3.39	2.91	3.44	2.83	0.45	0.37	0.39	0.32	0.74	0.68	0.68	0.56	0.32	0.34	0.39	0.34

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

Table 7: Estimates of specific combining ability effects for number of fruits per plant, number of fruits per cluster, fruit weight and fruit yield per plant

Crosses	Number of fruits per plant				Number of fruits per cluster				Fruit weight (g)				Fruit yield per plant (kg)			
	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄
P1 x P2	12.21**	10.00**	11.42**	8.67**	1.02**	0.88**	0.89**	0.90**	31.10**	37.33**	33.34**	35.26**	1.17**	1.23**	1.09**	1.17**
P1 x P3	-2.30**	-1.87**	-0.69	0.61	-0.26**	-0.21**	-0.33**	-0.16*	-15.70**	-16.41**	-17.08**	-17.42**	-0.52**	-0.43**	-0.47**	-0.44**
P1 x P4	0.14	-0.90	-0.77	-0.87	-0.51**	-0.42**	-0.47**	-0.42**	-2.76	2.13	-12.95**	17.03**	-0.14	0.06	-0.11	-0.17
P1 x P5	-2.77**	-3.92**	-4.50**	-5.02**	-0.18*	-0.21**	-0.23**	-0.19**	15.15**	14.60**	31.44**	15.59**	0.29*	0.23*	0.24*	0.36**
P1 x P6	3.50**	0.78	2.36**	-2.12**	-0.21*	-0.19*	-0.18*	-0.08	0.83	-6.42	-1.61	-10.00**	0.67**	0.27*	0.41**	0.16
P1 x P7	-0.48	1.20	1.23	3.09**	-0.17	-0.35**	-0.15	-0.50**	1.85	-9.41**	2.44	-1.87	0.03	-0.04	-0.01	-0.33**
P1 x P8	-0.04	0.69	-0.38	-1.08	-0.02	0.10	0.02	-0.05	-7.18	-2.84	-10.27*	-7.54*	-0.19	-0.05	-0.05	-0.18*
P1 x P9	-2.03*	-1.05	-1.72*	1.38*	0.61**	0.44**	0.56**	0.27**	-0.14	-0.74	0.77	3.20	-0.30*	-0.37**	-0.36**	-0.26**

P1 x P10	-1.27	-1.77*	-3.36**	-3.17**	0.48**	0.52**	0.54**	0.50**	-0.92	-10.67**	-4.78	-13.74**	-0.24	-0.37**	-0.19	-0.10
P2 x P3	-1.15	0.02	-0.78	3.08**	-0.36**	-0.46**	-0.42**	-0.58**	4.19	-7.50*	0.26	-9.04*	0.41**	0.17	0.09	0.11
P2 x P4	7.59**	9.94**	8.12**	7.20**	1.19**	1.19**	1.10**	1.14**	53.85**	45.83**	52.59**	30.49**	1.62**	1.47**	1.61**	1.35**
P2 x P5	-4.36**	-2.33**	-4.17**	-3.34**	0.72**	0.56**	0.63**	0.45**	-17.28**	-16.08**	-17.15**	-9.61*	-0.72**	-0.16	-0.40**	-0.09
P2 x P6	0.62	-2.16**	-3.15**	-2.64**	0.49**	0.26**	0.27**	0.36**	-25.14**	-14.66**	-22.99**	-15.69**	0.26*	0.49**	0.60**	0.45**
P2 x P7	-6.85**	-5.18**	-4.82**	-6.22**	-1.27**	-1.17**	-1.40**	-1.21**	-2.95	-1.25	0.05	-0.88	-1.14**	-1.12**	-1.09**	-0.93**
P2 x P8	-2.52**	-3.65**	-4.94**	-3.30**	-0.41**	-0.37**	-0.21*	-0.08	19.81**	24.54**	21.29**	25.01**	-0.09	-0.36**	-0.23*	0.01
P2 x P9	4.11**	2.73**	3.61**	1.70**	-0.39**	-0.26**	-0.38**	-0.34**	-1.25	-3.40	-1.29	-7.32	0.27*	0.44**	0.51**	-0.64**
P2 x P10	-1.52	-0.90	0.68	-1.40*	0.18*	0.25**	0.35**	0.37**	28.32**	23.23**	28.32**	17.22**	0.52**	0.53**	0.17	0.34**
P3 x P4	2.63**	1.23	1.31	0.79	-0.28**	-0.40**	-0.40**	-0.32**	-7.54	-8.99*	-7.76	-11.49**	0.10	0.04	-0.40**	0.11
P3 x P5	-0.70	-2.42**	-2.28**	-4.76**	0.24**	0.25**	0.15	0.07	14.42**	35.49**	25.27**	36.8**	0.43**	0.35**	0.52**	0.27**
P3 x P6	0.94	-0.47	0.38	-2.25**	-0.18*	-0.04	-0.08	0.05	5.28	17.05**	13.63**	7.18	0.47**	0.32**	0.53**	0.47**
P3 x P7	3.42**	2.40**	1.47*	2.70**	-0.04	0.02	0.29**	0.17**	-15.85**	-19.38**	-20.50**	-18.69**	0.05	-0.13	0.04	-0.32**
P3 x P8	-0.46	-0.88	-1.14	-1.70**	0.22*	0.07	0.01	0.07	-11.43**	-11.24**	-12.29**	-8.40*	-0.14	-0.30**	-0.09	-0.34**
P3 x P9	-0.13	0.37	0.96	-1.43*	-0.16	-0.21**	-0.03	-0.19**	-4.29	-6.61	-8.18	-8.78*	-0.10	-0.08	-0.05	0.12
P3 x P10	11.20**	11.10**	10.22**	9.61**	1.06**	1.02**	1.09**	0.95**	75.49**	69.39**	77.25**	68.10**	0.53**	1.17**	0.79**	0.75**
P4 x P5	-1.59	-3.57**	-3.27**	-5.02**	-0.31**	-0.31**	-0.30**	-0.30**	6.32	8.48*	14.57**	22.47**	-0.14	-0.23*	0.09	0.05
P4 x P6	1.80*	-0.01	0.30	-0.99	-0.23**	-0.24**	-0.18*	-0.12	-0.79	-15.25**	-6.02	-13.14**	-0.81**	-0.67**	-0.59**	-0.59**
P4 x P7	-5.10**	-7.01**	-3.71**	-6.32**	1.01**	1.11**	1.08**	0.87**	-8.88	-7.84*	-12.80**	-15.54**	0.20	-0.22	-0.07	-0.35**
P4 x P8	3.07**	1.94**	4.38**	2.24**	-0.33**	-0.30**	-0.23**	-0.21**	-8.72	-12.70**	-11.50**	-9.76**	-0.02	-0.10	-0.05	-0.07
P4 x P9	-4.39**	-3.93**	-4.71**	0.88	0.59**	0.49**	0.47**	0.52**	0.65	-5.86	2.37	11.09**	0.36**	0.25*	0.25*	0.21*
P4 x P10	-1.71*	-1.41*	-0.96	0.04	-0.05	0.03	0.09	-0.13*	-41.56**	-22.96**	-32.29**	-43.17**	-0.50**	-0.25*	-0.31**	-0.21*
P5 x P6	-1.63	-1.97**	-1.22	-0.33	-0.21*	0.09	-0.07	0.07	0.83	-4.44	1.76	5.37	-0.57**	-0.77**	-0.76**	-0.83**
P5 x P7	1.36	0.40	1.21	-0.96	-0.07	-0.12	-0.09	0.40**	-14.62**	-14.85**	-9.90*	-11.63**	0.21	0.46**	0.39**	0.64**
P5 x P8	4.00**	4.10**	4.45**	4.27**	-0.01	0.16*	-0.07	0.10	-28.88**	-10.78**	-22.78**	-26.61**	-0.26*	-0.37**	-0.35**	-0.52**
P5 x P9	8.67**	7.71**	8.86**	8.53**	-0.19*	-0.33**	-0.12	-0.32**	-7.99	-5.42	-6.78	-18.49**	0.68**	0.63**	0.83**	0.71**
P5 x P10	0.84	0.19	1.27	3.36**	-0.22*	-0.37**	-0.20*	-0.40**	-23.58**	-14.90**	-21.46**	-26.66**	0.45**	0.50**	0.63**	0.61**
P6 x P7	3.55**	3.31**	3.99**	5.55**	-0.09	-0.28**	-0.20*	-0.36**	-13.94**	-4.22	-12.19**	-18.63**	0.68**	0.73**	0.53**	0.73**
P6 x P8	7.46**	8.84**	7.37**	6.64**	0.87**	0.75**	0.73**	0.16*	62.74**	52.24**	55.88**	61.38**	1.33**	1.36**	1.29**	1.07**
P6 x P9	-3.65**	-3.57**	-3.62**	-3.13**	-0.21*	-0.22**	-0.16	-0.15*	1.22	-4.78	-0.91	-20.26**	-0.21	-0.22	-0.28*	-0.09
P6 x P10	-5.40**	-3.75**	-3.58**	-0.80	-0.15	-0.17*	-0.18*	-0.23**	-2.94	0.34	-2.35	10.19**	-0.38**	-0.40**	-0.36**	-0.39**
P7 x P8	-1.91*	-2.05**	-4.10**	-2.58**	0.11	-0.30**	0.04	-0.19**	12.14**	-3.86	12.23**	-11.70**	1.14**	1.11**	1.09**	1.14**
P7 x P9	9.80**	9.08**	9.12**	5.31**	0.83**	1.01**	0.84**	0.99**	48.91**	57.80**	49.36**	60.16**	1.06**	0.97**	0.95**	1.04**
P7 x P10	3.45**	1.76*	1.70*	0.78	-0.21*	-0.14	-0.25**	-0.14*	3.47	-17.35**	-8.59*	-20.85**	-0.86**	-0.94**	-0.71**	-0.98**
P8 x P9	-3.51**	-5.57**	-3.77**	-5.94**	-0.21*	-0.21**	-0.24**	-0.17**	-4.26	-8.89*	-8.69*	-10.07**	-0.22	-0.23*	-0.40**	-0.26**
P8 x P10	-1.72*	-1.99**	-1.40	-0.58	-0.15	-0.20**	-0.26**	0.00	-3.84	-2.81	-4.13	1.98	-0.17	-0.12	-0.10	-0.07
P9 x P10	-1.31	-3.81**	-3.60**	-6.50**	-0.28**	-0.35**	-0.41**	-0.26**	-38.78**	-26.83**	-34.83**	-17.83**	-0.42**	-0.53**	-0.52**	-0.52**
SE (S _{ij})	0.84	0.68	0.73	0.59	0.09	0.08	0.08	0.06	4.57	3.58	4.24	3.71	0.12	0.11	0.11	0.09
SE(S _{ij} S _{ik})	1.24	0.99	1.07	0.87	0.13	0.11	0.12	0.09	6.72	5.26	6.23	5.45	0.18	0.17	0.15	0.13
SE (S _{ij} S _{kl})	1.18	0.95	1.02	0.83	0.12	0.11	0.12	0.09	6.41	5.01	5.94	5.19	0.17	0.16	0.15	0.12

* Significant at 5% level

** Significant at 1% level

Table 8: Comparative statement of the top ranking three best cross combinations for different characters in different environments on the basis of SCA effects

Characters	Best three crosses				SCA effect				Mean value			
	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄	E ₁	E ₂	E ₃	E ₄
Days to anthesis of first flower	P1 x P2	P1 x P2 P6	P6 x P8 P1	P1 x P2 P7	-13.59**	-12.27**	-11.97**	-17.05**	53.74	58.63	65.33	61.00
	P7 x P9	x P8 P7 x	x P2 P7 x	x P9 P2 x	-13.25**	-10.13**	-11.46**	-13.44**	59.03	70.23	57.96	68.52
	P4 x P5	P9	P9	P4	-8.08**	-6.30**	-9.67**	-10.25**	68.42	72.23	64.83	71.23
Days to 50 per cent flowering	P1 x P2 P7	P1 x P2 P6	P1 x P2 P6	P1 x P2 P6	-11.84**	-10.27**	-10.92**	-14.69**	61.36	68.60	67.23	71.67
	x P9 P4 x	x P8 P2 x	x P8 P2 x	x P8 P7 x	-9.47**	-7.73**	-9.84**	-10.74**	71.86	79.62	74.21	80.50
	P5	P4	P4	P9	-8.38**	-7.62**	-7.02**	-8.91**	77.90	77.23	75.36	81.50
Days to first fruit picking	P7 x P9 P1	P1 x P2 P3	P2 x P4 P1	P1 x P2 P6	-9.92**	-13.25**	-10.39**	-15.71**	87.36	81.40	88.12	85.96
	x P2 P3 x	x P10 P7 x	x P2 P3 x	x P8 P7 x	-9.17**	-10.50**	-9.77**	-11.42**	78.23	95.50	84.30	96.21
	P10	P9	P10	P9	-7.89**	-10.10**	-8.88**	-9.47**	91.32	92.58	92.36	97.66
Leaf area (cm ²)	P3 x P10	P1 x P2 P7	P3 x P10	P7 x P9 P2	16.83**	21.54**	15.17**	15.19**	133.43	128.92	127.42	107.14
	P7 x P9 P1	x P9 P3 x	P7 x P8 P2	x P4 P1 x	12.13**	17.35**	11.97**	15.15**	129.28	120.10	123.66	115.21
	x P2	P10	x P4	P2	8.35**	14.61**	9.79*	15.13**	130.17	120.65	131.47	115.71
Plant height (cm)	P7 x P9 P3	P7 x P9 P3	P7 x P9 P2	P7 x P9 P3	15.56**	16.18**	15.88**	13.81**	88.20	75.91	84.29	67.88
	x P10	x P10 P6 x	x P4 P3 x	x P10 P2 x	14.46**	16.17**	15.12**	10.78**	77.60	68.32	80.36	61.44
	P2 x P4	P8	P10	P4	14.35**	15.67**	13.95**	10.67**	81.70	65.74	73.91	67.73
Plant spread (m ²)	P7 x P9 P6	P7 x P9 P6	P7 x P9 P6	P7 x P9 P2	0.1429**	0.1303**	0.1237**	0.1319**	0.4465	0.3953	0.4215	0.3599
	x P8 P3 x	x P8 P2 x	x P8 P2 x	x P4 P3 x	0.0776**	0.0639**	0.0741**	0.0639**	0.3460	0.2957	0.3215	0.3325
	P10	P4	P4	P10	0.0633**	0.0661**	0.0548**	0.0559**	0.3216	0.3612	0.3755	0.2557
Number of branches per plant	P1 x P5 P2	P1 x P5 P7	P1 x P5 P7	P7 x P9 P1	3.24**	2.78**	2.96**	2.64**	14.73	13.20	14.20	09.74
	x P4 P7 x	x P9 P1 x	x P9 P1 x	x P2 P3 x	1.71**	2.52**	1.98**	2.04**	10.80	10.23	10.74	10.98
	P9	P2	P2	P10	1.55**	1.71**	1.75**	1.94**	11.27	12.32	13.30	09.81
Fruit length (cm)	P1 x P2 P7	P7 x P9 P3	P7 x P9 P1	P7 x P9 P1	5.46**	5.04**	6.82**	7.09**	24.80	21.58	23.98	21.25
	x P9 P3 x	x P10 P1 x	x P2 P3 x	x P2 P3 x	5.34**	4.77**	5.08**	6.45**	23.73	18.90	23.29	20.74
	P10	P2	P10	P10	3.54**	4.72**	4.14**	5.41**	19.45	21.23	19.23	17.88

Fruit width (cm)	P ₁ x P ₂ P ₇	P ₃ x P ₁₀	P ₇ x P ₉ P ₁	P ₃ x P ₁₀	2.62**	3.57**	3.01**	3.52**	8.48	9.33	8.12	9.10
	x P ₉ P ₃ x	P ₁ x P ₂ P ₇	x P ₂ P ₃ x	P ₁ x P ₂ P ₇	2.54**	2.37**	2.58**	3.05**	8.34	7.99	8.33	7.97
	P ₁₀	x P ₉	P ₁₀	x P ₉	2.48**	1.69**	2.45**	1.93**	9.68	6.21	8.52	6.51
Number of fruits per plant	P ₁ x P ₂ P ₃	P ₃ x P ₁₀	P ₁ x P ₂ P ₃	P ₃ x P ₁₀	12.21**	11.10**	11.42**	9.61**	42.67	30.29	38.33	26.91
	x P ₁₀ P ₇ x	P ₁ x P ₂ P ₂	x P ₁₀ P ₇ x	P ₁ x P ₂ P ₅	11.20**	10.00**	10.22**	8.67**	33.56	35.19	30.98	30.21
	P ₉	x P ₄	P ₉	x P ₉	9.80**	9.94**	9.12**	8.53**	38.16	28.53	35.84	25.12
Number of fruits per cluster	P ₂ x P ₄ P ₃	P ₂ x P ₄ P ₄	P ₂ x P ₄ P ₃	P ₂ x P ₄ P ₇	1.19**	1.19**	1.10**	1.14**	4.20	3.85	3.90	3.52
	x P ₁₀ P ₁ x	x P ₇ P ₃ x	x P ₁₀ P ₄ x	x P ₉ P ₃ x	1.06**	1.11**	1.09**	0.99**	3.36	3.70	3.30	3.47
	P ₂	P ₁₀	P ₇	P ₁₀	1.02**	1.02**	1.08**	0.95**	3.90	3.01	3.88	2.67
Fruit weight (g)	P ₃ x P ₁₀	P ₃ x P ₁₀	P ₃ x P ₁₀	P ₃ x P ₁₀	75.49**	69.39**	77.25**	68.10**	200.75	184.11	199.29	169.25
	P ₆ x P ₈ P ₂	P ₇ x P ₉ P ₆	P ₆ x P ₈ P ₂	P ₆ x P ₈ P ₇	62.74**	57.80**	55.88**	61.38**	177.80	153.63	165.52	158.01
	x P ₄	x P ₈	x P ₄	x P ₉	53.85**	52.24**	52.59**	60.16**	195.30	155.74	190.29	147.33
Fruit yield per plant (kg)	P ₂ x P ₄ P ₆	P ₂ x P ₄ P ₆	P ₂ x P ₄ P ₆	P ₂ x P ₄ P ₁	1.62**	1.47**	1.61**	1.35**	5.24	4.78	5.10	4.40
	x P ₈ P ₁ x	x P ₈ P ₁ x	x P ₈ P ₁ x	x P ₂ P ₇ x	1.33**	1.36**	1.29**	1.17**	3.36	3.16	3.25	4.02
	P ₂	P ₂	P ₂	P ₈	1.17**	1.23**	1.09**	1.14**	4.65	4.36	4.44	3.60

Conclusion

Pusa Uttam and Pusa Upkar were the best among the ten parents as it showed desirable mean and GCA effects for most of yield and its contributing traits and yield and other traits respectively. Therefore these parents could be used extensively in hybrid breeding program with a view to increase eggplant yield with quality. Furthermore, based on mean and SCA effects 3 hybrids Pusa Purple Long x Pusa Uttam, Pusa Upkar x Azad-331 and Pusa Uttam x Selection-2 were proved to be the best to increase the eggplant yield with better yield attributing characters. For varietal improvement, these crosses could also be utilized for exploiting promising recombinants and it could be useful towards enhancing eggplant yield and other characters.

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