

Estimation of Combining Ability and Elucidation of Gene Action and Heritability of Quantitative Characters in Brinjal (*Solanum Melongena* L.)

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Abstract

Brinjal is one of the major solanaceous vegetable crops cultivated in all parts of India. Brinjal has a significant genetic diversity for several characters, which can be used to improve the crop both quantitatively and qualitatively. A combining ability analysis was conducted during June, 2022 to December, 2023 at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra on 8 x 8 half diallel set of crosses in brinjal. Eight parents, 28 crosses and 2 standard hybrids checks were evaluated in two seasons viz., *kharif* and summer. Combining ability analysis indicated that both additive and non-additive gene effects play a crucial role for the inheritance of characters in both the seasons. Parents, RHRBR-196, RHRBR-54 and RHRBR-74 identified as good general combiner for plant height, number of primary branches per plant, plant spread (S-N and E-W), days to 50% flowering, fruit length, fruit diameter, average weight of fruit, number of fruits per plant yield per plant and yield per ha. Whereas, Puna Selection x RHRBR-1, Puna Selection x RHRBR-196, Puna Selection x P₅, RHRBR-196 x RHRBR-54, RHRBR-196 x RHRBR-74, RHRBR-54 x RHRBR-74, RHRBR-54 x RHRBR-34, RHRBR-54 x RHRBR-2, RHRBR-74 x RHRBR-34 were identified as good specific combiner for yield and yield attributing traits in both the seasons. High heritability was noted for plant height, fruit length, fruit diameter and average weight of fruit. There was the preponderance of both additive and non-additive gene action for inheritance of yield and its contributing traits.

INTRODUCTION

Brinjal is one of the major commercially and nutritionally important vegetable crops grown extensively in all parts of India. In India, Brinjal is being cultivated in 691 thousand ha area with an average annual production of 13246.26 thousand MT and productivity is 18.80 MT/ha. Among states, West Bengal is the leading producer with annual production of 3086.44 thousand MT of Brinjal whereas, Maharashtra ranked 9th with 321.22 thousand MT brinjal production from 21.02 thousand ha of area (Anonymous, 2026).

Combining ability analysis is one of the best ways to determine the finest combiner to use in crosses, whether to exploit heterosis or to accumulate productive genes. A true understanding of the genetic characteristics of the various aspects is necessary in determining an appropriate breeding system and parent selection as well as identification of superior crosses can benefit from estimates of the general and specific combining ability (Sprague and Tatum, 1942).

Gene action is measured in terms of genetic variance components or combining ability effects. The nature of gene action, as determined by GCA and SCA variance is very helpful in determining inheritance of character and consequently, in choosing an appropriate breeding program. The estimation of heritability enables the breeders to understand the proportion of variation is due to genotypic effect or additive effect and provide accurate indication of the amount of improvement achieved through selection (Panse, 1957). The objective of the present study is to provide information regarding the combining ability of parents and cross combinations, gene action and heritability of numerous quantitative characteristics which are directly or indirectly contributing to the yield.

MATERIALS AND METHODS

The present investigation was undertaken in brinjal during June, 2022 to December, 2023 at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra with the objective to study the general and specific combining ability, the gene action and heritability. The material for the present investigation comprised of eight genetically diverse genotypes (shown in Figure-1) of brinjal viz., Ruchira (P₁), Puna Selection (P₂), RHRBR-1 (P₃), RHRBR-196 (P₄), RHRBR-54 (P₅), RHRBR-74 (P₆), RHRBR-34 (P₇) and RHRBR-2 (P₈). The experiment was laid down in randomized block design in two replications. These parents were crossed in diallel pattern without reciprocals to obtain crossed seeds to raise the F₁s. All eight parents and 28 F₁ hybrids and two standard hybrid checks i.e., Krishna and Phule Arjun were evaluated during summer 2023 and *kharif* 2023. In each replication, 38 plots measuring 3.6 x 3.0 m² were made. Planting was done at a spacing of 90 cm x 75 cm. Each plot had 16 plants.

Five plants per treatments were randomly selected from each replication for recording the observations on parameters i.e., plant height, number of primary branches per plant, days to 50% flowering, plant spread (S-N) and (E-W), length of fruit, fruit diameter, number of fruits per plant, average fruit weight, yield per plant and yield per hectare. The analysis for combining ability was done according to procedure detailed by Griffing (1956), Model I (fixed effect model) and Method II (parents and one set of F₁'s excluding reciprocals). The data analysis was done using INDOSTAT.

RESULT AND DISCUSSION

The analysis of variance for general and specific combining ability of parents and their 28 F₁s is presented in Table 1. Combining ability analysis indicated that both additive and non-additive gene effects play a crucial role for the inheritance of characters in both the seasons.

Table 1
Analysis of variance for combining ability in 8x8 half diallel of brinjal

Source	DF	Plant height (cm)		Number of flowers per inflorescence		Number of primary branches per plant		Days to 50% flowering		Plant spread (cm) (S-N)		Plant spread (cm) (E-W)	
		<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer
GCA	7	993.03**	860.36**	0.04 *	0.08**	0.14 **	0.22 **	12.12**	9.22 **	253.11**	254.91**	150.32**	123.10**
SCA	28	123.01**	116.19**	0.02	0.03	0.11**	0.14 **	12.88**	5.04 **	130.24**	138.34**	78.49**	65.06**
Error	35	2.50	3.22	0.01	0.03	0.03	0.02	1.63	0.77	4.96	3.59	4.34	3.41

Table 1
(contd...)

Source	DF	Length of fruit (cm)		Fruit diameter (cm)		Number of fruits per plant		Average weight of fruit (g)		Yield per plant (kg)		Yield per hectare (q)	
		<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer	<i>Kharif</i>	Summer
GCA	7	1.64**	1.83 **	1.76**	1.73 **	89.24**	83.17 **	783.89**	677.25**	0.86**	0.61**	18882.89**	13446.83**
SCA	28	0.25**	0.28 **	0.13**	0.14 **	61.75**	49.33 **	90.51**	93.47 **	0.44**	0.32 **	9719.44 **	6926.49**
Error	35	0.00	0.01	0.00	0.01	0.66	0.69	0.97	0.70	0.00	0.00	81.45	73.85

The general combining ability effects of parents for both the seasons are described in favorable direction, and presented in Table 2. For plant height, number of primary branches per plant, plant spread (S-N and E-W), number of fruits per plant, fruit length, fruit diameter, average fruit weight, yield per plant and yield per hectare, positive and significant GCA effects were desirable except for days to 50% flowering where negative and significant GCA effects were taken into consideration for parents.

Table 2
Estimation of general combining ability effects for different characters of Brinjal in 8 x 8 half diallel

Parents	Plant Height (cm)		Number of primary branches per plant		Days to 50% flowering		Plant spread (cm) (S-N)		Plant spread (cm) (E-W)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
P ₁	10.32 **	9.84 **	-0.03	0.07	0.59	1.37 **	3.33**	4.06 **	1.93 **	2.93**
P ₂	-5.28**	-4.92 **	-0.01	-0.03	-0.05	0.07	1.83**	2.67 **	1.34 *	0.86
P ₃	-15.75**	-14.79**	0.03	0.18 **	1.21**	-0.31	2.72**	2.59 **	1.44 *	1.71**
P ₄	4.42**	4.81**	0.13*	0.15**	-1.58**	-0.77 **	2.23**	1.99 **	-0.26	0.21
P ₅	9.79 **	9.69 **	0.07	0.05	-1.68**	-1.35 **	2.39**	2.00 **	5.13**	3.58**
P ₆	7.62**	5.12 **	0.14*	-0.10 *	-0.11	-0.51	3.31**	2.48 **	1.98 **	1.48 *
P ₇	0.67	1.12 *	-0.16**	-0.04	0.83*	0.15	-5.81**	-5.71 **	-5.28 **	-4.69 **
P ₈	-11.79**	-10.86**	-0.17**	-0.28 **	0.81 *	1.34 **	-1.00**	-10.07**	-6.28**	-6.07 **
S.E.± (gi)	0.47	0.53	0.05	0.04	0.38	0.26	0.66	0.56	0.62	0.54
C.D. at 5%	1.11	1.25 **	0.12	0.09**	0.89	0.61**	1.56	1.33**	1.46	1.29 **
C. D. at 1%	1.64	1.86 **	0.18	0.14 **	1.32	0.91 **	2.30	1.96**	2.16	1.91 **
Parents	Length of fruit (cm)		Fruit diameter (cm)		Number of fruits per plant		Average weight of fruit (g)		Yield per (kg)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
P ₁	0.19 **	0.29**	0.47 **	0.48 **	-3.94 **	-4.76**	-0.02	0.68**	-0.26**	
P ₂	0.06 **	0.00	-0.01	-0.01	0.10	0.40	-2.53**	-1.83**	-0.04*	
P ₃	-0.55 **	-0.58 **	-0.57**	-0.57**	2.59**	3.43**	-9.64**	-9.27**	-0.20**	
P ₄	0.84 **	0.85**	0.72**	0.72 **	-2.09**	-1.96**	20.13**	18.47**	0.47**	
P ₅	-0.09 **	-0.13 **	-0.04**	-0.09 **	5.06 **	3.10**	0.53	0.04	0.38**	
P ₆	-0.01	0.03	-0.05**	-0.08 **	1.91 **	1.11**	-1.94**	-2.04**	0.09**	
P ₇	-0.21**	-0.14 **	-0.17 **	-0.13**	-1.73 **	-0.81**	-0.21	0.21	-0.09**	
P ₈	-0.23 **	-0.32 **	-0.36 **	-0.33 **	-1.89**	-1.38**	-6.33 **	-6.26**	-0.34**	
S. E. ± (gi)	0.02	0.03	0.02	0.02	0.24	0.24	0.29	0.25	0.02	
C. D. at 5%	0.04	0.07 **	0.04	0.05 **	0.57	0.58 **	0.69	0.58 **	0.04	
C. D. at 1%	0.06	0.11 **	0.05	0.07 **	0.84	0.86 **	1.02	0.86 **	0.06	

During both the seasons, parents viz., P₁, P₄, P₅ and P₆ performed good for plant height and plant spread (S-N and E-W), P₃, P₄ and P₅ for number of primary branches per plant. P₄, P₅ and P₆ for days to 50% flowering, P₁, P₄ and P₅ for length of fruit, fruit diameter and average fruit weight, P₂, P₃, P₅ and P₆ for outperformed for number of fruits per plant, P₄, P₅ and P₆ performed good for yield per plant and yield per hectare. As per the results, among all the parents, P₄, P₅ and P₆ considered good general combiners which outperformed for the most of the yield and yield contributing traits.

The specific combining ability effects of crosses are described in favorable direction and presented in Table 3. The results of present study depicted that the crosses had exhibited the significantly positive SCA effect for plant height, number of primary branches per plant, fruit length, fruit diameter, average fruit weight, number of fruits per plant, yield per plant and yield per hectare except for days to 50% flowering.

Table 3
Estimation of specific combining ability effects for different characters of Brinjal in 8 x 8 half diallel

Hybrids	Plant Height (cm)		Number of primary branches/plants		Days to 50% flowering		Plant spread (cm) (S-N)		Plant spread (cm) (E-W)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
P ₁ x P ₂	9.08 **	9.29 **	-0.04	-0.27 *	-3.26**	-0.70	-6.93 **	-4.88 **	-1.30	-3.13
P ₁ x P ₃	12.04 **	13.63 **	0.02	-0.18	-5.21**	-3.73 **	-11.96**	-11.58 **	-10.63**	-7.92 **
P ₁ x P ₄	4.36 **	2.46	0.12	0.25	-2.12	-3.16 **	5.41 *	7.96 **	6.97 **	8.30 **
P ₁ x P ₅	-5.24 **	-5.74 **	-0.22	-0.15	-3.72 **	-3.21 **	14.59 **	9.00 **	9.63 **	6.46 **
P ₁ x P ₆	9.82 **	8.30 **	-0.09	0.10	-1.69	-2.33 **	12.60 **	12.39 **	16.03 **	11.85 **
P ₁ x P ₇	-4.41 **	-2.67	0.51 **	0.34 **	-0.33	-0.09	2.66	4.70 *	-3.71	-0.15
P ₁ x P ₈	7.47 **	9.00 **	-0.08	0.08	1.09	2.63 **	-0.26	1.66	3.16	1.60
P ₂ x P ₃	-3.07*	-4.26*	-0.10	-0.18	-5.68 **	-2.93 **	12.67 **	10.13 **	10.99 **	0.51
P ₂ x P ₄	24.27 **	22.90 **	0.80 **	0.85**	-1.69	-2.63 **	5.14 *	-0.16	-2.78	-0.56
P ₂ x P ₅	11.42 **	10.34 **	0.46 **	0.05	-0.29	-1.09	20.75 **	22.67 **	16.67 **	19.33 **
P ₂ x P ₆	1.16	6.35 **	0.09	0.50**	-2.46 *	-0.42	-8.73 **	-5.16 **	-3.13	-3.55 *
P ₂ x P ₇	1.95	2.88	-0.21	-0.16	3.91**	2.02 *	20.57 **	22.08 **	8.09**	11.99 **
P ₂ x P ₈	-11.86 **	-10.41 **	-0.09	-0.22	4.03 **	0.53	-4.97 *	-1.63	-4.26 *	-6.18 **
P ₃ x P ₄	1.22	1.38	-0.14	0.04	4.76 **	1.72*	8.52 **	10.28**	4.41 *	6.17 **
P ₃ x P ₅	12.32 **	12.98 **	0.32	0.44 **	1.16	-0.01	3.04	-2.33	0.89	2.92
P ₃ x P ₆	0.01	3.06	0.25	0.59 **	3.19 *	2.85 **	9.74 **	8.13 **	0.98	2.63
P ₃ x P ₇	-10.03**	-8.46**	0.25	0.33*	6.26**	1.69 *	-9.82**	-9.68 **	-2.84	-7.93 **
P ₃ x P ₈	-1.63	-1.74	0.26	0.37 **	4.17 **	0.51	-2.59	0.45	-7.61 **	-5.48 **
P ₄ x P ₅	-2.53	-1.17	0.22	0.57 **	-0.95	2.46 **	-13.52**	-13.35 **	-8.30 **	-7.20 **
P ₄ x P ₆	2.26	4.30 *	-0.35 *	-0.38**	-0.72	-0.49	10.02**	12.37 **	0.43	1.02
P ₄ x P ₇	0.55	2.11	-0.15	-0.24	-2.06	-0.14	-2.73	-3.08	2.60	1.79
P ₄ x P ₈	-2.74	-1.35	-0.24	-0.20	-3.74 **	0.47	11.79 **	6.42 **	4.87 *	7.93 **
P ₅ x P ₆	0.74	-1.04	0.51 **	0.02	-0.10	-0.21	3.82	10.18 **	8.26**	4.84 **
P ₅ x P ₇	-1.19	0.73	-0.19	0.06	-0.06	-0.77	-3.54	0.60	0.85	0.12
P ₅ x P ₈	16.30 **	10.29 **	0.12	-0.10	-0.14	-1.62	2.29	4.98**	6.95 **	1.84
P ₆ x P ₇	5.45 **	-0.62	0.04	0.11	-1.63	-2.11 *	-5.84**	-13.73 **	-9.08**	-8.82 **
P ₆ x P ₈	1.38	-4.62**	-0.15	-0.05	0.79	0.81	6.16 **	6.53 **	7.62 **	6.34 **
P ₇ x P ₈	15.93 **	16.83 **	0.05	0.09	-2.95 *	-0.25	4.56*	0.57	-0.97	-0.27
S. E. ± Sij	1.43	1.63	0.16	0.12	1.16	0.80	2.02	1.72	1.89	1.67
C.D @ 5%	2.94	3.34	0.33	0.25	2.38	1.63	4.14	3.53	3.87	3.44

Table 3
(contd...)

Hybrids	Length of fruit (cm)		Fruit diameter (cm)		Number of fruits per plant		Average weight of fruit (g)		Yield per plant (kg)		Yield per hectare (q)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
P ₁ x P ₂	-0.25**	-0.12	-0.02	0.01	-3.23**	-3.94**	3.64**	4.11**	-0.15*	-0.19**	-22.13*	-27.27**
P ₁ x P ₃	0.35**	0.18	0.20**	0.11	-8.21**	-7.27**	8.66**	8.86**	-0.21**	-0.16**	-30.71**	-23.88**
P ₁ x P ₄	-0.05	0.07	-0.15**	-0.20**	-1.93*	-2.38**	-11.92**	-10.38**	-0.55**	-0.52**	-81.83**	-76.85**
P ₁ x P ₅	0.39**	0.26*	0.41**	0.27**	7.61**	5.16**	4.33**	3.58**	0.67**	0.45**	99.88**	66.14**
P ₁ x P ₆	-0.06	0.01	0.08	0.07	4.36**	3.35**	1.81	2.47**	0.33**	0.28**	48.47**	40.51**
P ₁ x P ₇	-0.14*	-0.13	-0.27**	-0.23**	-2.80**	-3.63**	-2.51**	1.56*	-0.27**	-0.22**	-40.44**	-31.98**
P ₁ x P ₈	0.20**	0.30**	0.45**	0.50**	-3.84**	-2.16**	7.05**	6.85**	-0.04	0.08	-5.52	12.40
P ₂ x P ₃	-0.45**	-0.21*	-0.02	0.00	26.74**	25.07**	6.82**	4.43**	1.92**	1.64**	283.61**	242.65**
P ₂ x P ₄	-0.05	0.00	0.09	0.02	7.03**	4.86**	12.83**	9.37**	1.03**	0.68**	152.61**	101.17**
P ₂ x P ₅	0.41**	0.22*	0.11*	0.17*	-5.93**	-3.70**	6.54**	8.70**	-0.25**	-0.02	-36.76**	-3.49
P ₂ x P ₆	-0.22**	0.03	0.02	0.08	-5.78**	-4.11**	-2.19*	-1.25	-0.48**	-0.34**	-71.98**	-49.43**
P ₂ x P ₇	-0.13*	-0.21*	-0.19**	-0.30**	-9.74**	-10.09**	-12.65**	-13.80**	-0.95**	-0.92**	-139.98**	-137.18**
P ₂ x P ₈	-0.51**	-1.20**	0.07	0.11	-4.18**	-4.52**	-1.95*	-3.44**	-0.30**	-0.32**	-44.02**	-46.97**
P ₃ x P ₄	-0.60**	-0.39**	-0.09	0.01	-7.06**	-6.27**	12.05**	13.72**	-0.15*	-0.04	-21.78*	-5.78
P ₃ x P ₅	-0.35**	-0.34**	-0.03	0.11	-6.02**	-4.53**	-13.07**	-10.39**	-0.80**	-0.62**	-118.39**	-91.06**
P ₃ x P ₆	0.48**	0.64**	0.02	0.13	-5.77**	-4.14**	-3.94**	-3.15**	-0.44**	-0.33**	-65.50**	-48.56**
P ₃ x P ₇	0.48**	0.45**	-0.14**	-0.23**	-3.43**	-4.02**	-8.22**	-8.14**	-0.40**	-0.42**	-59.34**	-61.57**
P ₃ x P ₈	0.66**	0.660**	0.34**	0.24**	-4.57**	-4.55**	-2.82**	-1.50	-0.24**	-0.20**	-35.67**	-29.95**
P ₄ x P ₅	0.86**	0.76**	0.87**	1.01**	3.17**	4.06**	7.77**	5.59**	0.65**	0.58**	95.82**	86.29**
P ₄ x P ₆	0.44**	-0.04	0.58**	0.47**	3.62**	3.45**	8.08**	9.01**	0.60**	0.56**	88.68**	82.85**
P ₄ x P ₇	0.33**	0.14	-0.27**	-0.21**	-2.14**	-1.93*	8.18**	10.49**	-0.05	0.07	-8.45	9.50
P ₄ x P ₈	0.63**	0.80**	-0.43**	-0.34**	-3.08**	-3.46**	13.51**	16.07**	0.06	0.10	9.46	16.03*
P ₅ x P ₆	-0.14*	-0.08	-0.22**	-0.20**	5.26**	1.69*	1.48	3.03**	0.35**	0.17**	50.84**	25.36**
P ₅ x P ₇	0.48**	0.50**	-0.12*	-0.08	3.30**	4.21**	7.44**	8.37**	0.46**	0.57**	68.81**	84.44**
P ₅ x P ₈	-0.07	0.02	-0.09	-0.07	6.86**	6.48**	4.77**	0.75	0.60**	0.42**	89.58**	62.27**
P ₆ x P ₇	0.27**	0.34**	-0.05	-0.01	8.75**	7.50**	6.36**	3.90**	0.79**	0.61**	116.37**	89.94**
P ₆ x P ₈	0.36**	0.63**	0.34**	0.33**	-3.29**	-2.83**	-2.70**	-2.21**	-0.28**	-0.20**	-41.40**	-29.76**
P ₇ x P ₈	-0.52**	-0.30**	0.50**	0.53**	-5.35**	-1.91*	-3.46**	-2.98**	-0.40**	-0.36**	-58.94**	-53.28**
S. E. ± Sij	0.05	0.09	0.05	0.06	0.74	0.75	0.89	0.76	0.06	0.05	8.18	7.79

Hybrids	Length of fruit (cm)		Fruit diameter (cm)		Number of fruits per plant		Average weight of fruit (g)		Yield per plant (kg)		Yield per hectare (q)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
C.D @ 5%	0.11	0.19	0.10	0.13	1.51	1.54	1.83	1.55	0.11	0.11	16.79	15.99

Table 4
Estimation of ratio GCA and SCA variance, additive and dominance variance and narrow sense heritability

S.N.	Character	Season	GCA/ SCA	sl ² a	sl ² D	sl ² a/sl ² D	Gene action	Heritability h ² (ns) %
1.	Plant Height (cm)	Kharif	0.82	198.11	120.52	1.64	Additive gene action	61.90%
		Summer	0.76	171.43	112.97	1.52	Additive gene action	59.60%
2.	Number of primary branches per plant	Kharif	0.14	0.02	0.08	0.25	Non- additive gene action	16.50%
		Summer	0.16	0.04	0.12	0.32	Non- additive gene action	22.10%
3.	Days to 50% flowering	Kharif	0.09	2.09	11.25	0.19	Non- additive gene action	13.90%
		Summer	0.20	1.69	4.27	0.4	Non- additive gene action	25.10%
4.	Plant spread (cm) (S-N)	Kharif	0.20	49.63	125.28	0.4	Non- additive gene action	27.50%
		Summer	0.19	50.27	134.75	0.37	Non- additive gene action	26.60%
5.	Plant spread (cm) (E-W)	Kharif	0.20	29.20	74.15	0.39	Non- additive gene action	27.10%
		Summer	0.19	23.94	61.65	0.39	Non- additive gene action	26.80%
6.	Length of fruit (cm)	Kharif	0.67	0.33	0.25	1.32	Additive gene action	56.70%
		Summer	0.67	0.36	0.27	1.34	Additive gene action	56.20%
7.	Fruit diameter (cm)	Kharif	1.42	0.35	0.12	2.92	Additive gene action	73.50%
		Summer	1.29	0.34	0.13	2.59	Additive gene action	71.30%
8.	Number of fruits per plant	Kharif	0.15	17.72	61.09	0.29	Non- additive gene action	22.20%
		Summer	0.17	16.50	48.65	0.34	Non- additive gene action	25.00%
9.	Average weight of fruit (g)	Kharif	0.87	156.58	89.53	1.75	Additive gene action	63.30%
		Summer	0.73	135.31	92.78	1.46	Additive gene action	59.10%
10.	Yield per plant (kg)	Kharif	0.20	0.17	0.44	0.39	Non- additive gene action	27.80%
		Summer	0.20	0.12	0.31	0.39	Non- additive gene action	27.80%
11.	Yield per hectare (q)	Kharif	0.20	3760.29	9637.99	0.39	Non- additive gene action	27.80%
		Summer	0.20	2674.60	6852.64	0.39	Non- additive gene action	27.80%
*Gene action: if > 1 then additive & if < 1 then non- additive gene action								
*Heritability: high (above 30%), moderate (10–30%) and low (5–10%) [Robinson, 1966]								

The estimates of specific combining ability depicted that the cross combinations, P₂ x P₄ and P₅ x P₆ for plant height and number of primary branches per plant, P₂ x P₅, P₂ x P₇ for plant spread (S-N and E-W direction), P₂ x P₃, P₁ x P₅ and P₁ x P₃ for days to 50% flowering, P₃ x P₈, P₄ x P₅ and P₄ x P₆ for fruit length and fruit diameter, P₂ x P₃ and P₆ x P₇ for number of fruits per plant and for average weight of fruit, P₂ x P₄, P₃ x P₄ and P₄ x P₈ exhibited highest significant SCA effects in desirable direction for both the seasons. The highest SCA effect for yield per plant and yield per hectare was observed in the crosses, P₂ x P₃ followed P₂ x P₄. The results obtained in the present study are in conformity with the earlier findings of Bhushan et al., (2012), Kumar and Arumugam, (2013), Gohil et al., (2017), Chaurasia et al., (2018), Singh et al., (2018) and Mondal et al., (2021). Some of the promising hybrids identified for yield and its contributing characters were shown in Figure-2.

The data representing the estimation of GCA and SCA variance, gene action and heritability is mentioned in Table-4. The ratio of general combining ability variances to the specific combining ability variances was lower than unity which represented the preponderance of additive gene action. Most of the characters have shown moderate heritability range except plant height, length of fruit, fruit diameter, average weight of fruit which have shown high heritability in *kharif* and summer. The estimates of narrow sense heritability are directly proportional to the additive genetic variance, higher the magnitude of additive genetic variance higher the estimates of narrow sense heritability and vice-versa. These findings are supported by Chaitanya et al., (2018), Yadav et al., (2018), Kumar et al., (2019), Srivastava et al., (2019), Bajpai et al., (2020), Deshmukh et al., (2020), Balasubramaniam et al., (2021) and Mondal et al., (2021).

CONCLUSION

Among parents, RHRBR-196, RHRBR-54 and RHRBR-74 outperformed for most of the yield and its contributing characters. Therefore, it is recommended that these parental lines be employed in any future breeding programs. Whereas, the specific combining ability studies reported that Puna Selection x RHRBR-1 exhibited highest positive significant SCA effects followed by Puna Selection x RHRBR-196, RHRBR-74 x RHRBR-34, Ruchira x RHRBR-54, RHRBR-196 x RHRBR-54, RHRBR-196 x RHRBR-74, RHRBR-54 x RHRBR-2, RHRBR-54 x RHRBR-34 and RHRBR-54 x RHRBR-74 for yield per plant and yield per hectare in both the seasons. The information obtained on general and specific combining ability can be utilized in identifying superior varieties to serve as parents for hybridization programme and also to select cross combinations that are likely to produce desirable segregates. The estimates of narrow sense heritability depicted that there was the preponderance of both additive and non-additive gene action for growth, yield and yield contributing characters.

Declarations

CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

Author Contribution

All the authors contributed to the study conception and design. M.N assisted me with the design of the present investigation and also with statistical analysis. Material preparation, data collection and analysis were performed by P. M. The first draft of the manuscript was written by PM. M.N., S. J. and S. S. P. helped in drafting the manuscript and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability

All data supporting the findings of this study are available within the paper. The analysis of data for all the parameters has been done using INDOSTAT.

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Figures



Ruchira (P₁)



Puna Selection (P₂)



RHRBR-1 (P₃)



RHRBR-196 (P₄)



RHRBR-54 (P₅)



RHRBR-74 (P₆)



RHRBR-196 (P₇)



RHRBR-2 (P₈)

Figure 1

Image showing the eight morphologically and genetically diverse genotypes



P₁ x P₅



P₂ x P₃



P₂ x P₄



P₄ x P₅



P₄ x P₆



P₅ x P₆



P₅ x P₇



P₅ x P₈



P₆ x P₇

Figure 2

Image showing the promising hybrids for yield and its contributing characters