Comparative study of advance lines along with their single cross hybrids for yield and other horticultural traits in okra [*Abelmoschus esculentus* (L.) Moench]

Abstract

A field experiment was conducted during *Kharif* 2022-23 at the ICAR-Indian Institute of Vegetable Research, Varanasi, to evaluate the performance of ten parental lines of okra and their forty-five hybrids. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications for sixteen horticultural traits including earliness, plant architecture, fruit characteristics, yield contributing traits and Enation Leaf Curl Virus (ELCV) incidence. Analysis of variance revealed significant differences among parental lines and hybrids for all traits except for the number of effective branches and fruit length. Among the parents, VRO-220 and VRO-219 exhibited the earliest flowering and first harvest, while VRO-200 demonstrated the highest fruit yield per plant. Hybrids such as VRO-220×VRO-219 and VRO-216×VRO-200 showed superior performance in terms of earliness, yield, and fruit traits. Plant architectural traits, such as internodal length and plant height, varied significantly, with VRO-106 exhibiting the tallest plants and the maximum number of effective branches. Fruit traits showed substantial variability, with VRO-200 producing the highest number of fruits per plant and fruit weight. For ELCV resistance, VRO-216 exhibited the lowest disease incidence, and several hybrids showed promising resistance to the virus. The results suggest that hybridization can significantly enhance desirable traits such as earliness, yield, and disease resistance in okra, thereby improving its productivity and adaptability in field conditions.

Key words: Leaf Angle, ELCV, hybrids, Mean performance, plant architecture

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop widely grown across tropical and subtropical regions for its tender fruits, which are rich in vitamins, minerals, and dietary fiber (Karmakar et al., 2022). As a member of the Malvaceae family, okra holds immense importance in both culinary and medicinal contexts (Wahyuni & Trianisa 2024). In terms of production, it is cultivated for its high productivity, fast-growing nature, and adaptability to various environmental conditions. With increasing global demand for fresh produce and the need to enhance the productivity of smallholder farms, improving the yield and quality of okra through breeding has become a primary focus (Singh, et al., 2023). One of the key methods for enhancing yield potential in okra is the use of hybridization (Maurya, et al., 2024). Open-pollinated varieties have been traditionally favored due to their stability, seed-saving potential, and ease of cultivation (Nkongho, et al., 2022). However, their yield potential and performance in various environmental conditions can be variable. In contrast, single cross hybrids, the result of controlled pollination between two genetically distinct parental lines, often exhibit heterosis or hybrid vigour, leading to enhanced growth, yield, and resilience to environmental stresses compared to OPVs. The comparative study of F_1's and open-pollinated varieties in okra has become an interesting area of research to determining the most effective strategies for improving yield and other horticultural traits (Suma, et al., 2023). Looking at the importance of hybrids and OPVs of okra an experiment was undertaken to examine the comparative analysis between single cross hybrids and open-pollinated varieties (OPVs) of okra with regard to yield performance and other key horticultural traits. Through this comparative study, we aim to contribute to the broader objective of enhancing sustainable production of okra, with an emphasis on maximizing both yield and quality, while considering economic feasibility and environmental adaptability.

Material and Methods

The field experiment was conducted during the *Kharif* 2022 at experiment farm of ICAR-Indian Institute of Vegetable Research, Varanasi (Uttar Pradesh). The experiment was laid out into Randomized Complete Block Design (RCBD) with 3 replications. Ten advance lines of okra derived from ICAR-Indian Institute of Vegetable Research, Varanasi i.e., VRO-220, VRO-216, VRO-208, VRO-219, VRO-200, VRO-227, VRO-109, VRO-106, SB-4 and VROT-103 along with their forty-five hybrids developed through half-diallel mating design were used in this experiment. The soil of the field was sandy loam type with pH around 7.00 with (0.45%) organic carbon. Each genotype and hybrid were planted in three row and replicated thrice with spacing of 60cm x 40cm. The fertilizer doses were as per the recommendation for the commercial cultivation and the cultural practices were followed as and when required. Observation of sixteen different horticultural traits was recorded from five randomly selected plants from the middle row of each variety in each replication viz., days to 50% flowering (D50F), days to 1st harvest (DFH), first fruiting Node (FFN), internodal length-IL (cm), plant height-PH (cm), number of effective branches (NEB), leaf length (LL), leaf angle- LA (°), number of fruits per plant (NFPP), fruit length-FL (cm), fruit diameter-FD, fruit weight-FW (g), yield per plant-YPP (g), number of harvest (NH), yield/plot (kg), ELCV incidence (ELCV). The statistical analysis were done by using Indosat software. ELCV screening scored on 0-7 scale suggested by Alegbejo (1997) was used to find out the susceptible and resistant genotypes against ELCV disease. Percent disease incidence (PDI), and coefficient of infection (CI) value was calculated by the procedure coined by Venkataravanappa, et al. (2022).

Result and Discussion

Analysis of variance for parents and hybrids

ANOVA for mean performance of 10 parents and 45 F_1's hybrids is described under (Table 1&2). The variance due to parents exhibited significance for all the sixteen characters except number of effective branches and fruit length (cm). Similarly, the variance due to hybrids was also found significant for the all characters under study indicating therefore, significant differences among these sources of variations with respect to the traits under studies (Table 1).

(A) Earliness traits

Data presented in Table 2 &4 for days to 50% flowering, among the parent's its range vary from 51.04 to 41.07 days with mean value (44.29). The minimum days require to 50 percent flowering was observed in VRO-220 (41.07) followed by VRO-219 (41.22) and SB-4 (41.67) whereas, maximum days taken to 50% flowering was observed in VRO-200 i.e., 51.04. Among the hybrids, minimum days taken to 50 % flowering was noted in VRO-220×VRO-219 (37.25) followed by VRO-219 X SB-4 (39.14) and VRO-219 X VRO-227 (39.23). whereas maximum days required for this character was observed in VRO-109 X VRO-106 (53.68). Minimum days required for flowering is considered as desired characters in okra for earliness. It was supported to the results observed by (Maurya, et al., 2022); (Ranga, et al., 2024). Early harvesting is considered as desirable character in okra. Among parents first harvest in days value range from 43.09 (VRO-220) to 54.32 (VRO-200) with mean value 47.19. The parental line VRO-200

(43.09) take minimum days to harvest followed by SB-4 (44.33) and VRO-219 (44.70 days). While, among hybrids minimum days for first harvest exhibited by the crosses VRO-220×VRO-219 (40.33 days) followed by VRO-220 ×VRO-216 (42.07) and VRO-220×VRO-200 (42.22). The maximum days for first harvesting was recorded in VRO-208×VRO-106 (56.00) (Table 2&5). This study is in agreement with Maurya et al. (2023) who reported that early days to first harvest is the important characters of okra for earliness. The lower node to first fruit appears is desirable. The parental line VRO-219 (4.02) showed lower node for first fruiting followed by VRO-200 (4.33) and VRO-208 (4.67), whereas, among the cross combinations VRO-220×VRO-219 (3.25) exhibited early node to first fruit appear followed by VRO-216×VRO-219 (3.76) and VRO-208×VRO-219 (3.77). The upper node for first fruiting was noted in VROT-103 (7.00) and VRO-208×SB-4 (7.67) among parents and hybrids respectively (Table 3&4). Similar result results for this parameter were also reported by Kerure and Pitchaimuthu (2019) and Koli et al. (2020) in okra.

(B) Plant architectural traits

Among the parents, lowest internodal length was recorded in VRO-216 (3.43 cm) followed by VRO-219 (3.53 cm) and VRO-220 (3.54 cm), whereas, highest internodal length was recorded with VRO-106 (7.37cm) (Table 2&5). Out of 45 F_1's, the cross combination VRO-109×VRO-106 (2.87cm) was recorded lowest internodal length followed by VRO-216×VRO-219 (3.15cm) and VRO-220×VRO-200 (3.20cm), while maximum internodal length was observed in VRO-219×VRO-106 (9.13cm). A critical examination of Table 2, genotype VRO-106 (174.67 cm) was showed the maximum plant height followed by VROT-103 (160.33cm) and SB-4 (160.00 cm), whereas, minimum plant height was recorded with VRO-216 (66.82 cm). Out of 45 F_1's, the cross combination VRO-106×SB-4 (177.95cm) was recorded highest plant height followed by VRO-106×VROT-103 (177.55cm) and SB-4×VROT-103 (166.81cm), while minimum plant height was recorded in VRO-220×VRO-216 (65.31cm) during experimentation. Intermediate type of plant height is considerable in okra which resist against lodging and helped for easy in picking was reported by Patel, et al. (2016) and Nagesh, et al. (2014) in cultivated okra. Maximum number of effective branches per plant was exhibited by VRO-106 (3.67) followed by VRO-208 (3.33) and VRO-216 (3.00), whereas, minimum mean values for number of branches per plant was recorded in VROT-103 (1.33). Out of 45 F_1's, the cross combination VRO-227×VROT-103 (5.67) showed maximum branches which were followed by VRO-227×SB-4 (4.67) and VRO-220×SB-4 (4.67), Whereas minimum number of branches was observed in VRO-208×VROT-103, VRO-219×SB-4 and VRO-219×VRO-200 i.e., (0.67) during experimentation (Table 2&3). Among the parents, maximum leaf length was recorded in VRO-208 & VRO-200 i.e., (16.00 cm) followed by VRO-216 (15.67 cm) and VROT-103 (13.43 cm), whereas, minimum leaf length was recorded with SB-4 (9.23cm) (Table 2). Out of 45 F_1's, the cross combination VRO-200×VRO-227 (10.27cm) was recorded minimum leaf length followed by VRO-219×VROT-103 (11.76 cm) and VRO-220×SB-4 (12.00 cm), while maximum leaf length was observed in VRO-216×VRO-208 (17.67 cm) (Table 2). Maximum leaf angle was recorded in SB-4 (80.00) followed by VROT-103 (78.67) and VRO-106 (77.33), whereas, minimum leaf angle was recorded in VRO-220 (33.33) (Table). Out of 45 F_1's, the cross-combination SB-4×VROT-103 (80.67) was showed maximum leaf angle followed by VRO-220×SB-4 (80.00) and VRO-220×VRO-106 (79.67), while minimum leaf angle was observed in VRO-208×VRO-109, VRO-208×VRO-227 and VRO-200×VRO-106 i.e., 31.00 (Table 2). Similar findings were also reported earlier by

Medagam, et al. (2012); Patel and Patel (2016); Kishor, et al. (2013) and Kirthana, et al. (2021) in okra.

(C) Fruit related traits

Number of fruits per plant for parent's range vary from VROT-103 (7.00) to VRO-200 (34.67) with mean value (23.66). The maximum number of fruits was observed in VRO-200 (34.67) followed by VRO-216 (32.00) and VRO-219 (29.67). Whereas minimum number of fruits was observed in VROT-103 (7.00). Out of 45 F_1's, maximum number of fruits was recorded in VRO- 220×VRO-219 (44.88) followed by VRO-216×VRO-227 (43.63) and VRO-200×VRO-106 (43.31). while, minimum number of fruits per plant was observed in SB-4×VROT-103 (14.33) (Table 2&3). The length of fruit varied from 11.10 (VRO-109) to 14.53 (SB-4) among the parents. The highest fruit length was observed in SB-4 (14.53) followed by VRO-220 (14.33) and VRO-200 (13.07) whereas, minimum fruit length was noticed in VRO-109 (11.10). Out of 45 F_1's, maximum fruit length was observed in VRO-109×VRO-106 (13.57) followed by VRO-227×VRO-106 (13.45) and VRO-216×VRO-106 (13.40). while, VRO-220×VRO-109 (7.23) showed minimum value for this trait (Table 2&3). Fruit diameter is a measure of fruit thickness, range varied from 1.39 (VROT-103) to 1.66 (SB-4) for parental lines and 1.30 (VRO-216×VRO-208) to 1.65 (VRO-109×VRO-106) for F_1's hybrids (Table 2&3). The parental line SB-4 (1.66) had maximum fruit diameter followed by VRO-220 (1.62) and VRO-200 (1.56). Among the hybrids, VRO-109×VRO-106 showed maximum fruit diameter (1.65) followed by VRO-227×VRO-106 (1.60) and VRO-220×SB-4 (1.55) whereas minimum fruit diameter was observed in VRO-216×VRO-208 (1.30) Table 2&3. Among parent's fruit weight range vary from 9.52 to 11.74 and in hybrids it was range from 8.60 to 13.73. Within parental line the maximum fruit length was observed in VRO-219 (11.74) followed by VRO-227 (11.35) and VRO-208 (11.32) whereas minimum fruit weight was observed in VROT-103 (9.52) (Table.). Out of 45 F_1's, maximum fruit weight was observed in VRO-216×VRO-200 (13.73) followed by VRO-109×VROT-103 (13.72) and VRO-219×VRO-103 (13.64) whereas minimum fruit weight was observed in VRO-227×VROT-103 (8.60) (Table 2&3). Several workers also observed that okra yield was directly affected by various fruit traits (Jaiprakashnarayan et al., 2008; Kirthana, et al., 2021 and Patel, et al., 2024).

(D) Yield related traits

The maximum fruit yield per plant was observed in parental line VRO-200 (389.59 g) followed by VRO-219 (349.65 g) and VRO-216 (345.47), while, lowest fruit yield per plant was observed in parent VROT-103 (65.58 g), while in the crosses, cross VRO-216×VRO-200 was high yielding hybrid with 572.83 g fruit yield per plant followed by VRO-220×VRO-219 (569.71 g) and VRO-216×VRO-227 (535.56), whereas, the cross SB-4 × VROT-103 gave the lowest yield of 164.34 g per plant (Table 3&4). The maximum number of harvests was observed in parental line VRO-200 (30.33) followed by VRO-209 (29.67) and VRO-216 (29.33), while, minimum number of harvests per plant was observed in VROT-103 (7.33), while in the crosses, cross VRO-200×VRO-219 was gave maximum number of harvests i.e., (41.42) followed by VRO-220×VRO-216 (40.33) and VRO-220×VRO-227 (38.00), whereas, the cross SB-4× VROT-103 (20.46) gave the minimum number of harvest (Table 3). The maximum fruit yield per plot was observed in parental line VRO-200 (11.69 Kg) followed by VRO-219 (10.49 Kg) and VRO-216 (10.36 Kg), while, lowest fruit yield plot plant was observed in parent VROT-103 (1.97 Kg), while in the crosses, cross VRO-216×VRO-200 was high yielding hybrid with 17.19 Kg fruit yield per plant followed by VRO-220×VRO-219 (17.09 Kg) and VRO-216×VRO-227 (17.07 Kg), whereas, the cross VRO-106×VROT-103 gave the lowest yield of 3.27 Kg per plot (Table 4). The present findings strongly corroborate with the observations made by Koli et al. (2020); Kirthana, et al. (2021) and Patel, et al. (2024).

ELCV incidence

Among parental line the coefficient of infection for enation leaf curl virus was found maximum in SB-4 (85.00) followed by VROT-103 (83.33) and VRO-106 (76.67), while minimum ELCV incidence was observed in VRO-216 (0.94) (Table 3). Whereas out of 45 F1's, ELCV infection value range from (0.00) to (85.00) with their mean value of 20.90. seventeen crosses were found disease free and showed (0.00) coefficient of infection. While, maximum ELCV infection was found in SB-4×VROT-103 (85.00) (Table4). For ELCV resistance selection of hybrids is appropriate for use under field situations where crop failure is common due to the presence of disease was confirmed by Yadav, et al. (2018); Devi, et al. (2020).

Table1: Analysis of variance for parents and hybrids in okra

Source of variation	Replicates		Parents	Hybrids	Error (A)	
	Parents	Hybrids			Parents	Hybrids
DF	2	2	9	44	18	88
D50F	0.324	0.951	33.053 **	46.246 **	1.611	1.097
DFH	2.908	4.706	37.324 **	43.985 **	1.562	1.585
FFN	0.096	0.357	2.884 **	3.036 **	0.509	0.576
IL	0.028	0.003	7.613 **	5.199 **	0.095	0.205
PH	16.556	8.28	5304.637 **	2332.006 **	19.711	15.202
NEB	1.433	2.985	1.811	4.548 **	0.767	0.773
LL	0.644	4.934	16.633 **	7.509 **	1.98	1.446
LA	6.433	32.177	981.037 **	932.164 **	34.581	46.808
NFPP	7.277	16.924	282.965 **	204.942 **	4.407	9.031
FL	1.2	5.628	4.23	5.629 **	1.805	2.031
FD	0.002	0.034	0.021 **	0.021 **	0.005	0.011
F	0.544	0.07	1.757 *	4.592 **	0.614	0.884
YPP	2397.979	2226.043	40083.250 **	34573.350 **	1026.919	1756.897
NH	0.633	4.544	219.144 **	93.186 **	2.189	2.242
Yield/Plot	2.152	2.002	36.074 **	31.127 **	0.925	1.579
ELCV	0.013	5.661	4449.125 **	1867.405 **	6.835	21.227

***, ** significant at 5% and 1% level, respectively**

Table2: Best performing parents and top 5 hybrids in desirable direction

Characters	**Parents**	**Hybrids**
D50F	VRO-220 (41.07)	VRO-220×VRO-219 (37.25), VRO-219 X VRO-106 (39.14), VRO-220×VRO-216 (39.21), VRO-219 X VRO-227 (39.23), VRO-208×VRO-219 (39.31)
DFH	VRO-200 (43.09)	VRO-220×VRO-219 (40.33), VRO-219 X SB-4 (41.33), VRO-220×VRO-216 (42.07), VRO-220×SB-4 (42.50) and VRO-219 X VRO-227 (42.79)
FFN	VR0-219 (4.02)	VRO-220×VRO-219 (3.25), VRO-216×VR0-219 (3.76), VRO-208×VRO-219 (3.77), VRO-220×VRO-208 (4.00), VRO-220×VRO-109 (4.45)
IL	VRO-216 (3.43)	VRO-109 X VRO-106 (2.87), VRO-208×VRO-200 (2.87), VRO-216×VR0-219 (3.15), VRO-220×VRO-200 (3.20) and VRO-219 X VRO-227 (3.21)

PH	VRO-216 (66.82)	VRO-216×VR0-219 (64.32), VRO-220×VRO-216 (65.31), VRO-220×VRO-219 (69.06), VRO-216×VRO-200 (70.15), VRO-220×VRO-200 (73.43)
NEB	VRO-106 (3.67)	VRO-219 X SB-4 (0.67), VRO-208×VROT-103 (0.67), VRO-219 X VRO-227 (0.67), VRO-220×VRO-227 (1.00), VRO-208×VRO-109 (1.00)
LL	VRO-220 (16.00)	VRO-216×VRO-208 (17.67), VRO-216×VRO-109 (16.83), VRO-219×VRO-200 (16.67), VRO-109 X SB-4 (16.43), VRO-208×VRO-227 (16.33)
LA	VRO-220 (33.33)	VRO-219 X VRO-227 (29.67), VRO-200 X VRO-227 (31.00), VRO-208×VRO-219 (31.00), VRO-208×VRO-200 (31.00) and VRO-216×VRO-200 (32.67)
NFPP	VRO-200 (34.67)	VRO-220×VRO-219 (44.88), VRO-216×VRO-227 (43.63), VRO-200 X VRO-227 (43.31), VRO-220×VRO-200 (43.02) and VRO-216×VRO-200 (41.64)
FL	SB-4 (14.53)	VRO-227 X SB-4 (13.57), VRO-200 X VROT-103 (13.45), VRO-216× VRO-106 (13.40), VRO-200 X VRO-109 (12.94), VRO-208×VRO-200 (12.90)
FD	SB-4 (1.66)	VRO-227 X SB-4 (1.65), VRO-200 X VROT-103 (1.60), VRO-200 X VRO-109 (1.55) and VRO-216× VRO-106 (1.54) VRO-109 X VRO-106 (1.53)
FW	VRO-219 (11.74)	VRO-216×VRO-200 (13.73), VRO-109 X VRO-106 (13.72), VRO-219 X VRO-106 (13.64), VRO-220×VRO-216 (12.89), VRO-220×VRO-219 (12.75)
YPP	VRO-200 (389.59)	VRO-216×VRO-200 (572.83), VRO-220×VRO-219 (569.71), VRO-216×VRO-227 (535.56), VRO-220×VRO-200 (468.51) and VRO-200 X VRO-227 (459.56)
NH	VRO-200 (30.33)	VRO-220×VRO-219 (41.42), VRO-220×VRO-216 (40.33), VRO-220×VRO-227 (38.00), VRO-208×VRO-219 (37.33) and VRO-216×VRO-109 (36.67)
Yield/Plot (Kg)	VRO-200 (11.69)	VRO-216×VRO-200 (17.19), VRO-220×VRO-219 (17.09), VRO-216×VRO-227 (16.07), VRO-220×VRO-200 (14.06) and VRO-200 X VRO-227 (13.79)
ELCV	VRO-216 (0.94)	VRO-220×VRO-216 (0.00), VRO-220×VRO-208 (0.00), VRO-220×VRO-219 (0.00), VRO-220×VRO-227 (0.00), VRO-216×VRO-208 (0.00), VRO-216×VRO-200 (0.00), VRO-216×VRO-227 (0.00), VRO-216× VRO-106 (0.00), VRO-208×VRO-219 (0.00), VRO-208×VRO-200 (0.00), VRO-208×VRO-227 (0.00), VRO-219 X VRO-227 (0.00), VRO-219 X VRO-109 (0.00), VRO-200 X VRO-227 (0.00), VRO-200 X VRO-109 (0.00), VRO-200 X VRO-106 (0.00)

Table3: Mean performance of 10 parental lines of okra

Parents	D50F	DFH	FFN	IL	PH	NEB	LL	LA	NFPP	FL	FD	FW	YPP	NH	Yield/Plot (Kg)	ELCV
VRO-220	41.07	43.09	4.33	3.54	70.29	2.00	16.00	33.33	27.33	14.33	1.62	11.27	308.56	28.67	9.26	3.04
VRO-216	47.64	50.61	6.33	3.43	66.82	3.00	15.67	38.33	32.00	11.83	1.55	10.80	345.47	29.33	10.36	0.94
VRO-208	41.84	44.73	4.67	3.70	116.96	3.33	16.00	45.33	25.00	12.60	1.52	11.32	282.98	22.67	8.49	1.90
VRO-219	41.22	44.70	4.02	3.53	68.67	2.67	11.97	38.00	29.67	12.20	1.47	11.74	349.65	27.00	10.49	1.98
VRO-200	51.04	54.32	5.00	3.60	75.33	2.33	11.68	59.67	34.67	13.07	1.56	11.25	389.59	30.33	11.69	1.52
VRO-227	42.90	45.00	5.33	4.02	118.33	1.67	11.00	50.33	28.00	12.30	1.51	11.35	319.17	25.00	9.58	1.39
VRO-109	47.00	49.69	6.00	5.47	130.00	2.00	11.70	65.67	28.92	11.10	1.42	10.93	315.80	29.67	9.47	3.77
VRO-106	44.64	47.20	6.00	7.37	174.67	3.67	11.50	77.33	14.33	11.70	1.49	10.03	144.93	17.00	4.35	76.67
SB-4	41.67	44.33	6.33	6.67	160.00	1.67	9.23	80.00	9.67	14.53	1.66	9.73	93.87	9.33	2.82	85.00
VROT-103	43.89	48.25	7.00	6.80	160.33	1.33	13.43	78.67	7.00	11.20	1.39	9.52	65.58	7.33	1.97	83.33
Mean	44.29	47.19	5.50	4.81	114.14	2.37	12.82	56.67	23.66	12.49	1.52	10.79	261.56	22.63	7.85	25.95
Max.	51.04	54.32	7.00	7.37	174.67	3.67	16.00	80.00	34.67	14.53	1.66	11.74	389.59	30.33	11.69	85.00
Min.	41.07	43.09	4.02	3.43	66.82	1.33	9.23	33.33	7.00	11.10	1.39	9.52	65.58	7.33	1.97	0.94
SE ±	**0.733**	**0.722**	**0.412**	**0.178**	**2.563**	**0.506**	**0.812**	**3.95**	**1.212**	**0.776**	**0.041**	**0.453**	**18.501**	**0.854**	**0.555**	**1.509**
CV	**2.866**	**2.649**	**12.963**	**6.405**	**3.890**	**36.997**	**10.978**	**10.378**	**8.873**	**10.759**	**0.727**	**7.261**	**12.252**	**6.537**	**12.254**	**10.073**

Table4: Mean performance of 45 F_1's of okra

Parents	D50F	DFH	FFN	IL	PH	NEB	LL	LA	NFPP	FL	FD	FW	YPP	NH	Yield/Plot (Kg)	ELCV
VRO-220×VRO-216	39.21	42.07	5.00	3.33	65.31	2.00	13.40	35.67	33.72	10.73	1.35	12.89	434.84	40.33	13.05	0.00
VRO-220×VRO-208	39.5	43.00	4.00	4.08	87.90	4.00	12.60	45.5	30.53	7.33	1.32	11.30	344.44	34.67	10.33	0.00
VRO-220×VRO-219	37.25	40.33	3.25	4.23	69.06	4.00	13.45	46.67	44.88	11.10	1.45	12.75	569.71	41.42	17.09	0.00
VRO-220×VRO-200	42.5	44.22	5.67	3.20	73.43	2.33	14.26	60.67	43.02	10.47	1.36	10.86	468.51	36.33	14.06	1.18
VRO-220×VRO-227	44.11	45.89	5.00	3.65	91.45	1.00	10.27	37.00	35.96	12.47	1.46	12.52	450.73	38.00	13.52	0.00
VRO-220×VRO-109	41.68	45.36	4.45	4.03	101.63	1.67	13.43	50.00	24.33	7.23	1.46	11.64	282.47	33.00	8.47	3.32
VRO-220×VRO-106	44.5	47.33	5.33	5.74	128.63	1.33	16.23	79.67	28.00	10.67	1.4	12.19	341.07	24.67	10.23	38.33
VRO-220×SB-4	40.7	42.50	6.33	6.40	114.64	4.67	120	80.00	17.00	11.50	1.33	11.44	192.92	26.00	5.79	41.67
VRO-220×VROT-103	44	48.67	5.33	4.77	110.39	3.33	15.63	70.67	26.33	12.17	1.39	11.30	297.88	25.67	8.94	49.19
VRO-216×VRO-208	43.28	46.96	4.67	6.83	93.89	1.33	17.67	34.33	32.30	10.10	1.30	11.30	364.45	33.00	10.93	0.00
VRO-216×VR0-219	40.24	44.67	3.76	3.15	64.32	2.67	15.00	35.67	35.09	11.00	1.40	9.09	317.11	35.00	9.51	23.33
VRO-216×VRO-200	43.00	45.33	5.00	4.93	70.15	4.00	14.52	32.67	41.64	10.83	1.34	13.73	572.83	31.33	17.19	0.00
VRO-216×VRO-227	49.00	53.00	4.67	5.20	91.65	3.33	14.07	34.33	43.63	12.80	1.50	12.27	535.56	32.33	16.07	0.00
VRO-216×VRO-109	41.50	45.33	4.67	4.41	96.22	3.00	16.83	42.67	25.67	12.27	1.39	11.48	294.59	36.67	8.84	2.81
VRO-216× VRO-106	52.50	54.17	6.08	4.94	116.89	4.33	15.07	72.00	26.29	13.40	1.54	12.06	317.35	25.33	9.52	0.00
VRO-216×SB-4	40.14	43.14	6.49	4.69	110.83	1.67	12.47	68.80	24.00	11.60	1.40	10.89	262.72	26.24	7.88	33.50
VRO-216×VROT-103	44.50	49.00	5.67	4.73	143.96	3.67	15.73	77.74	28.67	11.50	1.46	11.31	323.74	26.16	9.71	18.42
VRO-208×VRO-219	39.31	44.67	3.77	6.73	98.43	3.33	13.43	31.00	29.33	11.70	1.34	12.22	358.59	37.33	10.76	0.00
VRO-208×VRO-200	50.50	54.06	6.00	2.87	90.33	3.00	15.33	31.00	24.67	12.90	1.52	9.04	222.13	33.67	6.66	0.00
VRO-208×VRO-227	51.00	53.91	5.67	4.43	117.09	2.67	16.33	33.33	26.33	11.77	1.37	11.57	305.46	33.33	9.16	0.00
VRO-208×VRO-109	41.00	45.00	5.52	6.43	120.05	1.00	12.45	44.67	20.67	11.43	1.34	11.12	231.49	35.67	6.94	40.00
VRO-208×VRO-106	52.00	56.00	6.33	5.00	143.55	3.67	16.00	63.33	27.67	11.67	1.39	9.56	264.74	26.09	7.94	68.33
VRO-208×SB-4	39.38	42.81	7.67	5.40	135.2	4.33	13.00	78.67	20.00	10.27	1.38	12.34	247.50	26.03	7.43	35.00
VRO-208×VROT-103	43.00	48.33	7.00	3.70	131.62	0.67	13.34	73.47	24.33	11.67	1.38	10.22	249.15	27.69	7.47	35.00
VRO-219×VRO-200	42.03	49.00	5.33	3.67	80.67	1.67	16.67	42.00	24.67	10.49	1.31	11.95	292.67	34.56	8.78	1.90

Continued…

VRO-219 X VRO-227	39.23	42.79	4.83	3.21	93.27	0.67	15.20	29.67	26.67	12.70	1.43	12.67	336.61	36.33	10.1	0.00
VRO-219 X VRO-109	41.14	45.00	6.00	4.57	98.62	3.67	14.13	58.00	21.00	11.73	1.43	11.57	242.77	33.31	7.28	0.00
VRO-219 X VRO-106	41.17	44.00	4.58	9.13	120.19	3.67	15.60	76.33	24.33	12.83	1.50	13.64	333.85	24.89	10.02	33.33
VRO-219 X SB-4	39.14	41.33	5.33	5.37	114.68	0.67	15.54	75.33	21.67	10.33	1.35	11.66	252.64	26.12	7.58	45.00
VRO-219 X VROT-103	42.62	45.33	5.67	5.20	116.68	2.67	11.76	75.67	27.67	12.53	1.49	11.41	313.1	24.42	9.39	25.00
VRO-200 X VRO-227	44.01	46.00	7.00	4.13	92.26	2.33	15.57	31.00	43.31	12.08	1.47	10.63	459.56	31.38	13.79	0.00
VRO-200 X VRO-109	44.92	47.33	7.33	5.20	103.4	3.67	15.15	40.00	30.00	12.94	1.55	11.51	346.18	33.77	10.39	0.00
VRO-200 X VRO-106	44.46	48.00	6.00	3.90	122.48	3.33	12.31	60.67	25.67	10.17	1.37	10.87	276.7	25.16	8.30	0.00
VRO-200 X SB-4	46.35	48.68	6.33	4.33	116.18	3.67	12.59	73.33	20.06	12.63	1.52	9.92	199.25	24.90	5.98	7.03
VRO-200 X VROT-103	45	48.83	6.67	5.97	113.71	1.67	13.13	70.67	29.33	13.45	1.60	12.57	367.34	30.06	11.02	25.00
VRO-227 X VRO-109	41.32	45.09	5.00	8.77	126.44	4.00	13.47	35.67	30.45	10.91	1.39	12.30	374.7	29.86	11.24	0.00
VRO-227 X VRO-106	43.43	47.65	6.41	4.23	144.78	4.00	15.44	58.67	24.74	11.33	1.43	8.60	214.33	26.24	6.43	11.67
VRO-227 X SB-4	42.51	44.47	6.00	5.13	131.98	4.67	13.8	52.67	25.00	13.57	1.65	12.58	316.08	23.59	9.48	25.00
VRO-227 X VROT-103	43.49	45.67	5.67	3.50	140.69	5.67	13.57	63.33	26.33	11.60	1.46	8.67	229.48	28.05	6.88	15.00
VRO-109 X VRO-106	53.68	55.42	5.33	2.87	142.83	2.67	13.59	57.00	19.00	12.23	1.53	13.72	261.13	23.27	7.83	55.00
VRO-109 X SB-4	43.08	45.09	7.00	3.55	135.37	2.33	16.43	72.33	16.00	10.83	1.41	11.11	176.45	23.10	5.29	31.67
VRO-109 X VROT-103	42.08	46.00	6.67	4.90	143.3	3.67	14.74	50.00	15.00	12.37	1.52	12.22	180.71	23.97	5.42	25.00
VRO-106 X SB-4	41.64	44.42	6.00	5.67	177.95	3.67	13.37	80.67	14.33	10.1	1.34	11.38	164.34	20.60	4.93	83.33
VRO-106 X VROT-103	50.58	52.43	6.00	3.47	177.55	1.33	12.87	78.50	10.33	9.00	1.30	10.56	180.98	21.16	3.27	81.67
SB-4 X VROT-103	41.5	45.7	7.33	4.63	166.81	3.67	15.23	77.69	10.33	11.90	1.52	10.64	165.34	20.46	3.28	85.00
Mean	**43.49**	**46.76**	**5.64**	**4.76**	**113.92**	**2.90**	**14.28**	**55.97**	**26.67**	**11.43**	**1.43**	**11.45**	**309.65**	**29.58**	**9.20**	**20.90**
Max	**53.68**	**56.00**	**7.67**	**9.13**	**177.95**	**5.67**	**17.67**	**80.67**	**44.88**	**13.57**	**1.65**	**13.73**	**572.83**	**41.42**	**17.19**	**85.00**
Min	**37.25**	**40.33**	**3.25**	**2.87**	**64.32**	**0.67**	**10.27**	**29.67**	**10.33**	**7.23**	**1.300**	**8.60**	**164.34**	**20.46**	**3.27**	**0.00**
SE±	**0.604**	**0.727**	**0.434**	**0.242**	**2.151**	**0.499**	**0.694**	**3.435**	**1.7330**	**0.803**	**0.052**	**0.551**	**24.531**	**0.862**	**0.735**	**2.44**
CV	**2.405**	**2.694**	**13.33**	**8.814**	**3.271**	**29.857**	**8.412**	**10.631**	**11.254**	**12.175**	**6.355**	**8.332**	**13.849**	**5.047**	**13.84**	**20.28**

Conclusion

Based on this study, it is concluded that the hybrids such as VRO-220×VRO-219 and VRO-216×VRO-200 exhibited superior performance in terms of early flowering, first harvest, and fruit yield per plant. Genotype VRO-106 showed the highest plant height and number of branches, while VRO-200 recorded the highest fruit yield per plant. The hybrids also displayed notable differences in fruit traits. The incidence of Enation Leaf Curl Virus (ELCV) was lowest in VRO-216, with several hybrids exhibiting resistance to the disease. Overall, our findings highlight the potential of hybridization to improve earliness, yield, and disease resistance in okra, making it an effective strategy for enhancing productivity and adaptability under field conditions.

Disclaimer (Artificial intelligence): Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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