Studies on Combining Ability and Heterosis for Yield and its Contributing Characters in Bhendi (*Abelmoschus esculentus* (L.) Moench]

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ABSTRACT

Estimation of combining ability and magnitude of heterosis was conducted at the Department of Genetics and Plant Breeding Farm, Faculty of Agriculture, Annamalai University, in a set of 10 parents (seven lines and three testers) by making 21 cross combinations evaluated during February 2022 to April 2022 in RBD with three replications. The data on eight characters *viz.*, days to fifty per cent flowering (days), plant height (cm), number of branches per plant, number of fruits per plant (g), fruit length (cm), fruit girth, single fruit weight (g), yield per plant were utilized for the present study. The GCA/SCA variance ratio was less than one for all the traits studied, suggesting the predominance of dominance (non-additive) gene action governing the traits. The estimates of combining ability variances revealed that SCA variance was highly significant than the GCA variance as observed from the GCA/SCA ratios for all the traits studied which indicated the preponderance of non-additive gene action. The mean squares due to gca, sca effects were significant for fruit yield and yield contributing traits studied. None of the parents identified as good general combiner for fruit yield per plant but the parents Arka Anamika, Pusa A4, IC 045993, IC 058704 and IC 049972 were identified as average general combiners for yield per plant. Estimated heterosis showed that cross 'IC 049972 x Arka Anamika' had the higher Relative heterosis and Heterobeltiosis in total fruit yield also IC 058704 x Arka Anamika had higher relative heterosis in the same trait. Among twenty-one hybrid combinations, three crosses *viz.*, IC 058704 x Arka Anamika, IC 049972 x Arka Anamika and IC 045993 x Pusa – A4, should be exploited for further advancement in breeding programme.

Key words: Okra, Combining ability, Relative Heterosis, Heterobeltiosis, Standard Heterosis, Fruit yield per plant.

Introduction

Okra (*Abelmoschus esculentus* L.) Moench) is an important warm season fruit vegetable belonging to the family Malvaceae is commonly known as Ladies finger, Okra, Bhindi (Hindi), Dhenras (Bengali), vendai (Tamil), Bhindo (Gujarati), Bendekayi (Kannada), Ventaykka (Malayalam), Asra-Pattraka (Sanskrit) in the different geographical states of its cultivation. (Elkhalifa *et al.*, 2021). Worldwide okra production is estimated to be around 9.96 million tons, India leading rank first in the world with 6,371,000 tonnes (72%) of the total world production (lbitoye and Kolawole, 2022).

The knowledge of genotype x environment interactions gives an idea of stability or buffering ability of the population under study. Genotype x environment interaction is of common occurrence and often creates manifold difficulties in interpreting results and thus, hampers the progress of breeding

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S212

Eco. Env. & Cons. 29 (October Suppl. Issue) : 2023

programme aiming at further genetic improvement in crop plants (Zakir, 2018). Hence, the knowledge of magnitude and nature of genotype x environment interaction is very useful to a breeder for proper understanding and assessment of his material (Voltas *et al.*, 2002). Different models have been used to estimate genotype x environment interactions and stability parameters regarding individual genotype. Phenotypically stable varieties are usually sought for commercial production of crop plant. In any breeding programme it is necessary to screen and identify phenotypically stable genotypes, which can uniformly perform over large areas under different environmental conditions (Al-Naggar *et al.*, 2018).

Major problems of okra are lack of location specific varieties, tolerant or resistant to disease, pest and abiotic stresses. An important challenge would be to develop a variety/hybrid which responds well to resources and should be resistant to yellow mosaic virus. To exploit the heterosis of potential yield components, knowledge of genetic architecture of fruit yield and its attributes is important in crop improvement (Monicashree *et al.*, 2017). The knowledge of the kind of gene effect helps in deciding the breeding procedure and selection of parents for hybridization to build up a population, to determine the combining ability of parents and crosses and to further develop promising hybrids (Sapavadiya *et al.*, 2019). Therefore, an appropriate breeding programme in bhendi requires the knowledge of combining ability. Yield being a complex quantitative character, direct selection for yield may not result in successful improvement. Information on character association and direct and indirect effects of component traits on yield would greatly help in formulating the selection criteria and using them effectively in crop improvement programme. Therefore, it is necessary to partition the observed variability into heritable and non-heritable components by calculating genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance.

Breeding method for the improvement of a crop depends primarily on the nature and magnitude of gene actions involved in the expression of quantitative and qualitative traits. Combining ability (CA) analysis helps in the identification of parents with high general combining ability (GCA) and cross combinations with high specific combining ability (SCA) effects. Additive and non-additive gene actions in the parents estimated through combining

ability analysis may be useful in determining the possibility for commercial exploitation of heterosis. The present study is aimed to obtain the information on Combing Ability and Heterosis of 21 crosses.

Materials and Methods

The experiment was conducted at Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar which was locate at 11°39′ N latitude and 79°71′ E longitude at an altitude of 4.00m/13ft above sea level., Tamil Nadu during February 2022 to April 2022 in a randomized block design with three replications.

The parental materials representing geographical and morphological diversity. The genotypes consisted of seven lines IC 045993, IC 086008, IC 052322, IC 058704, IC 049972, IC 052308 and IC 052299 and three testers Arka Anamika, Pusa A4 and Parbhani kranthi. The experimental plot was ploughed repeatedly and land was brought to a fine tilth, Ridges and furrows were opened at a distance of 45 cm apart, two to three seeds of each genotype per hill were dibbed at a distance of 30 cm, cultural practices were followed as per the package of practices. To maintain a healthy crop stand, standard cultural and agronomical practices were followed as recommended, as well as need-based plant protection measures.

For each genotype, observations were made on five plants at random. The following were the different developmental and economic characters studied such as days to fifty per cent flowering (days), plant height (cm), number of branches per plant, number of fruits per plant (g), fruit length (cm), fruit girth, single fruit weight (gm), fruit yield per plant.

The collected data was computed in the line x tester analysis method. The combining ability variance analysis was observed on the method developed by Kempthrone, 1957 and the formula suggested by Wynne *et al.*, 1970 was used to test the significance of heterosis.

Results and Discussion

The analysis of variance indicated highly significant differences for all the characters suggesting presence of genetic variability. The ANOVA revealed significant differences (p d" 0.05) among the parents for all the eight characters studied. However, there was no

significant differences across the replications, indicating the minimal effect of environment over the trait expression and the predominance of inherent variability among all the cross combinations. GCA variance in all the traits studied. High significant SCA variance was also observed in all the traits as well. The GCA/SCA variance ratio was less than one for all the traits studied suggesting the predominance of dominance (non-additive) gene action governing the traits. The estimates of combining ability variances revealed that SCA variance were highly significant than the GCA variance as observed from the GCA/SCA ratios for all the traits studied which indicated the predominance of non-additive gene action which was in confirmation with the findings of Goksoy, *et al*. (2020) (Table 1). The mean performance of parents is depicted in the (Table 2).

Among the lines evaluated, IC 058704 had the highest mean for the traits fruit yield per plant (354.20), fruit weight (18.64), and fruit girth (6.13), while IC 049972 had the second-highest mean for these traits, fruit yield per plant (326.21), fruit girth (6.08), number of fruits per plant (23.01), and number of branches per plant (4.88), and IC 045993 ranked third with high mean values for the traits like fruit yield per plant (326. 00), fruit weight (18.36), fruit girth (6.01), fruit length (16.84). Among the testers, Pusa A4 had taken fewer days to days to fifty percent flowering, was of short stature and produced the number of fruits per plant and recorded highest mean for fruit yield per plant. Arka Anamika recorded highest mean for plant height, number of fruits per plant and fruit yield per plant. Based on the mean performance of different parental geno-

Table 1. Analysis of variance for combining ability analysis for yield and its component characters in Bhendi

Source of Variations	Df	FF	PH	NBPP	NFPP	FL	FG	FW	FYPP
Replication	2	0.27	0.10	0.10	1.29	0.16	0.01	0.38	14.16
Hybrid	20	43.93*	194.64*	4.11*	52.31*	8.90*	0.31*	7.88*	8207.38*
Lines	6	47.86*	420.80*	7.15*	143.61*	24.90*	0.89*	19.36*	22088.15*
Testers	2	213.27*	300.17*	1.86*	29.72*	0.97*	0.05	0.54*	2786.46*
L x T	12	13.73*	63.98*	2.96*	10.43*	2.22*	0.07*	3.37*	2170.48*
Error	40	0.75	3.60	0.02	0.33	0.24	0.02	0.14	67.95
GCA	0.786	3.403	0.030	1.091	0.174	0.006	0.118	157.211	0.786
SCA	4.327	20.125	0.980	3.364	0.660	0.015	1.077	700.844	4.327
GCA/SCA	0.182	0.169	0.031	0.324	0.264	0.420	0.109	0.224	0.182

*significant at 5 per cent level

Table 2. Mean performance of parents for yield and its component characters in Bhendi

Parents	DFF	PH	NBPP	NFPP	FL	FG	FW	FYPP
				Lines				
IC 045993	36.08*	69.78*	4.80*	21.34*	16.84	6.01	18.36*	326.00*
IC 086008	35.66*	68.63*	5.12*	23.45*	16.44	5.81	16.53	299.21
IC 052322	41.84	74.89	4.18	14.46	14.55	5.70	14.04	302.00
IC 058704	38.89	80.67	4.87*	22.14*	17.32*	6.13*	18.64*	354.20*
IC 049972	37.36*	82.78	4.88*	23.01*	16.35	6.08	18.27*	326.21*
IC 052308	41.93	83.23	3.67	16.46	15.54	5.84	15.38	308.00
IC 052299	39.29	85.25	3.40	17.50	17.50*	5.64	17.50*	266.21
				Testers				
Arka Anamika	48.27	99.73*	2.50	25.36	15.36	6.23	18.21	364.25*
Pusa - A4	40.73*	135.30	2.51	26.30*	14.65	6.16	17.98	365.64*
Parbhani Kranti	38.98*	137.56	2.47	23.64	14.70	6.13	17.50	318.36
Mean of Line (P)	38.72	77.89	4.42	19.76	16.36	5.89	16.96	311.69
Mean of Testers (P)	42.66	124.20	2.49	25.10	14.90	6.17	17.90	349.42
S.E.	0.48	1.28	0.07	0.32	0.26	0.09	0.22	4.90
CD	1.34	3.59	0.18	0.90	0.72	0.24	0.62	13.73

*significant at 5 per cent level

types, the lines IC 058704, IC 049972 and IC 045993 and Pusa - A4, while the testers Arka Anamika were adjudged as the superior parents and similar results were observed in Keerthana *et al.* (2021).

In the present study, the F1 combinations IC 049972 x Arka Anamika and IC 058704 x Arka Anamika recorded the significant mean values for the traits *viz.*, plant height, number of branches per plant, number of fruits per plant, fruit length, fruit girth, fruit weight and fruit yield per plant. The hybrid combination IC 052299 x Pusa - A4 recorded lower mean value for fruit yield per plant and number of branches per plant. IC 045993 x Arka Anamika and IC 045993 x Pusa - A4 cross combinations exhibited high mean for fruit weight and fruit yield per plant among other hybrids. The hybrid, IC 049972 x Arka Anamika produced considerably dwarf plants with low mean for plant height. IC 045993 x Pusa - A4, IC 052322 x Arka Anamika, IC 052322 x Pusa - A4 and IC 049972 x Parbhani Kranti produced high mean number of fruits per plant and fruit length. Anyaoha *et al.* (2022) also reported similar results (Table 3).

General combining ability aids in the identifica-

tion of superior parents, whereas specific combining ability aids in the identification of superior cross combinations. The results of gca effects on parental phenotypes have been depicted in Table 4. The line, IC 058704 showed significant and negative gca effect for days to fifty percent flowering and plant height and it was highly significant and positive for number of branches per plant, number of fruits per plant, fruit length, fruit girth, fruit weight and fruit yield per plant. IC 049972 showed negative gca effect for days to fifty percent flowering, plant height and fruit girth and positive significance for number of branches per plant, number of fruits per plant, fruit length, fruit weight and fruit yield per plant. The line IC 058704 was the best general combiner for number of branches per plant, fruit girth, IC 049972 was found to be a good general combiner for number of fruits per plant, fruit length, fruit weight. The tester genotype Arka anamika was the best general combiner for reduction in flowering duration, reduction in plant height and it showed positive and significant general combining effect for number of branches per plant, number of fruits per plant, fruit girth and fruit yield per plant. Pusa 4, an IIHR geno-

Table 3. Mean performance of hybrids for yield and its component characters in bhendi

	DFF	PH	NBPP	NFPP	FL	FG	FW	FYPP
IC 045993 x Arka Anamika	40.56	81.34	5.87	26.56*	17.56	5.40	18.66*	364.25*
IC 045993 x Pusa - A4	38.89*	66.80*	7.36*	24.45*	18.98*	5.30	19.24*	395.21*
IC 045993 x Parbhani Kranti	44.58	83.56	4.34	22.56	18.34*	5.20	16.45	365.48*
IC 086008 x Arka Anamika	39.89	72.45	4.32	22.45	16.45	6.20*	17.45	348.21
IC 086008 x Pusa - A4	35.67*	69.78*	5.76	18.67	15.67	5.80	18.23*	302.45
IC 086008 x Parbhani Kranti	46.78	75.45	6.55*	17.56	17.23	6.10*	18.87*	298.31
IC 052322 x Arka Anamika	44.67	89.67	6.34*	26.78*	18.65*	5.70	17.87	349.25
IC 052322 x Pusa - A4	41.76	82.56	5.87	25.62*	18.44*	5.80	16.56	332.45
IC 052322 x Parbhani Kranti	45.67	83.56	5.64	22.56	18.45*	5.40	17.78	347.25
IC 058704 x Arka Anamika	35.56*	63.65*	7.34*	29.08*	19.78*	6.30*	19.21*	415.67*
IC 058704 x Pusa - A4	37.99*	67.68*	6.87*	28.56*	18.55*	6.20*	18.65*	381.87*
IC 058704 x Parbhani Kranti	40.67	68.89*	6.56*	25.67*	18.34*	6.00	18.34*	367.87*
IC 049972 x Arka Anamika	34.84*	61.45*	7.24*	30.44*	20.34*	5.60	19.92*	410.25*
IC 049972 x Pusa - A4	36.98*	67.60*	5.76	29.56*	17.56	5.90	17.87	394.67*
IC 049972 x Parbhani Kranti	41.56	76.53	4.78	25.67*	18.89*	5.70	18.98*	345.87
IC 052308x Arka Anamika	43.78	76.78	6.54*	19.67	15.67	5.60	16.87	289.56
IC 052308 x Pusa - A4	40.56	73.77	5.77	21.45	16.87	5.70	17.89	321.46
IC 052308 x Parbhani Kranti	44.56	80.98	5.06	22.78	17.68	5.80	16.78	343.66
IC 052299 x Arka Anamika	38.07*	77.89	4.01	18.34	14.12	6.10*	13.02	289.31
IC 052299 x Pusa - A4	37.15*	78.97	3.12	16.32	14.56	6.20*	15.86	208.34
IC 052299 x Parbhani Kranti	47.31	89.90	4.68	19.87	14.67	6.10*	14.89	250.46
Mean of Cross	40.83	75.68	5.70	23.55	17.47	5.81	17.59	339.14
S.E.	0.48	1.28	0.07	0.32	0.26	0.09	0.22	4.90
CD	**1.34**	**3.59**	**0.18**	**0.90**	**0.72**	**0.24**	**0.62**	**13.73**

*significant at 5 per cent level

type showed negative and significant gca effect for days to fifty per cent flowering, plant height, fruit length and fruit yield per plant. The tester, Parbhani Kranti was a good general combiner for positive significant with days to fifty per cent flowering, plant height (Table 4). Based on the gca effects of the parents, the lines IC 045993, IC 058704 and IC049972 were good general combiners and the testers Arka Anamika and Pusa A4 were better testers with good gca effects. Hence, in the present study, the lines (IC 045993, IC 058704 and IC049972) and the testers (Arka Anamika and Pusa A4) have been selected for hybridization as they possess high mean and significant gca effects for most of the traits under study. The present findings are also in accordance with the results of Shinde *et al*. (2023); Ivin *et al*. (2022) and subakar ivin *et al*. (2022).

The sca effect should be given much importance for the evaluation of a hybrid. Among the twenty-one hybrid combinations, IC 058704 x Arka Anamika, IC 049972 x Arka Anamika and IC 045993 x Pusa - A4 was the best specific combiner for reduction in days to 50 percent flowering and reduction in plant height. Also, this combination exhibited the maximum sca effect for Number of branches per panicle, Fruit length, Fruit weight and Fruit yield per plant. Another cross combination, IC 045993 x Pusa - A4 was a good specific combiner with high fruit yield per plant including high significance with fruit weight. IC 045993 x Pusa - A4, IC 086008 x Arka Anamika, 049972 x Pusa - A4, exhibited significant and positive sca effect for grain yield

per plant were also reported Oladokun *et al*. (2022); Ibirinde *et al*. (2022) (Table 5). The hybrids IC 045993 x Pusa - A4, IC 049972 x Arka Anamika, IC 058704 x Arka Anamika and IC 045993 x Arka Anamika, IC 052308 x Parbhani Kranti, IC 052299 x Arka Anamika exhibited high mean performance and significant sca effects with high x high gca combinations for grain yield and yield related traits. These cross combinations exhibited superior mean performance for grain yield and other traits studied. Hence, these three hybrids could be exploited for heterosis breeding. This indicated that additive gene action played a predominant role and these crosses are found suitable for heterosis breeding. The other hybrids *viz.*, IC 052308 x Pusa - A4 and IC 045993 x Parbhani Kranti recorded non-significant sca effects for almost all the traits studied. The present findings are also in accordance with the results of Vani *et al*. (2020).

The estimates of relative heterosis, heterobeltiosis, and standard heterosis were found to be highly variable in direction and magnitude among crosses for all the characters under study. Kharat *et al*. (2022a); also reported such a variation in heterosis for different characters. The manifestation of negative heterosis observed in some of the crosses for different traits may be due to the combination of the unfavorable genes of the parents.

For number of fruit per plant, the desirable estimates of heterosis over mid parent was in IC 086008 x Arka Anamika, IC 086008 x Pusa - A4, IC 086008 x Parbhani Kranti, IC 052308 x Arka Anamika, IC

Table 4. Estimates of general combining ability (gca) effects for yield and its component characters in bhendi

	DFF	Ph	NBPP	NFPP	FL	FG	FW	FYPP
				Lines				
IC 045993	0.51	1.55*	0.15**	0.97**	0.83**	-0.51**	0.53**	35.84**
IC 086008	-0.05	-3.12**	-0.16**	-3.99**	-1.02**	0.22**	0.59**	-22.81**
IC 052322	3.20**	9.58**	0.25**	1.43**	1.05**	-0.18**	-0.19	3.85
IC 058704	-2.76**	-8.94**	1.22**	4.22**	1.42**	0.35**	1.14**	49.33**
IC 049972	-3.04**	-7.15**	0.22**	5.00**	1.46**	-0.08	1.33**	44.46**
IC 052308	2.13**	1.50*	0.09*	-2.25**	-0.73**	-0.11*	-0.41**	-20.91**
IC 052299	0.01	6.57**	-1.76**	-5.38**	-3.02**	0.32**	-3.00**	-89.76**
				Testers				
Arka Anamika	-1.21**	-0.93*	0.25**	1.21**	0.04	0.03	-0.02	13.22**
Pusa - A4	-2.41**	-3.23**	0.08**	-0.04	-0.23*	0.03	0.17*	-5.36**
Parbhani Kranti	3.61**	4.16**	-0.33**	-1.17**	0.19	-0.06	-0.15	-7.86**
SE(gca for line)	0.29	0.63	0.04	0.19	0.16	0.05	0.12	2.75
SE(gca for tester)	0.19	0.41	0.03	0.13	0.11	0.03	0.08	1.80

*significant at 5 per cent level

Table 5. Estimates of specific combining ability (s*ca*) effects for yield and its component characters in bhendi

	FF	PH	NBPP	NFPP	FL	FG	FW	FYPP
IC 045993 x Arka Anamika	0.43	5.04**	-0.23**	0.83*	-0.78**	0.07	0.56*	23.95**
IC 045993 x Pusa - A4	-0.05	-7.21**	1.42**	-0.04	0.92**	-0.03	0.96**	25.59**
IC 045993 x Parbhani Kranti	-0.38	2.17	-1.18**	-0.79*	-0.14	-0.04	-1.52**	-1.64
IC 086008 x Arka Anamika	0.32	0.82	-1.47**	1.68**	-0.04	0.14	-0.71**	18.67**
IC 086008 x Pusa - A4	-2.70**	0.45	0.13	-0.86*	-0.55	-0.26**	-0.12	-8.52
IC 086008 x Parbhani Kranti	2.39**	-1.27	1.34**	-0.82*	0.59*	0.12	0.83**	-10.15*
IC 052322 x Arka Anamika	1.85**	5.34	0.14	0.59	0.09	0.04	0.48*	-6.95
IC 052322 x Pusa - A4	0.13	0.52	-0.17*	0.67	0.16	0.14	-1.01**	-5.18
IC 052322 x Parbhani Kranti	-1.98**	-5.86	0.02	-1.26**	-0.25	-0.18	0.52*	12.13*
IC 058704 x Arka Anamika	-1.30*	-2.16	0.17*	0.10	0.85**	0.10	0.50*	13.98**
IC 058704 x Pusa - A4	2.32**	4.17	-0.14	0.83*	-0.11	0.01	-0.25	-1.24
IC 058704 x Parbhani Kranti	-1.02*	-2.01	-0.03	-0.93**	-0.74*	-0.11	-0.24	-12.74*
IC 049972 x Arka Anamika	-1.75**	-6.14	1.06**	0.68*	1.37**	-0.16	1.01**	13.43**
IC 049972 x Pusa - A4	1.59**	2.30	-0.25**	1.04**	-1.14**	0.14	-1.22**	16.43**
IC 049972 x Parbhani Kranti	0.15	3.84	-0.82**	-1.71**	-0.23	0.02	0.20	-29.86**
IC 052308x Arka Anamika	2.02**	0.54	0.50**	-2.84**	-1.11**	-0.13	-0.29	-41.89**
IC 052308 x Pusa - A4	0.00	-0.18	-0.10	0.19	0.36	-0.03	0.54*	8.59
IC 052308 x Parbhani Kranti	-2.02**	-0.36	-0.40**	2.65**	0.75*	0.16	-0.25	33.30**
IC 052299 x Arka Anamika	-1.56**	-3.43**	-0.18*	-1.04**	-0.37	-0.06	-1.55**	26.72**
IC 052299 x Pusa - A4	-1.29*	-0.06	-0.90**	-1.82**	0.34	0.04	1.10**	-35.67**
IC 052299 x Parbhani Kranti	2.85**	3.49**	1.07**	2.87**	0.03	0.02	0.45*	8.95
SE(sca effects)	4.327	20.125	0.980	3.364	0.66	0.015	1.077	700.844

*significant at 5 per cent level

052299 x Arka Anamika, IC 052299 x Pusa - A4, IC 052299 x Parbhani Kranti heterosis over better parent was in IC 058704 x Arka Anamika, IC 049972 x Arka Anamika, IC 045993 x Pusa - A4, IC 045993 x Arka Anamika, IC 052322 x Arka Anamika. Such extent of heterosis was also reported by Sapavadiya *et al*. (2019); Das *et al*. (2022). Among all the 21 crosses, two crosses exhibited significant and desirable relative heterosis; one cross exhibited desirable heterobeltiosis whereas three crosses exhibited desirable standard heterosis for number of Fruits per plant. IC 052322 x Arka Anamika had high values for Relative heterosis and high Heterobeltiosis of IC 049972 x Arka Anamika also showed high standard heterosis. These findings were comparable to that of previous findings by Prakash *et al*., (2019) and Ramesh *et al*. (2015). In case of average fruit weight, positive heterosis is desirable since it is directly related to total fruit yield. The maximum extent of heterosis was observed in hybrid IC 086008 x Parbhani Kranti (10.88%) over mid parent, IC 049972 x Arka Anamika (9.03%) over better parent while in IC 058704 x Arka Anamika (18.86%) over standard heterosis (Table 6). The outcome showed overall nine crosses for relative heterosis, three crosses for heterobeltiosis and five crosses for stan-

dard heterosis recorded positively significant estimates. Similar kind of results were reported by Singh and Arivazhagan, 2022; Kharat *et al*. (2022b) and Saleem *et al*., (2023). Yield per plant is the main parameter of focus in any breeding programme. This trait is a dependent character, depends on many yield components for its expression. Among all twenty-one crosses, nine crosses for relative heterosis, six for heterobeltiosis and eight crosses for standard heterosis exhibited positively significant estimates. The highest magnitude of relative heterosis, heterobeltiosis and standard heterosis was observed in hybrid IC 058704 x Arka Anamika (18.86%, 17.35% and 20.40%), IC 049972 x Arka Anamika (32.03%, 18.83%, 18.83%) and IC 045993 x Pusa - A4 (16.30%, 11.44%, 14.47%) respectively. Similar results with agreement to this finding were reported by Vekariya *et al*. (2019); Rynjah *et al*. (2020); Karadi *et al*. (2021).

Conclusion

In the current study, based on the per se performance of different traits of parents, the lines IC 045993, IC 058704 and IC 049972 and tester genotype Arka Anamika and Pusa A4 were found to be

Table 6. Percentage of heterosis for observations taken for the study in bhendi

Hybrids	RH (d_i)	H (d_{ii})	SH (d_{iii})	RH (d_i)	H (d_{ii})	SH (d_{iii})	RH (d_i)	H (d_{ii})	RH (d_{iii})
		NFP			F	W		FYPP	
IC 045993 x Arka Anamika	13.75**	4.73**	4.73**	2.05	1.63	2.47	8.69**	5.50**	5.50**
IC 045993 x Pusa - A4	2.64	-7.03**	-3.59*	5.89**	4.79**	5.66**	16.30**	11.44**	14.47**
IC 045993 x Parbhani Kranti	0.31	-4.57*	-11.04**	-8.25**	-10.40**	-9.67**	8.55**	4.91*	5.86**
IC 086008 x Arka Anamika	-8.00**	-11.47**	-11.47**	0.46	-4.17*	-4.17*	6.25**	0.86	0.86
IC 086008 x Pusa - A4	-24.95**	-29.02**	-26.39**	5.65**	1.39	0.11	-9.02**	-14.72**	-12.40**
IC 086008 x Parbhani Kranti	-25.40**	-25.71**	-30.74**	10.88**	7.81**	3.61*	-9.41**	-14.37**	-13.60**
IC 052322 x Arka Anamika	34.51**	5.60**	5.60**	10.82**	-1.87	-1.87	7.92**	1.16	1.16
IC 052322 x Pusa - A4	25.71**	-2.59	1.03	3.46*	-7.88**	-9.04**	1.26	-6.26**	-3.71
IC 052322 x Parbhani Kranti	18.41**	-4.58*	-11.05**	12.75**	1.60	-2.36	6.79**	-0.32	0.58
IC 058704 x Arka Anamika	22.45**	14.67**	14.67**	4.26**	3.06	5.49**	18.86**	17.35**	20.40**
IC 058704 x Pusa - A4	17.93**	8.59**	12.62**	1.86	0.05	2.42	7.75**	7.68**	10.61**
IC 058704 x Parbhani Kranti	12.15**	8.59**	1.22	1.49	-1.61	0.71	4.72**	3.86	6.55**
IC 049972 x Arka Anamika	25.86**	20.03**	20.03**	9.21**	9.03**	9.39**	32.03**	18.83**	18.83**
IC 049972 x Pusa - A4	19.89**	12.40**	16.56**	-1.39	-2.17	-1.85	25.12**	11.29**	14.31**
IC 049972 x Parbhani Kranti	10.05**	8.59**	1.22	6.12**	3.89*	4.23*	10.75**	-0.72	0.18
IC 052308x Arka Anamika	-5.93**	-22.44**	-22.44**	0.43	-7.38**	-7.38**	-11.35**	-16.13**	-16.13**
IC 052308 x Pusa - A4	0.33	-18.44**	-15.42**	7.25**	-0.50	-1.76	-2.98	-9.36**	-6.89**
IC 052308 x Parbhani Kranti	13.62**	-3.64	-10.17**	2.07	-4.11*	-7.85**	4.72*	-1.35	-0.46
IC 052299 x Arka Anamika	-14.42**	-27.68**	-27.68**	-27.06**	-28.48**	-28.48**	-11.18**	-16.20**	-16.20**
IC 052299 x Pusa - A4	-25.48**	-37.95**	-35.65**	-10.58**	-11.77**	-12.89**	-36.95**	-41.25**	-39.65**
IC 052299 x Parbhani Kranti	-3.40	-15.95**	-21.65**	-14.91**	-14.91**	-18.23**	-23.47**	-28.10**	-27.46**

*Significant at 5 per cent level
RH- Relative Heterosis; H- Heterobeltiosis; SH- Standard Heterosis
NFPP- Number of fruits per plant; FW- Fruit Weight; FYPP- Fruit yield per plant

best performers for grain yield and its component traits. Thus, based on per se mean performance and gca effects, the lines IC 058704, IC 049972 and tester genotype Arka Anamika, Pusa A4 was adjudged as superior for grain yield and other related traits. The recorded mean grain yield was highest for IC 058704 x Arka Anamika which was closely followed by IC 049972 x Arka Anamika and IC 045993 x Pusa - A4. IC 058704, IC 049972 and IC 045993 are good general combiner liners for fruit yield per plant and other related traits. Among the tester genotypes, Arka Anamika and Pusa A4 have shown good general combining ability for most of the economic traits. Among twenty-one hybrid combinations, three crosses viz., IC 045993 x Pusa - A4, IC 058704 x Arka Anamika and IC 049972 x Arka Anamika were highly significant and positive specific combiner for fruit yield per plant and its component traits. Thus, it is concluded based on the mean performance, sca effect and heterosis, the hybrids IC 058704 x Arka Anamika, IC 049972 x Arka Anamika, IC 045993 x Pusa - A4, which can be exploited for further advancement in breeding programme.

Acknowledgement

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S218

Eco. Env. & Cons. 29 (October Suppl. Issue) : 2023

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