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Analysis of Heterotic Potential for Earliness, Yield and its Attributing Traits in Okra (*Abelmoschus esculentus* L. Moench)

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ABSTRACT

The present study was conducted during the late *kharif* season (July to November, 2023) at the Genetics and Plant Breeding Research Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab India. This study assessed heterosis in okra (*Abelmoschus esculentus* L.) for 12 traits, including earliness and fruit yield using Randomized Block Design. Thirty-five F_1s were obtained from crossing 7 lines with 5 testers in line×tester method and compared with one commercial check (Punjab-8) to estimate standard heterosis and heterobeltiosis among better parents. Significance of mean square due to genotypes revealed the presence of considerable genetic variability among the material studies for almost all the traits. The best positive heterotic cross over better parent (Heterobeltiosis) and standard check (Punjab 8) for fruit yield plant^{-1} was Go-6×Arka Abhay (72.32%) and Phule Prajatiti×Arka Abhay (41.63%) respectively. While Punjab Suhanani×GAO-5 (-12.05%) was found as negatively heterotic cross for days to 50% flowering over better parent and GAO-8×Arka Abhay (-13.26%) over standard check respectively. For days to first picking Pusa Savani×VRO-106 (-14.44%) exhibited negatively significant heterosis over better parent and Phule Prajatiti×Arka Abhay (-14.49%) over standard check respectively, that are important to exploit the earliness traits in okra. The hybrid Phule Prajatiti×Arka Abhay, which has a high potential for yield and fruits can be picked earlier which may evaluated further for early *kharif* season in Punjab.

KEYWORDS: Earliness, heterosis, heterobeltiosis, standard check, yield

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Okra (*Abelmoschus esculentus*) is a vegetable crop that is widely grown in warm-season i.e. tropical and subtropical regions around the World. Okra (*Abelmoschus esculentus* L. Moench) is a widely cultivated vegetable crop in tropical and subtropical regions, with a chromosome number of 2n=2x=130 (Patil et al., 2015). India is the largest global producer of okra, contributing over 72% (6.47 mt) from an area of 0.5 mha, as per the National Horticulture Board report Anonymous (2022). It accounts for the 60% of the total fresh vegetable export from India (Chaudhary et al., 2023). It is native to tropical Africa (Benchasri, 2012) and is known for its immature green seed pods, which are consumed as a cooked vegetable, fresh or sundried (Liu et al., 2021). It was believed that okra centre of origination is South Africa near Ethiopia as per Vavilov (1951). The origin of okra can be traced back to the Hindustani region, where it was primarily cultivated in India, Pakistan, and Burma (Zeven and Zhuckovsky, 1975). Immature okra pods utilized for making pickles (Chavan et al., 2023). In Punjab, okra is commercially cultivated across approximately 4.57 thousand hectare of land and yields an annual production of 47.65 thousand tonnes.

Exploiting heterosis in okra plays a crucial role in enhancing yield and related traits within crop improvement programs. Being a cross pollinated crop, it has a high level of genetic diversity (Duggi et al., 2013), making it important to evaluate the germplasm for genetic variability as the first step in okra improvement (Singh et al., 2012). The second step is to generate crosses using a suitable mating design, to understand the extent of heterosis for various economic traits and the inheritance pattern of desired characters (Das et al., 2020). Yield is a pivotal trait in both okra cultivars and hybrids, prompting extensive endeavours have been undertaken to enhance yield, production and quality characteristics (Singh et al., 2017).

Heterosis play a major role in providing valuable insights for improving economically important traits in okra (Mkhabela et al., 2022). To overcome the yield limitations of existing open-pollinated okra varieties, the implementation of a hybridization-based breeding strategy is deemed essential (Waghmare, 2022). In cross-pollinated crops like okra, heterosis breeding has been found to be the most effective method for augmenting productivity. The anticipation and management of the projected demand for increased productivity are imperative due to the substantial size of its flower and monoadelphous stamens. Additionally, several researchers have documented a noteworthy occurrence of heterosis in okra, particularly in relation to various traits associated with fruit yield (Kumar et al., 2023).

In okra, heterosis has been observed for various traits including yield, plant height, fruit length and earliness (Chaudhary et al., 2023; Kumar et al., 2023). Hybrid okra varieties have been developed using different breeding methods, including conventional breeding and biotechnology approaches (Mishra et al., 2021). These hybrid varieties have shown improved yield potential and better resistance to pests and diseases compared to their parental lines. Overall, heterosis has significant potential for the development of hybrid okra varieties with improved yield potential, disease resistance and other desirable traits (Rynjah et al., 2020). The exploitation of heterosis in okra has been acknowledged as a useful method for improving yield and other significant traits in breeding programs (Reddy et al., 2023). Yield is a crucial trait of okra cultivars and hybrids and considerable efforts have been made to enhance yield production and quality properties (Alam et al., 2021). Taking into consideration all the relevant factors, this investigation employed a line x tester mating design that involved 12 genetically diverse genotypes of okra. The study aimed to estimate standard heterosis and heterobeltiosis for yield and its attributing traits in okra.

2. MATERIALS AND METHODS

The present research was conducted at the Genetics and Plant Breeding Research Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India by developing 35 F_1s using 12 genotypes of okra (7 lines and 5 testers) and one standard check (Table 1) evaluated in RBD with 3 replication in *kharif*, 2023. Twelve quantitative traits were examine from five randomly selected plants of each parent and F_1 generation *viz.* DF: Days to 50% flowering, DP: Days to first picking; PH: Plant height (cm), NBP: No. of branches plant^{-1}, NNP: No. of nodes plant^{-1}, IL: Internodal length (cm), NFP: No. of fruits plant^{-1}, FL: Fruit length (cm), FG: Fruit girth (cm), FYP: Fruit yield plant^{-1}, DTPP: Total number of picking plant^{-1}, NMFP: No. of marketable fruits plant^{-1}.

The significance of differences between treatments was

Table 1: List of parents used in crossing programme with a commercial check

Lines (7)		Testers (5)		Commercial check
Pusa Savani	L_1	Arka Abhay	T_1	Punjab-8
Phule Vimukta	L_2	GAO-5	T_2	
Phule Prajatiti	L_3	VRO-106	T_3	
Punjab Suhanani	L_4	K-54	T_4	
GAO-8	L_5	VRO-6	T_5	
GO-6	L_6			
Harita	L_7			

assessed by conducting an analysis of variance (ANOVA) for randomized block design (RBD) using the procedure outlined by Panse and Sukhatme (1985) for all the metric traits studied. The performance of the F_1 hybrid was evaluated based on the heterosis over better parent and standard check, following the method proposed by Fonseca and Patterson (1968). The percent increase or decrease in F_1 hybrids over better parent and standard checks was calculated to determine heterosis, using the formulae given by Singh and Chaudhary (1977). Significance of heterosis is tested with the help of standard error using 't' test.

1. Heterosis over Better parent (BPH)

BPH%=(F_1-BP/BP)×100

2. Heterosis over standard check (SH)

SH%=(F_1-SC/SC)×100

Where,

BPH=Mean performance of better parent, SC=Mean performance of standard check.

3. RESULTS AND DISCUSSION

3.1. Analysis of variance

Analysis of Variance (ANOVA) showed that mean squares due to genotypes was significant for almost all the studied characters (Table 2). This can be explained by the existence of distinct genotypic variations among the parents and their hybrids, which were manifested in the phenotype. The significance of mean squares due to parents vs. hybrids for all the traits proved that the differences in the performance of parents and hybrids were real and manifested in the presence of heterosis for most of the traits studied. Similar results were also revealed by Kumar et al. (2023); Chaudhary et al. (2023); Armand et al. (2021) and Pithiya et al. (2019) In the realm of vegetable breeding, including the development of okra hybrids, breeders have extensively utilized heterosis to enhance fruit yield (Ebert, 2020).

Table 2: Analysis of variance (ANOVA) for heterosis for yield and its attributing traits in okra

Source of variation	Df	DF	DP	PH	NBP	NNP	IL
Replication	2	4.30	3.70	5.03	0.49*	0.10	0.05
Crosses	34	10.27**	24.70**	430.19**	0.93**	5.89**	2.79**
Error	68	2.94	2.63	12.27	0.13	0.56	0.11

Table 2: Continue...

Source of variation	Df	NFP	FL	FG	FYP	DTPP	NMFP
Replication	2	4.29	0.75	0.09	95.36*	0.66	2.12
Crosses	34	58.94**	8.08**	0.92**	12765.13**	5.58**	10.68**
Error	68	1.94	0.67	0.12	29.13	0.67	1.89

DF: Days to 50% flowering; DP: Days to first picking; PH: Plant Height (cm); NBP: No. of branches plant^{-1}; NNP: No. of nodes plant^{-1}; IL: Internodal length (cm); NFP: No. of fruits plant^{-1}; FL: Fruit length (cm); FG: Fruit girth (cm); FYP: Fruit yield plant^{-1}; DTPP: Total number of picking plant^{-1}; NMFP: No. of marketable fruits plant^{-1}; *, ** Denotes significance at (p=0.05) and (p=0.05) respectively

3.2. Estimation of heterobeltiosis and standard heterosis

The heterobeltiosis and standard heterosis for 35 hybrids for 12 traits in okra are presented in Table 3. The top three crosses for standard heterosis, considering economic feasibility tabulated in Table 4.

3.1. Negative heterosis

3.1.1. Days to 50% flowering and days to first picking

Negative heterosis is desirable for earliness for days to 50% flowering and days to first picking where, the data pertaining for days to 50% flowering, out of 35 crosses, 3 crosses exhibited negative significant effect over heterobeltiosis range from -7.10% (Phule Vimukta×GAO-5) to -10.96% (Harita×GAO-5) and 9 crosses over standard heterosis range from -7.71% (Punjab Suhanani×VRO-106) to -13.26% (GAO-8×Arka Abhay). Cross Punjab Suhanani×GAO-5 exhibited both better parent and standard heterosis for this trait. For days to first picking, 6 crosses exhibited negative significant effect over heterobeltiosis range from -7.30% (Phule Prajatiti×VRO-106) to -14.44% (Pusa Savani×VRO-106) and 18 crosses exhibited negative significant over standard heterosis range from 7.28 % (GO-6×VRO-6) to -14.49% (Phule Prajatiti×Arka Abhay). Cross Phule Prajatiti×Arka Abhay exhibited both better parent and standard heterosis for this trait. Kumar et al. (2023); Shinde et al. (2023); Mundhe et al. (2022); Kharat et al. (2022) and Rynjah et al. (2020) also revealed similar results where negative heterosis for earliness found for days to 50% flowering and days to first picking. In this study, cross VRO-4×Azad Ganga exhibited high negative heterosis over both

Table 3: Heterosis for days to 50% flowering, days to first picking, plant height, number of branches, number of nodes and internodal length in okra

Cross No.	Genotypes	Days to 50% flowering		Days to First picking		Plant height		No. of branches		No. of nodes		Internodal length	
		BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH
C1	$L_1 \times T_1$	5.31	-6.32*	-9.92**	-13.09**	-15.38**	-18.78**	15.35*	2.70	0.56	16.88**	43.32**	11.73**
C2	$L_1 \times T_2$	-6.88*	-5.00	3.21	-5.69*	23.68**	5.75	3.04	5.18	-2.61	21.21**	6.79	0.56
C3	$L_1 \times T_3$	1.31	-8.47**	-14.44**	-11.88**	5.32	-7.49*	-2.65	13.88*	-4.05	12.77**	-26.54**	-22.63**
C4	$L_1 \times T_4$	-7.01*	-7.01*	3.29	0.25	5.54	-0.80	27.33**	15.74**	-11.73**	2.60	-14.03**	-21.45**
C5	$L_1 \times T_5$	12.52**	-0.76	2.84	-7.48**	-24.37**	-17.54**	-13.49**	-0.41	-10.43**	4.11	-8.34*	-1.40
C6	$L_2 \times T_1$	9.52**	-2.57	-6.44*	-13.85**	18.55**	13.79**	3.96	-2.27	12.03**	14.94**	-19.69**	-19.25**
C7	$L_2 \times T_2$	-7.10**	-6.46*	-4.81	-13.02**	31.84**	12.73**	15.21**	17.61**	-1.22	22.94**	-0.25	0.31
C8	$L_2 \times T_3$	9.22**	-1.32	-5.05	-12.57**	-6.04	-17.47**	-6.90	8.91	-13.44**	1.73	-2.65	2.54
C9	$L_2 \times T_4$	-2.50	-2.50	0.14	-7.79**	21.84**	14.53**	14.54*	7.67	4.98	18.61**	-11.36*	-10.87*
C10	$L_2 \times T_5$	10.55**	-2.50	0.14	-9.90**	3.17	14.18**	1.62	16.99**	5.91	8.66*	-9.35*	-2.49
C11	$L_3 \times T_1$	8.85**	-3.47	-11.37**	-14.49**	16.94**	4.09	5.61	16.99**	13.72**	36.36**	3.03	-13.66**
C12	$L_3 \times T_2$	1.41	-10.07**	12.92**	3.18	-0.66	-15.06**	-2.80	7.67	-17.57**	2.60	42.39**	34.08**
C13	$L_3 \times T_3$	2.82	-8.82**	-7.30**	-9.20**	18.58**	4.16	6.37	24.44**	3.61	24.24**	-7.96	-3.05
C14	$L_3 \times T_4$	13.16**	0.35	2.89	-0.14	23.62**	10.04**	-11.21*	-1.65	-3.07	16.23**	-13.45**	-20.92**
C15	$L_3 \times T_5$	10.79**	-2.29	2.98	-7.35**	20.96**	7.66*	-17.27**	-4.75	0.54	20.56**	-7.79	-0.81
C16	$L_4 \times T_1$	11.24**	-1.04	-5.89*	-9.20**	-13.94**	-17.40**	-2.12	14.50**	29.51**	32.03**	12.46**	5.89
C17	$L_4 \times T_2$	-12.05**	-10.83**	5.59*	-3.52	30.55**	11.63**	-22.83**	-9.72	-13.04**	8.23*	-13.05**	-18.13**
C18	$L_4 \times T_3$	2.15	-7.71**	-13.38**	-10.79**	-6.17	-17.58**	0.00	16.99**	-1.66	15.58**	27.29**	34.08**
C19	$L_4 \times T_4$	-6.53*	-6.53*	-2.43	-5.31*	19.66**	12.48**	-0.53	16.36**	8.43*	22.51**	7.12	0.87
C20	$L_4 \times T_5$	2.91	-9.24**	13.33**	1.97	-14.17**	-17.36**	1.06	18.23**	10.40**	12.55**	-1.04	6.45
C21	$L_5 \times T_1$	-2.50	-13.26**	5.75*	2.03	20.73**	15.88**	-5.18	-8.51	-17.73**	3.46	12.57**	17.32**
C22	$L_5 \times T_2$	9.42**	-0.76	-1.68	-10.16**	29.23**	10.50**	7.88	10.12	-10.15**	12.99**	0.00	4.22
C23	$L_5 \times T_3$	1.69	-8.13**	-4.63	-7.92**	23.82**	8.76**	-19.67**	-6.02	-18.07**	3.03	27.29**	34.08**
C24	$L_5 \times T_4$	-1.00	-10.21**	-6.48*	-9.71**	-10.21**	-15.59**	21.86**	17.58**	-4.48	20.13**	-1.07	3.10
C25	$L_5 \times T_5$	8.43**	-4.38	13.26**	1.91	8.48**	4.19	-24.30**	-12.86*	-17.21**	4.11	-26.49**	-20.92**
C26	$L_6 \times T_1$	11.79**	-0.56	3.80	-7.54**	-7.89*	-11.59**	-0.55	13.26*	13.09**	14.07**	45.28**	17.32**
C27	$L_6 \times T_2$	2.61	0.83	15.62**	2.99	9.57**	-6.32*	6.00	20.71**	-0.52	23.81**	6.53	0.31
C28	$L_6 \times T_3$	1.00	-8.75*	1.43	-9.64**	30.51**	14.64**	-17.52**	-3.51	-1.84	15.37**	-12.73**	-8.07
C29	$L_6 \times T_4$	1.41	-0.35	10.17**	-1.86	-11.53**	-16.84**	-13.64**	-1.65	-6.51	5.63	7.95	-1.37
C30	$L_6 \times T_5$	7.72*	-5.00	4.08	-7.28**	-0.47	0.41	-0.54	14.50**	20.82**	21.86**	-28.04**	-22.60**
C31	$L_7 \times T_1$	4.76	-6.81*	5.69*	1.97	14.68**	10.07**	-16.92**	-8.48	2.12	24.89**	26.39**	7.01
C32	$L_7 \times T_2$	-10.96**	-9.72**	9.08**	-0.33	16.81**	-0.12	4.51	15.12**	-10.43**	11.47**	-10.09*	-15.34**
C33	$L_7 \times T_3$	4.38	-5.69*	-10.27**	-8.88**	7.62*	-5.47	1.59	18.85**	-15.93**	2.81	-5.83	-0.81
C34	$L_7 \times T_4$	1.39	1.39	3.35	0.31	-12.69**	-17.93**	-2.26	7.67	0.53	22.94**	34.52**	22.91**
C35	$L_7 \times T_5$	7.80*	-4.93	5.39	-5.18*	7.00*	15.31**	-14.03**	-1.03	-15.22**	3.68	-23.37**	-17.57**

*, ** Denotes significance at (p=0.05) and (p=0.05) respectively

Table 3: Continue...

Table 3: Heterosis for days to 50% flowering, days to first picking, plant height, number of branches, number of nodes and internodal length in okra

Cross No.	Genotypes	No. of fruits plant^{-1}		Fruit length		Fruit girth		Fruit yield plant^{-1}		Total no. of picking plant^{-1}		No. of marketable fruits plant^{-1}	
		BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH
C1	$L_1 \times T_1$	-22.61**	-9.87	24.87**	15.12**	-2.87	11.06*	-11.89**	-33.38**	0.00	5.65	-11.76**	12.50*
C2	$L_1 \times T_2$	-28.39*	-12.53*	6.27	3.41	4.54	19.53**	41.29**	41.12**	5.81	11.79*	-6.02	4.00
C3	$L_1 \times T_3$	-32.28**	-19.87**	-17.34**	0.00	10.75*	26.63**	-29.72**	-28.48**	1.86	7.81	10.82*	28.00**
C4	$L_1 \times T_4$	68.57**	37.47**	13.23**	19.02**	-0.12	14.20**	-22.56**	-5.31**	2.14	8.11	1.91	15.67**
C5	$L_1 \times T_5$	34.89**	41.63**	-21.56**	-9.51	12.30**	28.40**	48.63**	6.25**	9.30*	15.48**	9.94*	21.67**
C6	$L_2 \times T_1$	-3.29	12.63*	2.27	9.76*	-6.44	3.09	-40.54**	-33.29**	20.07**	17.94**	-7.19	18.33**
C7	$L_2 \times T_2$	-19.52**	-1.70	-17.27**	-11.22*	-9.13*	0.13	-26.20**	-17.20**	11.79*	4.86	30.88**	24.33**
C8	$L_2 \times T_3$	18.28**	39.97**	4.84	26.83**	-9.13*	0.13	4.14*	16.85**	-7.20	-1.78	-15.58**	-2.50
C9	$L_2 \times T_4$	-7.14	-7.87	0.91	8.29	2.68	13.15*	-4.04**	17.33**	-7.20	-1.78	-4.41	8.50
C10	$L_2 \times T_5$	-8.45	-3.87	-19.03**	-6.59	15.99**	27.81**	-5.27**	6.29**	8.03	-7.43	14.14*	10.33
C11	$L_3 \times T_1$	-23.33**	-10.70	20.84**	18.78**	-2.64	9.01	1.88	41.18**	15.07**	13.02**	-3.27	23.33**
C12	$L_3 \times T_2$	13.50**	38.63**	16.63**	14.63**	-7.93	3.09	-22.80**	6.97**	-6.55	-12.34*	29.65**	23.17**
C13	$L_3 \times T_3$	-13.55**	2.30	0.81	21.95**	-8.46	2.50	-37.31**	-13.13**	-16.48**	-11.61*	-10.97*	2.83
C14	$L_3 \times T_4$	-13.60*	-11.03	16.01**	21.95**	1.06	13.15*	2.21	41.63**	-6.50	-1.04	-2.06	11.17*
C15	$L_3 \times T_5$	34.73**	41.47**	12.05**	29.27**	2.52	14.79**	-51.64**	-32.99**	20.25**	8.05	22.41**	18.33**
C16	$L_4 \times T_1$	-3.01	12.97*	24.39**	24.39**	-2.32	0.12	42.98**	8.11**	10.06*	8.11	-22.48**	-1.17
C17	$L_4 \times T_2$	-24.29**	-7.53	12.20*	12.20*	-1.76	0.12	-6.03**	-6.14**	11.79*	4.86	4.63	28.00**
C18	$L_4 \times T_3$	-13.83**	1.97	-1.21	19.51**	8.02	11.36*	4.73**	6.60**	-14.63**	-9.64	-1.91	20.00**
C19	$L_4 \times T_4$	74.91**	42.63**	9.05	14.63**	4.35	13.14*	-11.82**	7.82**	-0.93	4.86	-9.81*	10.33
C20	$L_4 \times T_5$	-20.03**	-16.03**	5.71	21.95**	11.26*	22.60**	-1.53	-31.34**	-7.42	-14.06**	-20.03**	-2.17
C21	$L_5 \times T_1$	-29.91**	-18.37**	8.41	13.17**	-1.06	10.19*	-51.02**	-32.29**	20.07**	17.94**	-4.71	21.50**
C22	$L_5 \times T_2$	-23.89**	-7.03	-2.34	1.95	-3.19	7.83	-48.27**	-28.49**	-1.57	-7.67	6.95	10.33
C23	$L_5 \times T_3$	-4.25	13.30*	-6.25	13.41**	-14.88**	-5.19	-14.17**	18.66**	-1.39	4.37	-9.81*	4.17
C24	$L_5 \times T_4$	-21.60**	-9.87	-12.30**	-7.80	5.31	17.29**	-17.21**	14.45**	-11.38*	-6.20	2.79	16.67**
C25	$L_5 \times T_5$	23.34**	41.80**	-3.17	11.71*	8.38	20.71**	-22.97**	6.49**	13.13*	-0.55	14.70**	18.33**
C26	$L_6 \times T_1$	-22.43**	-3.03	-4.83	-13.41**	11.51*	24.85**	72.32**	30.29**	12.57*	10.57*	-3.01	23.67**
C27	$L_6 \times T_2$	-13.36**	8.30	8.77	5.85	3.17	15.51**	-9.78**	-9.89**	12.72*	8.79	-8.66	7.17
C28	$L_6 \times T_3$	-30.29**	-12.87*	-4.44	15.61**	7.87	20.78**	10.49**	12.45**	-8.36	-3.01	13.64**	33.33**
C29	$L_6 \times T_4$	-2.03	22.47**	-12.99**	-8.54	14.15**	27.81**	-17.15**	1.30	-17.88**	-13.08**	2.13	19.83**
C30	$L_6 \times T_5$	14.24**	42.80**	-2.54	12.44*	14.15**	27.81**	39.07**	-0.64	-8.92	-12.10*	-7.24	8.83
C31	$L_7 \times T_1$	-29.40**	-8.37	7.06	7.32	6.21	11.38*	-14.86**	-31.01**	20.07**	17.94**	-13.59**	10.17
C32	$L_7 \times T_2$	9.63*	42.30**	-12.90**	-12.68*	2.26	7.23	18.18**	18.04**	23.11**	15.48**	-7.52	16.83**
C33	$L_7 \times T_3$	-21.44**	1.97	-11.69**	6.83	-0.56	4.28	-21.48**	-20.09**	11.43*	17.94**	-18.87**	2.50
C34	$L_7 \times T_4$	6.93	38.80**	-8.12	-3.41	-13.10**	-5.78	-4.62**	16.62**	2.14	8.11	-9.10*	14.83**
C35	$L_7 \times T_5$	-11.56**	14.80*	-0.85	14.39**	3.10	13.61**	-17.29**	-32.98**	25.24**	7.32	-22.16**	-1.67

*, ** Denotes significance at (p=0.05) and (p=0.05) respectively

Table 4: Top three crosses performing standard heterosis over commercial check (Punjab-8) for yield and its attributing traits

Sl. No.	Characters	Crosses			Sl. No.	Characters	Crosses		
1.	Days to 50% flowering	C17	L_4×T_2	Punjab Suhanani×GAO-5	7.	No. of fruits plant^{-1}	C30	L_6×T_5	GO-6×VRO-6
		C24	L_5×T_4	GAO-8×K-54			C15	L_3×T_5	Phule Prajatiti×VRO-6
		C12	L_3×T_2	Phule Prajatiti×GAO-5			C5	L_1×T_5	Pusa Savani×VRO-6
2.	Days to first picking	C11	L_3×T_1	Phule Prajatiti×Arka Abhay	8.	Fruit length (cm)	C16	L_4×T_1	Punjab Suhanani×Arka Abhay
		C6	L_2×T_1	Phule Vimukta×Arka Abhay			C15	L_3×T_5	Phule Prajatiti×VRO-6
		C1	L_1×T_1	Pusa Savani×Arka Abhay			C8	L_2×T_3	Phule Vimukta×VRO-106
3.	Plant height (cm)	C21	L_5×T_1	GAO-8×Arka Abhay	9.	Fruit girth (cm)	C26	L_6×T_1	GO-6×Arka Abhay
		C35	L_7×T_5	Harita×VRO-6			C5	L_1×T_5	Pusa Savani×VRO-6
		C9	L_2×T_4	Phule Vimukta×K-54			C10	L_2×T_5	Phule Vimukta×VRO-6
4.	No. of branches plant^{-1}	C13	L_3×T_3	Phule Prajatiti×VRO-106	10.	Fruit yield plant^{-1} (g)	C14	L_3×T_4	Phule Prajatiti×K-54
		C27	L_6×T_2	GO-6×GAO-5			C2	L_1×T_2	Pusa Savani×GAO-5
		C33	L_7×T_3	Harita×VRO-106			C11	L_3×T_1	Phule Prajatiti×Arka Abhay
5.	No. of nodes plant^{-1}	C11	L_3×T_1	Phule Prajatiti×Arka Abhay	11.	Total no. of picking plant^{-1}	C5	L_1×T_5	Pusa Savani×VRO-6
		C16	L_4×T_1	Punjab Suhanani×Arka Abhay			C21	L_5×T_1	GAO-8×Arka Abhay
		C31	L_7×T_1	Harita×Arka Abhay			C31	L_7×T_1	Harita×Arka Abhay
6.	Internodal length (cm)	C12	L_3×T_2	Phule Prajatiti×GAO-5	12.	No. of marketable fruits plant^{-1}	C28	L_6×T_3	GO-6×VRO-106
		C18	L_4×T_3	Punjab Suhanani×VRO-106			C3	L_1×T_3	Pusa Savani×VRO-106
		C23	L_5×T_3	GAO-8×VRO-106			C17	L_4×T_2	Punjab Suhanani×GAO-5

*, ** Denotes significance at (p=0.05) and (p=0.05) respectively

better parent and standard check respectively indicating their potential for exploiting heterosis for earliness in okra.

3.2. Positive heterosis

3.2.1. Plant height and number of branches

Positive heterosis is desirable yield and its attributing traits where out of 35 crosses the trait plant height, 18 crosses exhibited positive significant effect over heterobeltiosis range from 8.48% (GAO-8×VRO-6) to 31.84% (Phule Vimukta×GAO-5) and 12 crosses exhibited positive significant over standard heterosis range from 10.04% (Phule Prajatiti×K-54) to 15.31% (Harita×VRO-6). Similar findings reported were consistent with the results obtained by Shinde et al. (2023); Shwetha et al. (2021) and Chavan et al. (2023). For number of branches only 3 crosses exhibited significant for heterobeltiosis range from 15.21% (Phule Vimukta×GAO-5) to 27.33% (Pusa Savani×K-54) and 14 crosses exhibited positive significant heterosis over standard heterosis range from 14.50% (Punjab Suhanani×Arka Abhay, GO-6×VRO-6) to

24.44% (Phule Prajatiti×VRO-106). Increase in number of branches ultimately lead to increase in number of fruits plant^{-1}. Increase in number of fruits plant^{-1} was significantly associated with increase in yield. Same type of findings for number of branches per plant and number of fruits plant^{-1} in okra have been reported earlier by many researchers where, significant standard heterosis and high per se performance for fruit yield plant^{-1} were also resulted by Armand et al. (2021) and Verma and Sood, 2020.

3.2.2. *For number of nodes and internodal length*

For number of nodes, it was recorded that 6 crosses exhibited significant heterobeltiosis range from 10.40% (Punjab Suhanani×VRO-6) to 27.33% (Punjab Suhanani×Arka Abhay) and 14 crosses exhibited positive significant heterosis over standard heterosis range from 11.47% (HARITA×GAO-5) to 36.36% (Phule Prajatiti×Arka Abhay). For internodal length it was recorded that 9 crosses exhibited positive significant effect over heterobeltiosis range from 12.46% (Punjab Suhanani×Arka Abhay) to 45.28% (GO-6×Arka Abhay) and 7 crosses exhibited standard heterosis range from 11.73% (Pusa Savani×Arka Abhay) to 34.08 % (Phule Prajatiti×GAO-5). Phule Prajatiti×GAO-5 exhibited both better parent and standard heterosis for this trait. Similar results found earlier by Armand et al. (2021) and Srikanth et al. (2019).

3.2.3. For fruit length and fruit girth

For Fruit length out of 35 crosses, 7 crosses exhibited positive significant effect over heterobeltiosis range from 12.05% (Phule Prajatiti×VRO-6) to 24.87% (Pusa Savani×Arka Abhay) and 17 crosses exhibited standard heterosis range from 13.17% (GAO-8×Arka Abhay) to 29.27% (Phule Prajatiti×VRO-6). Punjab Suhanani×Arka Abhay exhibited both better parent and standard heterosis for this trait. For Fruit girth 4 crosses exhibited positive significant effect over heterobeltiosis range from 12.30% (Pusa Savani×VRO-6) to 15.99% (Phule Vimukta×VRO-6) and 15 crosses exhibited standard heterosis range from 13.61% (Harita×VRO-6) to 28.40% (Pusa Savani×VRO-6). Pusa Savani×VRO-6 exhibited both better parent and standard heterosis for this trait. The outcomes reported are consistent with the results obtained by Prakash et al. (2023); Kapadia et al. (2021) and Yadav et al., 2023.

3.2.4. For number of fruits plant^{-1} and yield plant^{-1}

For number of fruits plant^{-1} 8 crosses exhibited positive significant effect over heterobeltiosis range from 14.24% (GO-6×VRO-6) to 74.91% (Punjab Suhanani×K-54) and 11 crosses exhibited standard heterosis range from 2.47% (GO-6×K-54) to 42.80% (GO-6×VRO-6). For yield plant^{-1} 9 crosses exhibited positive significant effect over heterobeltiosis range from 4.14% (Phule Vimukta×VRO-106) to 72.32% (GO-6×Arka Abhay) and 18 crosses exhibited standard heterosis range from 6.25% (Pusa Savani×VRO-6) to 41.18% (Phule Prajatiti×Arka Abhay). The findings reported are in agreement with the results obtained by Sood et al. (2022); Singh and Arivazhagan (2022) Karadi and Hanchinamani (2021) and Zate et al. (2021).

3.2.5. For total number of piking plant^{-1} and number of marketable fruit plant^{-1}

For total number of piking plant^{-1} 7 crosses exhibited positive significant effect over heterobeltiosis range from 15.07% (Phule Prajatiti×Arka Abhay) to 25.24% (Harita×VRO-6) and 7 crosses exhibited standard heterosis range from 13.02% (Phule Prajatiti×Arka Abhay) to 17.94% (Phule Vimukta×Arka Abhay). Phule Vimukta×Arka Abhay exhibited both better parent and standard heterosis for this trait. For number of marketable fruit plant^{-1} 5 crosses exhibited positive significant effect over heterobeltiosis range from 13.64% (GO-6×VRO-106) to 30.88% (Phule Vimukta×GAO-5) and 17 crosses exhibited standard heterosis range from 14.83% (Harita×K-54) to 33.33% (GO-6×VRO-106). Phule Vimukta×GAO-5 exhibited both better parent and standard heterosis for this trait. Similar results found by Zate et al. (2021) and Rajani et al. (2021).

For both yield attributes, *viz.* fruit yield plant^{-1} and number of fruit plant^{-1} crosses Pusa Savani×GAO-5 and Punjab Suhanani×K-54 respectively, exhibited highly positive heterosis effect over both better parent and standard check. Significant standard heterosis and high per se performance for fruit yield plant^{-1} were also resulted by Shinde et al. (2023); Sood et al. (2022) and Das et al. (2022). Significant heterosis in both direction i.e. positive and negative heterosis was observed for all the growth, earliness and yield attributes. It is inferred that the magnitude of economic or standard heterosis was higher for most of the growth and earliness characters and the estimates of standard heterosis was found to be highly variable in direction and magnitude among crosses for all the characters under study. The manifestation of negative heterosis recorded in crosses for different traits may be due to the combination of the unfavourable genes of the parents. Hence, negative heterosis is desirable for earliness while positive heterosis is desirable for plant height and yield of the crop. These results are in accordance with Shinde et al. (2023) and Nanthakumar et al. (2021).

4. CONCLUSION

The best positive heterotic cross over standard check (Punjab 8) for fruit yield plant^{-1} was Phule Prajatiti×Arka Abhay. While, GAO-8×Arka Abhay exhibited negatively significant heterosis for days to 50%

flowering and Phule Prajatiti×Arka Abhay for days to first picking over standard check respectively, which has a high potential for yield and fruits can be picked earlier which may evaluated further for early *kharif* season in Punjab.

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