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Research Article

Analysis of heterotic potential for yield and its attributing traits in okra (*Abelmoschus esculentus* L. Moench)

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Abstract
The present investigation was conducted on okra (*Abelmoschus esculentus)* to determine the extent of heterosis for 12 traits, including fruit yield and its attributing traits. A total of 28 F_1s produced by crossing seven lines with four testers of okra in Line x Tester fashion were evaluated along with standard check during late *Kharif* 2022 season. The cross C20-HRB-55 x Varsha Uphar recorded best heterobeltiosis and the cross C10-VRO-4 x Azad Ganga recorded best standard heterosis for yield plant^{-1}. The cross C10- VRO-4 x Azad Ganga showed negative heterosis over better parent and standard check for the traits days to 50% flowering and days to first picking. The F_1 hybrid C10- VRO-4 x Azad Ganga, which has a high potential for yield can be evaluated further for early *Kharif* season in Punjab.

Keywords: Heterobeltiosis, standard check, heterotic, yield and earliness.

INTRODUCTION

India is the largest producer of okra (*Abelmoschus esculentus*) in the world, contributing over 72% (6.47 million tonnes) from an area of 0.5 million hectare (National Horticulture Board Report, 2022). De Candolle (1883) and Vavilov (1951) placed Ethiopia as the centre of origin for okra. The origin of okra can be traced back to the Hindustani region, where it was primarily cultivated in India, Pakistan, and Burma (Zeven and Zhukovsky, 1975). It is grown widely as a vegetable crop in the tropical and subtropical regions of the world, while in some places, immature pods are utilized for making pickles (Hadiya *et al.,* 2018). In India, the production is more than 6 million tonnes with the highest output recorded in Gujarat (0.92 tonnes) followed by West Bengal (0.91 tonnes), Bihar (0.78 tonnes), Madhya Pradesh (0.63 tonnes) and Odisha (0.56 tonnes) (APEDA,2021). In Punjab, okra occupies approximately an area of 4.57 thousand hectare with production of 47.65 thousand metric tonnes.

Exploiting heterosis in okra plays a crucial role in enhancing yield and related traits within crop improvement programs. 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. 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. Vijayaraghavan and Warrier (1946) reported the first report for heterosis in okra. The anticipation and management of the projected demand for increased productivity are imperative due to the substantial size of its flower and monoadelphous stamens (Bailey, 1897). Additionally, several researchers

have documented a noteworthy occurrence of heterosis in okra, particularly in relation to various traits associated with fruit yield (Shwetha *et al*., 2018).

In okra, heterosis has been observed for various traits including yield, plant height, fruit length and earliness. 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. The exploitation of heterosis in okra has been acknowledged as a useful method for improving yield and other significant traits in breeding programs. 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).

MATERIALS AND METHODS

The experimental material comprising of 28F_1s along with seven lines, four testers and a standard check namely Punjb-13 (**Table 1)** , were sown in a Randomized Block Design replicated thrice at the Genetics and Plant Breeding Research Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab *Kharif* 2022 . Observations on 12 quantitative traits *viz.* days to 50% flowering, days to first picking, fruit length at maturity and harvest (cm), number of internodes, number of branches, number of fruits plant^{-1}, number of seeds fruit^{-1}, seed index (g), fruit weight (g), yield plant^{-1} (g) and plant height (cm) were recorded from five randomly selected plants in every entry in each replication.

To evaluate the significance of differences between treatments, an analysis of variance (ANOVA) for Randomized Block Design (RBD) was conducted, following the procedure outlined by Panse and Sukhatme (1985), for all the metric traits under study. The performance of the F_1 hybrid was evaluated based on the heterosis over mid-parent, better parent, and standard check, following the method proposed by Fonseca and Patterson (1968). The percent increase or decrease in F1 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.

Heterosis over better parent (BPH) $BPH\ \% = \frac{F1 - BP}{BP} \text{x } 100$

Heterosis over standard check (SH) $SH\ \% = \frac{F1 - SC}{SC} \text{x } 100$

Were, BPH = Mean performance of better parent, SH = Mean performance of standard check.

RESULTS AND DISCUSSION

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

Table 1. Salient features of the parents used in the crossing programme

Genotype	Source	Specific character
		Lines (Female)
VRO-6 (Kashi Pragati)	IIVR, Varanasi, UP	Plant are tall, height of 130 cm with effective 1-2 branches
VRO-22 (Kashi Kranti)	IIVR, Varanasi, UP	Earlier days to flowering and fruit picking
VRO-4 (Kashi Mangali)	IIVR, Varanasi, UP	Developed from pure line selection, tall height upto 120-125 cm
Sel-2 (Selection 2)	IARI, Pusa, Delhi	Green coloured Long and tender fruit 16-20 cm with 5 ridges
HRB-55 (Hisar Unnat)	HAU, Hisar, HR	Minimum number of branches, 5 ridged dark green fruit
GO-2 (Gujrat Okra 2)	JAU, Junagadh, GJ	Smooth, tender and long green fruit, 5 ridged and high yield potential.
GAO-5 (Gujrat Anand Okra)	AAU, Anand, GJ	Dark green stalk colour, tender, smooth and medium sized fruit
		Testers (Male)
Azad Kranti	CSAUA&T, Kanpur, UP	5 ridged, shining green with long beak fruit.
Azad Ganga	CSAUA&T, Kanpur, UP	Green coloured Long and tender fruit with 5 ridges
GJO-3	JAU, Junagadh, GJ	Tall, height upto 130-135 cm, tender long fruit, dark green coloured
Varsha Uphar	HAU, Hisar, HR	Medium height, shot internodes, 2-4 branches, higher yield
		Commercial Check (Hybrid)
Punjab -13	PAU, Ludhiana, PB	Medium size, light green coloured fruits, susceptible to YMV, developed by PAU Ludhiana, Punjab.

Table 2. ANOVA for RBD in okra for 12 traits

Source of Variation	Df	DFF	DFP	PH	NI	NB	FLM
Replication	2	0.11	1.46	2.43	0.06	0.16	0.01
Genotypes	39	17.31**	38.08**	1367.23**	9.40**	2.71**	3.94**
Crosses	27	20.96**	44.17**	1223.32**	8.01**	2.71*	4.36*
Error	78	0.51	0.90	2.89	0.14	0.20	0.03

Source of Variation	Df	FLH	NFP	NSF	SI	FW	YPP
Replication	2	0.48	0.02	1.52	0.01	0.04	5.30
Genotypes	39	21.14**	38.68*	7.79**	4.46**	5.15**	9074.50**
Crosses	27	22.96**	23.25**	8.07**	2.29*	4.54*	8930.83**
Error	78	0.79	0.72	3.36	0.01	0.04	105.40

DFF- Days to 50% flowering, DFP- Days to first picking, FLM and FLH- fruit length at maturity and harvest (cm), NI- Number of internodes, NB- Number of branches, NFP- Number of fruits plant^{-1}, NSF- Number of seeds fruit^{-1}, SI-Seed index (g), FW- fruit weight (g), YPP- Yield plant^{-1} (g) and PH- plant height (cm)

*, ** denotes significance at 5% and 1% respectively.

traits studied. Similar results were also revealed by Armand (2021); Patel *et al*. (2020); Pithiya *et al.* (2020); Joshi *et al.* (2019); Hadiya *et al.* (2018); Satish *et al.* (2017) and Kumar *et al.* (2017). In the realm of vegetable breeding, including the development of okra hybrids, breeders have extensively utilized heterosis to enhance fruit yield (Ebert, 2020).

Mean performance of parents and their hybrids: **Table 3** provides information on the mean performance of parents and their hybrids. Days to 50% flowering, was observed to range from 36.28 (VRO-4 x AZAD GANGA) to 46.89 (VRO-22 x GJO-3). Mundhe et al. (2022); Kharat et al. (2022) and Rynjah et al. (2020) reported similar wide range among hybrids. For days to first harvest, it was observed that the crosses ranged from 38.19 days (HRB-55 x VARSHA UPHAR) to 50.99 days (VRO-22 x AZAD KRANTI). Verma and Sood (2020) and Rynjah *et al.* (2020) reported similar results. The range of variation for number of internodes was from (10.47) to 17.27 in HRB-55 x AZAD GANGA and VRO-6 x AZAD GANGA respectively. For number of internodes, Shwetha *et al.* (2021) revealed similar results. For number of branches it was observed that crosses ranged from 1.27 branches in VRO-6 x AZAD GANGA to 5.05 branches in HRB-55 x AZAD KRANTI . Similar results were reported by Armand (2021); Srikanth *et al.* (2019) and Tiwari *et al.* (2015). Fruit length at maturity was observed to range from 9.28 cm in VRO-6 x AZAD GANGA to 13.61 cm in VRO-4 x AZAD GANGA and at harvest was observed it was observed to be minimum (15.59) in crosses VRO-22 x GJO-3 and maximum (25.38) in HRB-55 x VARSHA UPHAR. Abinaya *et al.* (2020) and Chavan *et al.* (2021) observed similar findings for fruit length. For number of fruits plant^{-1} it was observed that crosses range from 15.63 fruits in VRO-22 x GJO-3 to 25.32 fruits in HRB-55 x VARSHA UPHAR. For number of fruit plant^{-1} similar positive significant effect was also found by Chaudhary *et al*. (2023); Pithiya *et al*. (2019) and Das *et al.* (2020). Top ten crosses based on mean performance for fruit yield plant^{-1} illustrated in **Fig. 1.**

Estimation of Heterobeltiosis and Standard Heterosis: The heterobeltiosis and standard heterosis for 28 hybrids for 12 traits in okra are presented in **Table 4**. The top three crosses for standard heterosis, considering economic feasibility tabulated in **Table 5**. 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, 10 crosses exhibited negative significant effect over heterobeltiosis range from -4.72 % (VRO-4 x VARSHA UPHAR) to -13.39 % (VRO-4 x AZAD GANGA) and 13 crosses exhibited positive significant over standard heterosis range from -3.82 % (VRO-6 x GJO-3) to -16.03 % (VRO-4 x AZAD GANGA). For days to first picking, 7 crosses exhibited negative significant effect over heterobeltiosis range from -5.00 % (GAO-5 x AZAD KRANTI) to -15.71 (GO-2 x AZAD KRANTI) and 18 crosses exhibited negative significant over standard heterosis range from -4.03 % (HRB-55 x AZAD GANGA) to -22.82 % (HRB-55 x VARSHA UPHAR). Shinde *et al.* (2023); Mundhe *et al.* (2022); Kharat *et al.* (2022); Rynjah *et al.* (2020); Kerure and Pitchaimuthu (2019); Joshi *et al.* (2019) and Kumar *et al*. (2013) 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 x Azad Ganga exhibited high negative heterosis over both better parent and standard

Table 3. Mean performance of parents and their hybrids with commercial check for 12 traits in okra

S. No.	Genotypes	Days to 50% Flowering	Days to First Picking	Number of Internodes	Number of Branches	Fruit Length (Maturity)	Fruit Length (Harvest)
1	VRO-6 x AZAD KRANTI	44.18	49.48	15.93	3.67	11.29	20.82
2	VRO-6 x AZAD GANGA	44.54	48.64	17.27	1.27	9.28	16.03
3	VRO-6 x GJO-3	41.95	45.30	16.67	2.67	10.52	17.62
4	VRO-6 x VARSHA UPHAR	40.18	42.78	13.13	2.99	11.83	21.68
5	VRO-22 x AZAD KRANTI	46.05	50.99	13.60	3.97	12.54	21.17
6	VRO-22 x AZAD GANGA	44.57	48.13	16.33	2.00	9.88	21.97
7	VRO-22 x GJO-3	46.89	49.96	13.87	2.78	9.84	15.59
8	VRO-22 x VARSHA UPHAR	37.34	39.96	15.60	3.20	13.57	22.55
9	VRO-4 x AZAD KRANTI	38.44	42.08	14.53	2.65	12.32	22.74
10	VRO-4 x AZAD GANGA	36.28	38.91	13.33	2.30	13.61	24.79
11	VRO-4 x GJO-3	41.80	45.61	15.93	2.65	11.45	21.39
12	VRO-4 x VARSHA UPHAR	40.43	43.45	16.33	3.26	11.78	23.87
13	SEL-2 x AZAD KRANTI	42.25	43.71	13.93	4.87	11.26	22.95
14	SEL-2 x AZAD GANGA	42.00	45.14	12.00	1.43	10.88	17.96
15	SEL-2 x GJO-3	40.04	41.82	14.87	3.05	11.89	20.36
16	SEL-2 x VARSHA UPHAR	37.78	42.36	16.73	3.00	12.58	20.14
17	HRB-55 x AZAD KRANTI	44.15	48.81	17.13	5.05	12.34	23.39
18	HRB-55 x AZAD GANGA	43.39	47.71	10.47	2.23	10.85	24.35
19	HRB-55 x GJO-3	45.11	49.65	14.60	2.00	10.64	17.23
20	HRB-55 x VARSHA UPHAR	39.17	38.19	16.87	2.79	13.52	25.38
21	GO-2 x AZAD KRANTI	42.45	39.48	16.07	2.06	11.85	22.54
22	GO-2 x AZAD GANGA	41.48	42.66	14.20	3.05	12.86	21.20
23	GO-2 x GJO-3	41.68	43.99	15.87	4.46	13.16	25.27
24	GO-2 x VARSHA UPHAR	44.00	47.36	15.67	1.63	11.15	20.74
25	GAO-5 x AZAD KRANTI	40.13	44.54	15.73	2.31	11.45	20.64
26	GAO-5 x AZAD GANGA	40.14	40.71	16.47	3.19	12.82	23.35
27	GAO-5 x GJO-3	44.14	49.13	16.20	3.71	13.36	24.75
28	GAO-5 x VARSHA UPHAR	44.11	50.09	16.07	2.26	10.61	23.38
	Hybrid Mean	41.95	45.02	15.19	2.88	11.75	21.57
29	VRO-6	42.55	45.63	17.00	2.29	11.14	29.51
30	VRO-22	40.81	42.88	19.13	2.15	12.49	23.27
31	VRO-4	42.10	44.09	17.00	4.33	11.84	26.82
32	SEL-2	42.47	46.06	16.00	4.97	11.70	23.35
33	HRB-55	42.13	43.45	18.93	1.96	11.20	18.88
34	GO-2	38.07	42.52	18.67	2.77	12.47	20.97
35	GAO-5	38.25	37.56	14.40	3.05	13.56	22.71
36	AZAD KRANTI	43.17	46.68	15.20	4.28	14.23	24.00
37	AZAD GANGA	42.36	43.07	14.20	2.50	11.37	25.04
38	GJO-3	42.75	44.49	15.20	2.89	10.98	21.11
39	VARSHA UPHAR	41.93	43.73	14.27	2.45	11.31	23.10
	Parental Mean	41.51	43.65	16.36	3.06	12.03	23.52
40	PUNJAB -13	43.72	49.78	16.67	3.50	11.52	21.79
	Grand Mean	41.87	44.76	15.55	2.94	11.82	22.11
	Max.	46.89	50.99	19.13	5.05	14.23	29.51
	Min.	36.28	37.56	10.47	1.27	9.28	15.59
	SE±	0.41	0.55	0.22	0.26	0.10	0.51
	CD @ 5%	1.16	1.54	0.62	0.73	0.28	1.45
	CD @ 1%	1.54	2.05	0.82	0.97	0.37	1.92

Table 3. Mean performance of parents and their hybrids with commercial check for 12 traits in okra (Cont…)

S. No.	Genotypes	Number of Fruit Plant^{-1}	Number of Seeds Fruit^{-1}	Seed Index	Fruit weight	Yield Plant^{-1}	Plant height
1	VRO-6 x AZAD KRANTI	20.99	76.84	6.28	10.76	225.80	110.54
2	VRO-6 x AZAD GANGA	15.60	78.22	5.78	10.08	157.30	101.19
3	VRO-6 x GJO-3	16.95	77.36	8.43	10.57	179.16	86.63
4	VRO-6 x VARSHA UPHAR	20.77	80.27	7.83	13.79	286.45	92.17
5	VRO-22 x AZAD KRANTI	21.23	76.88	9.28	12.26	260.34	53.13
6	VRO-22 x AZAD GANGA	22.13	78.19	8.23	14.15	313.23	93.26
7	VRO-22 x GJO-3	15.63	78.91	8.78	10.44	163.10	68.44
8	VRO-22 x VARSHA UPHAR	22.61	77.78	8.63	14.01	316.78	102.62
9	VRO-4 x AZAD KRANTI	23.18	79.81	7.63	12.51	290.02	79.15
10	VRO-4 x AZAD GANGA	24.63	77.35	5.63	13.63	335.73	57.48
11	VRO-4 x GJO-3	20.64	82.21	7.13	11.77	243.06	119.79
12	VRO-4 x VARSHA UPHAR	23.57	76.62	7.28	13.24	312.11	68.76
13	SEL-2 x AZAD KRANTI	22.82	76.65	5.83	11.29	257.60	75.18
14	SEL-2 x AZAD GANGA	18.05	78.80	8.23	11.33	204.48	58.88
15	SEL-2 x GJO-3	19.68	80.48	7.28	12.03	236.82	95.02
16	SEL-2 x VARSHA UPHAR	21.38	77.38	9.18	12.97	277.34	71.04
17	HRB-55 x AZAD KRANTI	23.14	77.48	8.23	13.66	315.98	108.01
18	HRB-55 x AZAD GANGA	23.61	81.41	8.33	14.11	333.26	66.12
19	HRB-55 x GJO-3	16.92	78.64	9.18	10.57	178.86	89.03
20	HRB-55 x VARSHA UPHAR	25.32	78.63	7.23	12.57	318.20	123.90
21	GO-2 x AZAD KRANTI	22.11	79.71	5.28	12.08	267.18	114.40
22	GO-2 x AZAD GANGA	24.97	78.59	7.23	13.34	333.05	84.88
23	GO-2 x GJO-3	21.11	75.39	6.68	11.70	246.94	72.29
24	GO-2 x VARSHA UPHAR	18.41	77.64	5.88	10.80	198.75	101.61
25	GAO-5 x AZAD KRANTI	19.72	78.01	8.18	11.26	222.08	69.59
26	GAO-5 x AZAD GANGA	23.21	78.37	7.28	12.47	289.39	99.79
27	GAO-5 x GJO-3	24.56	76.43	9.13	12.07	296.42	74.99
28	GAO-5 x VARSHA UPHAR	23.25	80.70	7.98	12.67	294.50	115.95
	Hybrid Mean	21.29	78.38	7.57	12.22	262.64	87.64
29	VRO-6	19.00	77.38	9.03	10.58	201.04	73.27
30	VRO-22	24.22	78.32	9.28	12.56	303.91	136.22
31	VRO-4	26.59	75.56	7.28	12.65	336.32	71.57
32	SEL-2	22.93	78.94	5.63	11.71	268.38	86.31
33	HRB-55	18.94	79.32	7.03	11.25	213.01	92.91
34	GO-2	21.17	77.90	7.68	11.14	235.88	119.31
35	GAO-5	22.63	76.61	7.53	14.77	333.87	61.08
36	AZAD KRANTI	24.14	79.65	7.03	13.14	317.12	95.79
37	AZAD GANGA	24.87	80.08	5.93	15.54	386.42	70.41
38	GJO-3	20.74	75.22	4.68	11.25	233.27	104.63
39	VARSHA UPHAR	23.04	79.21	8.03	11.86	273.17	53.98
	Parental Mean	22.57	78.02	7.19	12.40	282.04	87.77
40	PUNJAB -13	22.34	78.14	7.08	11.24	251.17	108.30
	Grand Mean	21	78	7.5	12.2	267.7	88.2
	Max.	26.59	82.21	9.28	15.54	386.42	136.22
	Min.	15.60	75.22	4.68	10.08	157.30	53.13
	SE±	0.27	1.06	0.00	0.11	5.93	0.98
	CD @ 5%	0.77	2.98	0.00	0.32	16.69	2.76
	CD @ 1%	1.02	3.95	0.00	0.42	22.14	3.67

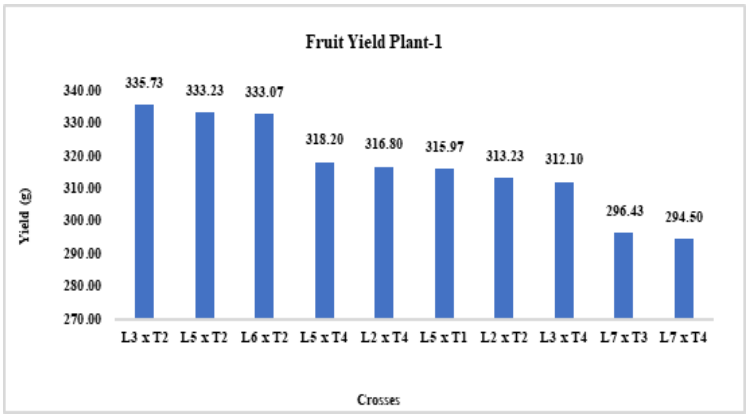

Fig. 1. Top ten crosses based on mean performance for fruit yield plant^{-1} in okra

check respectively indicating their potential for exploiting heterosis for earliness in okra.

Positive heterosis is desirable yield and its attributing traits where out of 28 crosses the trait plant height, 7 crosses exhibited positive significant effect over heterobeltiosis range from 12.72 % (HRB-55 x AZAD KRANTI) to 89.85 % (GAO-5 x VARSHA UPHAR) and 4 crosses exhibited positive significant over standard heterosis range from 5.63 % (GO-2 x AZAD KRANTI) to 14.40 % (HRB-55 x VARSHA UPHAR). Similar findings reported were consistent with the results obtained by Yadav *et al*. (2023); Shinde *et al*. (2023); Shwetha *et al*. (2021) and Hadiya *et al*. (2018). For number of internodes all crosses exhibited non-significant for standard heterosis and 5 crosses exhibited positive significant heterosis over heterobeltiosis range from 6.67 % (GAO-5 x GJO-3) to 13.95 % (GAO-5 x AZAD GANGA). Kharat *et al*. (2022) also reported similar results. For number of branches plant^{-1}, it was recorded that single cross show 55.56 % (GO-2 x GJO-3) positive significant effect over heterobeltiosis and 3 crosses exhibited positive significant over standard heterosis *viz.* 40.00 % (GO-2 x GJO-3) and 50.00 % (HRB-55 x AZAD KRANTI, SEL-2 x AZAD KRANTI). Similar results found earlier by Armand (2021); Srikanth *et al.* (2019) and Tiwari *et al.* (2015). For fruit length at maturity it was recorded that 7 crosses exhibited positive significant effect over heterobeltiosis range from 3.21 % (GO-2 x AZAD GANGA) to 19.76 % (HRB-55 x VARSHA UPHAR) and 15 crosses exhibited standard heterosis range from 3.19 % (GO-2 x AZAD KRANTI) to 18.55 % (VRO-4 x AZAD GANGA). Fruit length at harvest only 2 crosses exhibited positive significant over heterobeltiosis and 4 crosses for standard heterosis *viz.* 10.45 % (GAO-5 x GJO-3, VRO-4 x AZAD GANGA), 1.94 & (GO-2 x AZAD GANGA) and 14.93 % (HRB-55 x VARSHA UPHAR) for standard heterosis and 10.45 % (GAO-5 x GJO-3) and 13.24 % (HRB-55 x VARSHA UPHAR) for heterobeltiosis . The outcomes reported are consistent with the results obtained by Prakash *et al*. (2023); Kapadia *et al*. (2021) and Rynjah *et al*. (2020). For number of fruits plant^{-1} single cross exhibited heterobeltiosis 4.64 % (VRO-4 x GJO-3) and only 2 crosses exhibited positive significant over standard heterosis *viz.* 4.17 % (VRO-6 x VARSHA UPHAR) and 4.81 % (VRO-4 x GJO-3). However for number of seeds fruit^{-1} single 8.81 % (VRO-4 x GJO-3) exhibited heterobeltiosis and 4.27 % (HRB-55 x AZAD GANGA) and 5.56 % (VRO-4 x GJO-3) exhibited standard heterosis. Similar results found by Sidapara *et al.* (2021); Zate *et al.* (2021) and Rajani *et al.* (2021). For seed index, it was recorded that not a single cross show positive significant effect over heterobeltiosis but 19 crosses exhibited positive significant over standard heterosis range from 1.40 % (HRB-55 x VARSHA UPHAR, GO-2 x AZAD GANGA) to 30.84 % (VRO-22 x AZAD KRANTI). For Seed pod^{-1} Patel *et al.* (2020) and Chaudhary *et al*. (2023) revealed the magnitude of heterosis varied among the different crosses whereas for seed index Armand (2021) and Kumar *et al.* (2013) showed positive heterotic effect. For fruit weight, it was recorded that 7 crosses show positive significant effect over heterobeltiosis range from 3.85 % (GO-2 x GJO-3) to 16.29 %(VRO-6 x VARSHA UPHAR) and 19 crosses exhibited positive significant over standard heterosis range from 4.15 % (GO-2 x GJO-3) to 25.82 % (HRB-55 x AZAD GANGA). For fruit weight Chavan *et al.* (2021); Patel *et al.* (2020) and Tiwari *et al.* (2015) found similar findings. For yield plant^{-1}, only 16.94 % (HRB-55 x VARSHA UPHAR) exhibited positive significant effect over heterobeltiosis and 13 crosses exhibited positive significant over standard heterosis range from 10.42 % (SEL-2 x VARSHA UPHAR) to 32.67 % (HRB-55 x AZAD GANGA). The findings reported are in agreement with the results obtained by Karadi and Hanchinamani (2021); Zate *et al*. (2021); Sood *et al*. (2022); Singh and Arivazhagan (2022) and Rajani *et al*. (2021).

For both yield attributes, *viz.* total yield plant^{-1} and number of fruit plant^{-1} crosses HRB-55 x Varsha Uphar and VRO-4 x Azad Ganga respectively, exhibited highly positive heterosis effect over both better parent and standard check

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Table 4. Heterosis for days to 50% flowering, days to first picking, plant height, number of internodes, number of branches and fruit length at maturity

Cross No.	Genotypes	Days to 50% Flowering		Days to First Picking		Plant Height		Number of Internodes		Number of Branches		Fruit Length (Maturity)	
		BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH
C1	VRO-6 x AZAD KRANTI	2.31 ns	1.53 ns	6.43 **	-0.00 ns	15.38 **	2.06 ns	-5.88 **	-4.00 ns	-15.38 ns	10.00 ns	-20.61 **	-1.74 ns
C2	VRO-6 x AZAD GANGA	4.69 **	2.29 ns	6.57 **	-2.01 ns	38.06 **	-6.56 **	0.00 ns	2.00 ns	-50.00 **	-60.00 **	-18.71 **	-19.42 **
C3	VRO-6 x GJO-3	-1.56 ns	-3.82 **	-0.73 ns	-8.72 **	-17.20 **	-20.01 **	-1.96 ns	0.00 ns	-11.11 ns	-20.00 ns	-5.39 **	-8.41 **
C4	VRO-6 x VARSHA UPHAR	-5.47 **	-7.63 **	-5.84 **	-13.42 **	25.78 **	-14.87 **	-23.53 **	-22.00 **	28.57 ns	-10.00 ns	4.72 **	2.90 *
C5	VRO-22 x AZAD KRANTI	6.15 **	5.34 **	9.29 **	2.68 ns	-61.00 **	-50.94 **	-28.07 **	-18.00 **	-7.69 ns	20.00 ns	-11.94 **	8.99 **
C6	VRO-22 x AZAD GANGA	5.51 **	2.29 ns	11.63 **	-3.36 *	-31.54 **	-13.88 **	-14.04 **	-2.00 ns	-25.00 ns	-40.00 **	-20.86 **	-14.20 **
C7	VRO-22 x GJO-3	10.16 **	7.63 **	12.78 **	0.67 ns	-49.77 **	-36.81 **	-26.32 **	-16.00 **	-11.11 ns	-20.00 ns	-21.12 **	-14.49 **
C8	VRO-22 x VARSHA UPHAR	-9.60 **	-13.74 **	-9.16 **	-20.13 **	-24.69 **	-5.26 **	-19.30 **	-8.00 **	42.86 **	0.00 ns	9.09 **	18.26 **
C9	VRO-4 x AZAD KRANTI	-11.54 **	-12.21 **	-10.00 **	-15.44 **	-17.36 **	-26.90 **	-13.73 **	-12.00 **	-38.46 **	-20.00 ns	-13.35 **	7.25 **
C10	VRO-4 x AZAD GANGA	-13.39 **	-16.03 **	-12.12 **	-22.15 **	-19.66 **	-46.91 **	-23.53 **	-22.00 **	-46.15 **	-30.00 **	15.21 **	18.55 **
C11	VRO-4 x GJO-3	-2.34 ns	-4.58 **	3.01 ns	-8.05 **	14.50 **	10.62 **	-5.88 **	-4.00 ns	-38.46 **	-20.00 ns	-3.10 *	-0.29 ns
C12	VRO-4 x VARSHA UPHAR	-4.72 **	-7.63 **	-1.52 ns	-12.75 **	-3.91 *	-36.50 **	-5.88 **	-4.00 ns	-23.08 **	0.00 ns	-0.28 ns	2.61 *
C13	SEL-2 x AZAD KRANTI	-2.31 ns	-3.05 *	-6.43 **	-12.08 **	-21.54 **	-30.59 **	-12.50 **	-16.00 **	0.00 ns	50.00 **	-20.84 **	-2.03 ns
C14	SEL-2 x AZAD GANGA	-0.78 ns	-3.05 *	-1.45 ns	-8.72 **	-31.78 **	-45.61 **	-25.00 **	-28.00 **	-66.67 **	-50.00 **	-7.12 **	-5.51 **
C15	SEL-2 x GJO-3	-6.25 **	-8.40 **	-9.42 **	-16.11 **	-9.17 **	-12.25 **	-6.25 **	-10.00 **	-40.00 **	-10.00 ns	1.71 ns	3.48 **
C16	SEL-2 x VARSHA UPHAR	-10.94 **	-12.98 **	-7.97 **	-14.77 **	-17.72 **	-34.41 **	4.17 *	0.00 ns	-40.00 **	-10.00 ns	7.69 **	9.57 **
C17	HRB-55 x AZAD KRANTI	1.54 ns	0.76 ns	5.00 **	-1.34 ns	12.73 **	-0.28 ns	-10.53 **	2.00 ns	15.38 ns	50.00 **	-13.35 **	7.25 **
C18	HRB-55 x AZAD GANGA	3.15 *	-0.00 ns	10.00 **	-4.03 **	-28.81 **	-38.94 **	-45.61 **	-38.00 **	-12.50 ns	-30.00 **	-4.97 **	-5.80 **
C19	HRB-55 x GJO-3	5.47 **	3.05 *	11.28 **	-0.67 ns	-14.91 **	-17.79 **	-22.81 **	-12.00 **	-33.33 **	-40.00 **	-5.04 **	-7.25 **
C20	HRB-55 x VARSHA UPHAR	-7.14 **	-10.69 **	-12.21 **	-22.82 **	33.37 **	14.40 **	-10.53 **	2.00 ns	14.29 ns	-20.00 ns	19.76 **	17.68 **
C21	GO-2 x AZAD KRANTI	-2.31 ns	-3.05 *	-15.71 **	-20.81 **	-4.11 **	5.63 **	-14.29 **	-4.00 ns	-53.85 **	-40.00 **	-16.63 **	3.19 **
C22	GO-2 x AZAD GANGA	-1.57 ns	-4.58 **	-0.78 ns	-14.09 **	-28.86 **	-21.64 **	-23.21 **	-14.00 **	0.00 ns	-10.00 ns	3.21 **	11.88 **
C23	GO-2 x GJO-3	-2.34 ns	-4.58 **	-0.75 ns	-11.41 **	-39.40 **	-33.24 **	-14.29 **	-4.00 ns	55.56 **	40.00 **	5.61 **	14.49 **
C24	GO-2 x VARSHA UPHAR	4.80 **	-0.00 ns	8.40 **	-4.70 **	-14.81 **	-6.16 **	-14.29 **	-4.00 ns	-44.44 **	-50.00 **	-10.43 **	-2.90 *
C25	GAO-5 x AZAD KRANTI	-6.92 **	-7.63 **	-5.00 **	-10.74 **	-27.35 **	-35.73 **	4.44 *	-6.00 **	-46.15 **	-30.00 **	-19.44 **	-0.29 ns
C26	GAO-5 x AZAD GANGA	-4.72 **	-7.63 **	-5.43 **	-18.12 **	41.76 **	-7.85 **	13.95 **	-2.00 ns	11.11 ns	0.00 ns	-5.16 **	11.88 **
C27	GAO-5 x GJO-3	3.12 *	0.76 ns	10.53 **	-1.34 ns	-28.32 **	-30.75 **	6.67 **	-4.00 ns	22.22 ns	10.00 ns	-1.23 ns	16.52 **
C28	GAO-5 x VARSHA UPHAR	5.60 **	0.76 ns	13.74 **	-0.00 ns	89.85 **	7.05 **	11.63 **	-4.00 ns	-22.22 ns	-30.00 **	-21.62 **	-7.54 **
	SE±	0.58	0.60	0.78	0.76	1.32	1.43	0.30	0.34	0.36	0.38	0.14	0.13

*, ** denotes significance at 5% and 1% respectively.

Table 4 cont... Heterosis for fruit length at harvest, number of fruit plant^{-1}, number of seeds plant^{-1}, seed index, fruit weight and yield plant^{-1}

Cross No.	Genotypes	Fruit Length (Harvest)		Number of Fruits Plant^{-1}		Number of Seeds Fruit^{-1}		Seed Index		Fruit Weight		Yield Plant^{-1}	
		BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH	BPH	SH
C1	VRO-6 x AZAD KRANTI	-13.89 **	-7.46 *	-0.79 ns	0.16 ns	-3.77 *	-1.71 ns	-29.89 ns	-11.21 **	-18.02 **	-4.15 **	-28.79 **	-10.09 **
C2	VRO-6 x AZAD GANGA	-35.14 **	-28.36 **	0.00 ns	1.12 ns	-2.08 ns	0.43 ns	-35.42 ns	-18.22 **	-35.12 **	-10.09 **	-59.30 **	-37.39 **
C3	VRO-6 x GJO-3	-17.74 **	-23.88 **	0.49 ns	-0.96 ns	-0.43 ns	-0.85 ns	-6.64 ns	18.22 **	-6.21 **	-5.93 **	-23.20 **	-28.67 **
C4	VRO-6 x VARSHA UPHAR	-8.82 **	-7.46 *	2.52 ns	4.17 *	1.68 ns	3.42 ns	-13.28 ns	9.81 **	16.29 **	22.85 **	4.86 ns	14.04 **
C5	VRO-22 x AZAD KRANTI	-13.70 **	-5.97 ns	-0.47 ns	1.76 ns	-3.35 ns	-1.28 ns	0.00 ns	30.84 **	-6.60 **	9.20 **	-17.91 **	3.65 ns
C6	VRO-22 x AZAD GANGA	-10.81 **	-1.49 ns	-0.94 ns	1.28 ns	-2.50 ns	0.00 ns	-11.79 ns	15.42 **	-8.99 **	26.11 **	-18.94 **	24.71 **
C7	VRO-22 x GJO-3	-35.62 **	-29.85 **	-3.13 ns	-0.96 ns	0.43 ns	0.85 ns	-5.36 ns	23.83 **	-16.98 **	-7.12 **	-46.34 **	-35.08 **
C8	VRO-22 x VARSHA UPHAR	-6.85 *	1.49 ns	-0.94 ns	1.28 ns	-2.10 ns	-0.43 ns	-7.50 ns	21.03 **	11.67 **	24.93 **	4.24 ns	26.13 **
C9	VRO-4 x AZAD KRANTI	-13.75 **	2.99 ns	-1.27 ns	-0.32 ns	0.42 ns	2.56 ns	4.09 ns	7.01 **	-4.82 **	11.28 **	-13.76 **	15.47 **
C10	VRO-4 x AZAD GANGA	-7.50 **	10.45 **	-1.11 ns	0.00 ns	-3.33 ns	-0.85 ns	-23.18 ns	-21.03 **	-12.42 **	21.36 **	-13.12 **	33.67 **
C11	VRO-4 x GJO-3	-22.50 **	-7.46 *	4.64 *	4.81 *	8.81 **	5.56 **	-2.73 ns	0.00 ns	-6.60 **	5.04 **	-27.72 **	-3.22 ns
C12	VRO-4 x VARSHA UPHAR	-11.25 **	5.97 ns	-1.26 ns	0.32 ns	-3.36 ns	-1.71 ns	-8.71 ns	2.80 **	4.75 **	17.80 **	-7.20 **	24.26 **
C13	SEL-2 x AZAD KRANTI	-4.17 ns	2.99 ns	0.48 ns	1.44 ns	-3.77 *	-1.71 ns	-17.06 ns	-18.22 **	-13.96 **	0.59 ns	-18.77 **	2.56 ns
C14	SEL-2 x AZAD GANGA	-27.03 **	-19.40 **	-0.32 ns	0.80 ns	-1.67 ns	0.85 ns	38.76 ns	15.42 **	-27.19 **	0.89 ns	-47.09 **	-18.59 **
C15	SEL-2 x GJO-3	-14.49 **	-11.94 **	0.00 ns	-2.08 ns	2.11 ns	3.42 ns	30.18 ns	2.80 **	2.56 ns	7.12 **	-11.77 **	-5.72 ns
C16	SEL-2 x VARSHA UPHAR	-8.70 **	-5.97 ns	0.00 ns	1.60 ns	-2.52 ns	-0.85 ns	14.94 ns	29.44 **	9.27 **	15.43 **	1.53 ns	10.42 **
C17	HRB-55 x AZAD KRANTI	-4.17 ns	2.99 ns	-2.86 ns	-1.92 ns	-2.93 ns	-0.85 ns	17.06 ns	15.42 **	4.06 **	21.66 **	-0.37 ns	25.80 **
C18	HRB-55 x AZAD GANGA	-4.05 ns	5.97 ns	1.58 ns	2.72 ns	1.67 ns	4.27 *	18.48 ns	16.82 **	-9.21 **	25.82 **	-13.77 **	32.67 **
C19	HRB-55 x GJO-3	-17.74 **	-23.88 **	1.59 ns	2.08 ns	-0.84 ns	0.85 ns	31.28 ns	29.44 **	-5.92 **	-5.64 **	-23.33 **	-28.79 **
C20	HRB-55 x VARSHA UPHAR	13.24 **	14.93 **	1.26 ns	2.88 ns	-1.26 ns	0.43 ns	-9.96 ns	1.40 **	5.62 **	11.57 **	16.49 **	26.69 **
C21	GO-2 x AZAD KRANTI	-8.33 **	-1.49 ns	2.06 ns	3.04 ns	0.00 ns	2.14 ns	-31.03 ns	-25.23 **	-8.12 **	7.42 **	-15.76 **	6.37 ns
C22	GO-2 x AZAD GANGA	1.35 ns	11.94 **	0.79 ns	1.92 ns	-1.67 ns	0.85 ns	-6.47 ns	1.40 **	-14.35 **	18.69 **	-13.81 **	32.61 **
C23	GO-2 x GJO-3	0.00 ns	-5.97 ns	1.27 ns	2.24 ns	-2.99 ns	-2.99 ns	-12.93 ns	-5.61 **	3.85 **	4.15 **	4.69 ns	-1.69 ns
C24	GO-2 x VARSHA UPHAR	-17.65 **	-16.42 **	-1.74 ns	-0.16 ns	-2.10 ns	-0.43 ns	-26.14 ns	-16.82 **	-8.99 **	-3.86 **	-27.24 **	-20.86 **
C25	GAO-5 x AZAD KRANTI	-18.06 **	-11.94 **	-1.75 ns	-0.80 ns	-2.09 ns	0.00 ns	9.29 ns	15.42 **	-23.87 **	0.30 ns	-33.49 **	-11.59 **
C26	GAO-5 x AZAD GANGA	-5.41 ns	4.48 ns	-3.17 ns	-2.08 ns	-2.08 ns	0.43 ns	-2.65 ns	2.80 **	-19.91 **	10.98 **	-25.12 **	15.21 **
C27	GAO-5 x GJO-3	10.45 **	10.45 **	0.97 ns	-0.32 ns	-0.43 ns	-2.14 ns	21.24 ns	28.04 **	-18.47 **	7.42 **	-11.21 **	18.02 **
C28	GAO-5 x VARSHA UPHAR	1.47 ns	2.99 ns	1.26 ns	2.88 ns	1.68 ns	3.42 ns	-0.00 ns	12.62 **	-14.41 **	12.76 **	-11.79 **	17.25 **
	SE±	0.72	0.74	0.39	0.42	-3.77 *	-1.71 ns	0.01	0.00	0.16	0.15	8.41	9.02

*, ** denotes significance at 5% and 1% respectively.

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Table 5. Top three crosses performing standard heterosis over commercial check for yield and its attributing traits

CHARACTERS	CROSSES		CHARACTERS	CROSSES	
Days to 50% Flowering	C8	VRO-22 X Varsha Uphar	Fruit Length (Harvest)	C10	VRO-4 X Azad Ganga
	C10	VRO-4 X Azad Ganga		C20	HRB-55 X Varsha Uphar
	C16	SEL-2 X Varsha Uphar		C27	L7 X GJO-3
Days to First Picking	C8	VRO-22 X Varsha Uphar	Number of Fruits Plant^{-1}	C4	VRO-6 X Varsha Uphar
	C10	VRO-4 X Azad Ganga		C11	VRO-4 X GJO-3
	C20	HRB-55 X Varsha Uphar		-	-
Plant Height	C11	VRO-4 X GJO-3	Number of Seeds Fruit^{-1}	C11	VRO-4 X GJO-3
	C20	HRB-55 X Varsha Uphar		C18	HRB-55 X Azad Ganga
	C28	L7 X Varsha Uphar		-	-
Number of Internodes	-	-	Seed Index	C5	VRO-22 x Azad Kranti
	-	-		C16	SEL-2 X Varsha Uphar
	-	-		C19	HRB-55 x GJO-3
Number of Branches	C13	SEL-2 X Azad Kranti	Fruit Weight	C4	VRO-6 X Varsha Uphar
	C17	HRB-55 X Azad Kranti		C8	VRO-22 X Varsha Uphar
	C23	GO-2 X GJO-3		C17	HRB-55 X Azad Kranti
Fruit Length (Maturity)	C8	VRO-22 X Varsha Uphar	Yield Plant^{-1}	C10	VRO-4 X Azad Ganga
	C10	VRO-4 X Azad Ganga		C18	HRB-55 X Azad Ganga
	C20	HRB-55 X Varsha Uphar		C22	GO-2 x Azad Ganga

for total yield plant^{-1}. Whereas for number of fruit plant^{-1}, cross VRO-4 X GJO-3 exhibited highly positive heterosis effect over 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); Das *et al.* (2022); Chavan *et al.* (2021); Karadi and Hanchinamani (2021).

Okra exhibited heterosis for both yield and its attributing traits. However, the magnitude of heterosis varies among hybrids for each trait. To increase yield through selection, yield components should be taken into consideration. In this study, cross VRO-4 x Azad Ganga (-13.39 and -16.03) exhibited high negative heterosis over better parent and standard check respectively indicating their potential for exploiting heterosis for earliness in okra. For both yield attributes *viz.* total yield plant^{-1} and number of fruit plant^{-1} crosses HRB-55 x Varsha Uphar (16.49) and VRO-4 x Azad Ganga (33.67) respectively exhibited highly positive heterosis effect over better parent and standard check for total yield plant^{-1}. Whereas for number of fruit plant^{-1}, cross VRO-4 X GJO-3 (4.64, 4.81) exhibited highly positive heterosis effect over better parent and standard check. These crosses were identified as promising as the standard check (Punjab 13) and could be further tested for commercial cultivation during early *kharif* in Punjab.

REFERENCES

Abinaya, S., Saravanan, K. R., Thangavel, P., Madhubala, R. and Pushpanathan, K. R. 2020. Studies heterosis and combining ability analysis in okra (*Abelmoschus esculentus* L. Moench.). *Plant Archives*, **20**(1): 1340-1342.

Alam, M. A., Hafizuddin, A. A. B., Gobilik, J., Mijin, S. B. and Khandaker, M. M. 2021. Evaluation of best quality okra parental lines based on morpho-physiological and nutritional attributes. *Bulgarian Journal of Agricultural Science*, **27**(6): 1127–1135

APEDA. 2020 and 2021. The Agricultural and Processed Food Products Export Development Authority 2020, 2021. Available: https://agriexchange.apeda.gov.in

Armand, N. M. 2021. Genetic improvement of okra [*Abelmoschus esculentus* (L) Moench] based on Agromorphological, biochemical and ethnobotanical studies in three regions of Cameroon. *Scholars Academic Journal of Biosciences,* **1**: 10-21. [Cross Ref]

Bailey, F. M. 1897. *A Companion for the Queensland Student of Plant Life and Botany Abridged*. By authority, E. Gregory, government printer. [Cross Ref]

Bhatt, J., Patel, N., Acharya, R. and Kathiria, K. 2016. Heterosis for yield and its related traits in okra *Abelmoschus esculentus* L. Moench. *Electronic Journal of Plant Breeding*, **71**: 189-196. [Cross Ref]

Chaudhary, P. L., Kumar, B. and Kumar, R. 2023. Analysis of Heterosis and Heterobeltiosis for Earliness, Yield and Its Contributing Traits in Okra (*Abelmoschus esculentus* L. Moench). *International Journal of Plant and Soil Science*, **35**(11): 84-98. [Cross Ref]

Chavan, S. S., Jagtap, V. S., Dhakne, V. R., Veer, D. R. and Sargar, P. R. 2021. Heterosis studies in okra [*Abelmoschus esculentus* (L) Moench]. *The Pharma Innovation Journal*, **10**(10): 749-753.

Das, A., Yadav, R. K., Bhardwaj, R., Choudhary, H. and Khade, Y. P. 2022. Study of heterotic potential for important antioxidant and nutritional traits in okra (*Abelmoschus esculentus*). *Indian Journal of Agricultural Sciences*, **92**(8): 986-990. [Cross Ref]

Das, A., Yadav, R. K., Choudhary, H., Singh, S., Khade, Y. P. and Chandel, R. 2020. Determining genetic combining ability, heterotic potential and gene action for yield contributing traits and Yellow Vein Mosaic Virus (YVMV) resistance in Okra (*Abelmoschus esculentus* (L.) Monech.). *Plant Genetic Resources*, **18**(5): 316-329. [Cross Ref]

De Candolle, A.P. 1883. *Origine des plantes cultivees*, Paris, pp. 150-151.

Ebert, A. W. 2020. The role of vegetable genetic resources in nutrition security and vegetable breeding. *Plants*, **9**(6): 736. [Cross Ref]

Fonseca, S. and Patterson, F. 1968. Hybrid vigour in a seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Sciences,* **8**(1): 85-88. [Cross Ref]

Hadiya, D. N., Mali, S. C., Baraiya, V. K. and Patel, A. I. 2018. Studies on assessment of heterosis for fruit yield and attributing characters in okra [*Abelmoschus esculentus* (L.) Moench]. *IJCS*, **6**(5): 1919-1923.

Joshi, J. L., Rajan, R. E. B. and Kumar, C. P. S. 2019. Heterosis for earliness and fruit yield components in Bhendi [*Abelmoschus esculentus* (L.) Moench]. *Plant Archives*, **19**(1): 539-543.

Kapadia, S., Patel, K., Patel, P.K., Mempal, D., Patel, K.N. and Sapavadiya, S. 2021. An investigation on heterosis, general and specific combining ability for pod yield and its contributing parameters in okra [*Abelmoschus esculentus* (L.) Moench] *International Journal of Advanced Research,* **9** (Aug): 334-341. [Cross Ref]

Karadi, S. M. and Hanchinamani, C. N. 2021. Estimation of heterosis in okra [*Abelmoschus esculentus* (L.) Moench] for fruit yield and its components through line× tester mating design. *Bangladesh Journal of Botany*, **50**(3): 531-540. [Cross Ref]

Kerure, P. and Pitchaimuthu, M. 2019. Evaluation for heterosis in okra (*Abelmoschus esculentus* L. Moench). *Electronic Journal of Plant Breeding*, **10**(1): 248-255. [Cross Ref]

Kharat, M. A., Bhalerao, R. V., Bhise, D. R. and Sasane, P. A. 2022. Heterosis studies for yield and yield component in okra (*Abelmoschus esculentus* (L). Moench). *The Pharma Innovation Journal*, **11**(12): 2251-2258.

Kumar, A., Baranwal, D. K., Aparna, J. and Srivastava, K. 2013. Combining Ability and heterosis for yield and its contributing characters in Okra (*Abelmoschus esculantus* (L.) Moench). *Madras Agricultural Journal*, **100**(1-3): 30-35. [Cross Ref]

Kumar, S., Singh, A. K., Yadav, H. and Verma, A. 2017. Heterosis study in okra [*Abelmoschus esculentus* (L.) Moench] genotypes for pod yield attributes. *Journal of Applied and Natural science*, **9**(2): 774-779. [Cross Ref]

Mishra, G. P., Seth, T., Karmakar, P., Sanwal, S. K., Sagar, V., Priti, and Singh, B. 2021. Breeding strategies for yield gains in okra (*Abelmoschus esculentus* L.). In *Advances in Plant Breeding Strategies: Vegetable Crops: Volume 9: Fruits and Young Shoots* (pp. 205-233). Cham: Springer International Publishing. [Cross Ref]

Mundhe, S. S., Pole, S. P., Khandebharad, P. R. and Patil, A. R. 2022. Heterosis studies for yield and yield component traits in okra (*Abelmoschus esculentus* (L.) Moench). *The Pharma Innovation Journal*, **11**(12): 837-842.

Nanthakumar, S., Kuralarasu, C. and Gopikrishnan, A. 2021. Heterosis and Combining Abilities Studies in Okra [*Abelmoschus esculentus* (L.) Moench]. *Current Journal of Applied Science and Technology*, **40**(30): 25–33. [Cross Ref]

NHB. 2022. Indian Horticulture Database 2022. 197 p. National Horticulture Board (NHB), Gurgaon, India.

Panse, V. G. and Sukhatme, P. V. 1985. Statistical methods for agricultural research. *ICAR, New Delhi*, **8**: 308-318.

Patel, A. A., Patel, A. I., Parekh, V. B., Patel, R. K., Mali, S. C. and Vekariya, R. D. 2020. Estimation of standard heterosis over environments for fruit yield and its attributes in Okra [*Abelmoschus esculentus* (L.) Moench]. *IJCS*, **8**(6): 2542-2547. [Cross Ref]

Pithiya, D. J., Jethava, A. S., Zinzala, S. N. and Vachhani, J. H. 2020. Study on combining ability in okra [*Abelmoschus esculentus* (L.) Moench. *IJCS*, **8**(1): 676-679. [Cross Ref]

Pithiya, D. J., Pithiya, K. R., Jethava, A. S., Sapovadiya, M. H. and Vachhani, J. H. 2019. Heterosis studies in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*, **8**(12): 461-465.

Prakash, G., Halesh, G.K. and Fakrudin, B. 2023. Heterosis and combining ability studies in okra [*Abelmoschus esculentus* (L.) Moench] for yield and yield contributing traits. *Biological Forum – An International Journal*, **15**(1): 206-211.

Rajani, A., Naidu, L. N., Reddy, R. V. S. K., Kumari, N. R., Srikanth, D. and Babu, D. R. 2021. Studies on heterosis for growth and yield attributing characters in okra (*Abelmoschus esculentus* (L.) Moench). *The Pharma Innovation Journal*, **10(**10): 1380-1387.

Rynjah, S., Arumugam, T., Mohankumar, S. and Kamala Kannan, A. 2020. Exploitation of heterosis for yield and yield related traits in okra (*Abelmoschus esculentus* (L.) Moench). *IJCS*, **8**(4): 886-893. [Cross Ref]

Satish, K., Bhatt, K., Suresh, K., Prajapati, D. B. and Agalodiya, A. V. 2017. Heterosis study in okra [*Abelmoschus esculentus* (L.) Moench]. *Multilogic in Sci*, **7**(24): 85-89.

Shinde, S. L., Zate, D. K., Rathod, A. H.and Cheke, S. A. 2023. Heterosis studies by using L x T design for yield and yield contributing traits in okra (*Abelmoschus esculentus* (L.) Moench). *The Pharma Innovation Journal*, **12**(1): 228-237. [Cross Ref]

Shwetha, A., Mulge, R. and Khot, R. 2018. Exploitation of hybrid vigour for yield and quality parameters in okra [*Abelmoschus esculentus* (L.) Moench] through half diallel analysis. *Int. J Chem. Stud*, **6**(6): 1269-1273.

Shwetha, A., Mulge, R. and Raju, K. 2021. Heterosis studies in okra [*Abelmoschus esculentus* (L.) Moench] for growth and earliness parameters through half diallel analysis. *The Pharma Innovation Journal*, **10**(6): 1250-1254.

Sidapara, M. P., Gohil, D. P., Patel, P. U. and Sharma, D. D. 2021. Heterosis studies for yield and yield components in okra [*Abelmoschus esculentus* (L.) Moench]. *Journal of Pharmacognosy and Phytochemistry*, **10**(1): 1268-1275.

Singh, B., Prasanna, H. C., Singh, P. M., Pandey, S., Kumar, R., Mishra, G. P. and Singh, B. K. 2017. Harnessing heterosis in vegetable crops: a means for achieving high productivity and profitability. *Doubling farmers income through horticulture Astral International, New Delhi*, 263-278.

Singh, R.K. and Chaudhary, B.D. 1977 Biometrical methods in quantitative genetic analysis, 3rd edn. *Kalyani Publishers*, Ludhiana.

Singh, W. J. and Arivazhagan, R. K. E. 2022. Potential heterosis in bhendi (*Abelmoschus esculentus* (L.) Moench). *The Pharma Innovation Journal*, **11**(12): 632-637.

Sood, S., Sood, V. K. and Chadha, S. 2022. Heterotic expression for fruit yield and component traits in intervarietal hybrids of okra [*Abelmsochus esculentus* (L.) Moench]. *Himachal Journal of Agricultural Research*, **48**(2): 225-233.

Srikanth, M., Dhankhar, S. K., Mamatha, N. C. and Ravikumar, T. 2019. Estimation of heterosis and Inbreeding depression in Okra (*Abelmoschus esculentus* (L.) Moench). *Plant Archives*, **19**(1): 1195-1198.

Tiwari, J. N., Sanjeev, K., Ahlawat, T. R., Akhilesh, K. and Nishtha, P. 2015. Heterosis for yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]. *Asian Journal of Horticulture*, **10**(2): 201-206. [Cross Ref]

Vavilov, N.I. 1951. The origin, variation, immunity and breeding of cultivated plants. Chron. Bot., 13: 1949-1950.

Vekariya, R. D., Patel, A. I., Modha, K. G., Kapadiya, C. V., Mali, S. C. and Patel, A. A. 2020. Estimation of heterosis, gene action and combining ability over environments for improvement of fruit yield and its related traits in okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Current Microbiology and Applied Sci*ence, **9**(9): 866-881. [Cross Ref]

Verma, A. and Sood, S. 2020. Heterosis and combining ability of fruit yield and quality traits in intraspecific hybrids of okra. *Indian journal of horticulture*, **77**(4): 655-662. [Cross Ref]

Vijayaraghavan, C. and Warrier, V. A. 1946. Evaluation of high yielding hybrids in bhendi (*Hibischus esculentus*). In *Proceedings of 33rd Indian Science Congress*, (33): p. 33.

Waghmare, V. N. 2022. Cotton Breeding. In *Fundamentals of Field Crop Breeding* (pp. 609-676). Singapore: Springer Nature Singapore. [Cross Ref]

Yadav, K., Dhankhar, S.K., Singh, D., Singh, U., Amit and Yogita. 2023. Exploitation of combining ability

and heterosis potential for improvement in okra (*Abelmoschus esculentus*) genotypes. *The Indian Journal of Agricultural Sciences*, **93**(2): 127–132. [Cross Ref]

Zate, D. K., Khan, F., Rathod, A. H. and Jawale, L. N. 2021. Heterosis, heterobeltiosis and inbreeding depression study in okra (*Abelmoschus esculentus* (L.) Moench). *The Pharma Innovation Journal*, **10**(7): 401-410.

Zeven, A. C. and Zhukovsky, P. M. 1975. *Dictionary of cultivated plants and their centres of diversity: excluding ornamentals, forest trees and lower plants*. p. 219. Wageningen: Centre for Agricultural Publishing and Documentation.