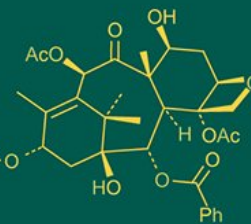
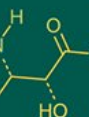
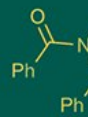


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(8): 1808-1813
www.biochemjournal.com
Received: 18-05-2026
Accepted: 21-06-2026

Naval A Mathukiya
M.Sc. Scholar, Department of
Genetics and Plant Breeding,
College of Agriculture,
Junagadh Agricultural
University, Junagadh,
Gujarat, India

DR Pancholi
M.S. Student, Department of
Chemistry and Biochemistry,
California State University,
San Bernardino, California,
USA
Orcid: 0009-0004-3399-490X

Heterosis of okra [*Abelmoschus esculentus* (L.) Moench] for fruit yield and its components traits

Naval A Mathukiya and DR Pancholi

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8St.9677>

Abstract

The experimental material consisted of seven lines, four testers of okra, their 28 hybrids generated through a line $\times$ tester mating design and one standard check hybrid (GJOH-4). The experimental material was evaluated in a randomized block design with three replications at the VRS, JAU, Junagadh during *kharif* 2025 to assess the extent and magnitude of heterotic effects of the hybrids over the better parent and standard check. The analysis of variance revealed highly significant differences among genotypes, parents and hybrids for all the traits studied. For fruit yield per plant, heterobeltiosis ranged from-19.64% (AOL-22-16 $\times$ GJO-3) to 20.07% (JOL-22-17 $\times$ GJO-3), whereas standard heterosis varied from-23.62% (AOL-22-16 $\times$ GAO-8) to 45.33% (JOL-22-17 $\times$ GJO-3). The promising performance of these crosses indicates their potential for further exploitation in the development of desirable okra hybrids. Heterosis breeding serves as an effective approach for identifying superior hybrid combinations and providing useful information to breeders for improving yield and other economically important traits.

Keywords: Okra, line $\times$ tester analysis, Heterosis

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is a major vegetable crop cultivated widely in tropical and subtropical areas and is a member of the Malvaceae family with India accounting for a substantial proportion of global production. It is a warm-climate annual crop propagated by seed with an indeterminate growth habit and a chromosome number is $2n = 130$. (Dutta and Naug, 1968) ^[6]. The crop grows well under hot and humid climatic conditions (Lamont, 1999) ^[14] and is widely cultivated for its tender edible pods, which are rich in dietary fibre, vitamins and minerals and contain a well-balanced amino acid composition comparable to that of soybean (Kumar *et al.*, 2013) ^[13]. Okra has diverse uses and can adapt to different soil conditions, although well-drained and fertile soils with an appropriate pH are considered most suitable for its cultivation (Jain *et al.*, 2012) ^[10]. The roots and stems of okra are also utilized in the clarification of gur, *khand* and raw sugar. Owing to its hardness, dietary fibre content and favourable seed protein composition, particularly the essential amino acids lysine and tryptophan. In India, major okra-producing states include Gujarat, Maharashtra, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Karnataka and Punjab. The crop is cultivated during both the *Kharif* and summer seasons. In Gujarat, Vadodara, Junagadh, Surat, Anand, Surendranagar and Banaskantha is the major okra-growing districts.

Materials and Methods

The investigational material consisted of seven female lines viz., JOL-24-108, JOL-24-113, JOL-21-106, JOL-12-13, AOL-22-16, SKNOL-23-03 and JOL-22-17, along with four male testers of okra viz., GJO-3, Kashi Lalima, GAO-8 and KS-404 (Table 1). A total of 28 F_1 hybrids were developed through a line $\times$ tester mating design along with one standard check hybrid (GJOH-4). The material was evaluated during *kharif* 2025 at the Vegetable Research Station, Junagadh Agricultural University, Junagadh using a randomized block design (RBD) with three replications. A spacing of 60 cm between rows and 30 cm between plants was maintained. The crop was raised following the recommended agronomic practices of the region to ensure proper crop growth and development.

Corresponding Author:
Naval A Mathukiya
M.Sc. Scholar, Department of
Genetics and Plant Breeding,
College of Agriculture,
Junagadh Agricultural
University, Junagadh,
Gujarat, India

Observations were recorded on five randomly selected competitive plants from each replication for each genotype. Twelve characters were studied, namely nodal position for first flowering, days to first flowering, days to first picking, plant height (cm), number of primary branches per plant, number of fruits per plant, fruit length (cm), fruit girth (cm), average fruit weight (g), days to last picking, number of pickings and total fruit yield per plant (g). The mean values obtained from these observations were used for statistical analysis. Analysis of variance for each character was carried out following the procedure outlined by Panse and Sukhatme (1995) [22]. Heterosis was assessed using two parameters: heterobeltiosis representing heterosis over the better parent, as proposed by Fonseca and Patterson (1968) [7] and standard heterosis representing heterosis over the standard check as suggested by Meredith and Bridge (1972) [18].

Results and Discussion

The analysis of variance revealed highly significant differences among the genotypes for all the characters studied. The total genotypic variance was further divided into components comprising parents (lines, testers and lines vs. testers), hybrids and parents vs hybrids. Significant differences were observed among the parents and hybrids for all the traits. The comparison between parents and hybrids was also highly significant for nodal position for first flowering, plant height (cm), number of primary branches per plant, number of fruits per plant, fruit length (cm), days to last picking, number of pickings and total fruit yield per plant (g). The mean squares attributable to lines were significant for all the characters, while those due to testers were also significant for all the traits, demonstrating the presence of substantial genetic variability within the experimental material. The lines vs testers component exhibited significant mean squares for all the characters, indicating differences between the female and male parents with respect to the traits studied. The contribution of testers to the total variance was comparatively greater for nodal position for first flowering, days to first flowering, days to first picking, plant height (cm), number of primary branches per plant, number of fruits per plant, fruit length (cm), average fruit weight (g), days to last picking, number of pickings and total fruit yield per plant (g) indicating a greater influence of testers on the variation observed for these characters. In contrast, lines contributed a larger proportion of the total variance for the remaining traits under investigation (Table 2). The findings were in agreement with the results reported by Patel and Patel (2016) [24], Punia *et al.* (2017) [29], Pithiya *et al.* (2019) [28], Das *et al.* (2020) [5], Patel *et al.* (2020) [23], Samindire *et al.* (2022) [36], Chaudhary *et al.* (2023) [4], Sakriya *et al.* (2023) [35], Pathania *et al.* (2024) [27], Ranga *et al.* (2024) [33], Vani *et al.* (2024) [41] and Vekariya *et al.* (2025) [42] for nodal position for first flowering, days to first flowering, days to first picking, plant height (cm), number of primary branches per plant, number of fruits per plant, fruit length (cm), fruit girth (cm), average fruit weight (g), days to last picking, number of pickings and total fruit yield per plant (g).

Several cross combinations exhibited significant heterosis in the desirable direction over both the better parent and the standard check for various traits. The number of crosses showing favourable heterosis over the better parent and standard check was 13 and 9 for nodal position of first

flowering, 7 and 7 for days to first flowering, 7 and 6 for days to first picking, 7 and 10 for plant height (cm), 6 and 12 for number of primary branches per plant, 5 and 8 for number of fruits per plant, 4 and 8 for fruit length (cm), 7 and 6 for fruit girth (cm), 4 and 6 for average fruit weight (g), 6 and 11 for days to last picking, 7 and 12 for number of pickings and 6 and 7 for total fruit yield per plant (g), respectively.

Evaluation of the crosses for heterosis over the better parent and the standard check (GJOH-4) indicated considerable heterotic effects in the desirable direction for nodal position for first flowering, plant height (cm), number of primary branches per plant, number of fruits per plant, fruit length (cm), number of pickings and total fruit yield per plant (g). In contrast, comparatively lower levels of heterobeltiosis and standard heterosis were observed for days to first flowering, days to first picking, average fruit weight (g), fruit girth (cm) and days to last picking. Comparable findings have also been reported by Punia *et al.* (2017) [29], Pithiya *et al.* (2019) [28], Das *et al.* (2020) [5], Patel *et al.* (2020) [23], Samindire *et al.* (2022) [36], Chaudhary *et al.* (2023) [4], Sakriya *et al.* (2023) [35], Pathania *et al.* (2024) [27], Ranga *et al.* (2024) [33], Vani *et al.* (2024) [41] and Vekariya *et al.* (2025) [42].

In okra, negative heterosis is considered desirable for nodal position for first flowering as it indicates earlier flowering. The heterobeltiosis values ranged from -26.85 percent (AOL-22-16 × GAO-8) to 4.46 percent (JOL-22-17 × Kashi Lalima), whereas standard heterosis ranged from -32.32 percent (AOL-22-16 × KS-404) to 18.18 percent (JOL-22-17 × Kashi Lalima) (Table 3). The present findings are in accordance with those reported by Nagesh *et al.* (2014) [19], Padadalli *et al.* (2019) [21], Pithiya *et al.* (2019) [28], Poluru *et al.* (2023) [30] and Vani *et al.* (2024) [41].

Early flowering is an important breeding objective in okra, and days to first flowering serves as a key component for determining earliness. The heterobeltiosis estimates for days to first flowering ranged from -9.88 percent (JOL-12-13 × GJO-3) to 5.3 percent (JOL-24-113 × GAO-8), while the standard heterosis values varied from -11.11% (JOL-12-13 × KS-404) to 6.54% (SKNOL-23-03 × GJO-3). The results obtained in the present study were consistent with the findings of Patel *et al.* (2015) [26], Tiwari *et al.* (2016) [40], Lyngdoh *et al.* (2017) [15], Rameshkumar *et al.* (2017) [31], Makdoomi *et al.* (2018) [17], Chaudhary *et al.* (2023) [4] and Ranga *et al.* (2024) [33].

Earliness for days to first picking is an important desirable attribute in okra. For this character heterobeltiosis ranged from -9.64 percent (AOL-22-16 × Kashi Lalima) to 5.56 percent (JOL-24-113 × GAO-8), whereas standard heterosis varied from -11.59% (JOL-12-13 × KS-404) to 6.71% (SKNOL-23-03 × GJO-3). The findings of the present investigation were comparable with those reported by Nagesh *et al.* (2014) [19], Pithiya *et al.* (2019) [28], Patel and Patel (2016) [24], Tiwari *et al.* (2016) [40] and Vani *et al.* (2024) [41].

Greater plant height is generally associated with higher yield in okra. Therefore, positive heterotic effects for this trait are considered desirable. The heterobeltiosis estimates for plant height varied from -24.98 percent (AOL-22-16 × GJO-3) to 15.83 percent (AOL-22-16 × KS-404). In comparison, heterosis over the standard check ranged from -21.67 percent (SKNOL-23-03 × KS-404) to 20.74 percent (JOL-12-13 × Kashi Lalima). The present findings were in agreement with

the observations reported by Patel and Patel (2016) ^[24], Lyngdoh *et al.* (2017) ^[15], Rameshkumar *et al.* (2017) ^[31], Das *et al.* (2020) ^[5], Ranga *et al.* (2024) ^[33] and Sood (2025) ^[37].

For the number of primary branches per plant, heterobeltiosis estimates varied from 46.51 percent (JOL-12-13 × KS-404) to 33.33 percent (SKNOL-23-03 × KS-404 and AOL-22-16 × KS-404). The standard heterosis values ranged from 40.54 percent (AOL-22-16 × GAO-8) to 45.95 percent (JOL-22-17 × Kashi Lalima). The results obtained were comparable with those reported by Nagesh *et al.* (2014) ^[19], Mahajan *et al.* (2017) ^[16], Punia and Garg (2017) ^[29], Padadalli *et al.* (2019) ^[21], Samindre *et al.* (2022) ^[36], Gawai and Patel (2023) ^[9] and Abdelkader *et al.* (2024) ^[1].

For the number of fruits per plant, heterobeltiosis showed a range from 22.01 percent (JOL-12-13 × GAO-8) to 21.33 percent (JOL-22-17 × GJO-3). The estimates of standard heterosis ranged from 27.42 percent (AOL-22-16 × GAO-8) to 37.63 percent (JOL-22-17 × GJO-3). The findings were consistent with those reported by Patel and Patel (2016) ^[24], Pithiya *et al.* (2019) ^[28], Patel *et al.* (2020) ^[23], Subhakar *et al.* (2022) ^[39], Poluru *et al.* (2023) ^[30], Abdelkader *et al.* (2024) ^[1] and Vekariya *et al.* (2025) ^[42].

Greater fruit length is generally considered favourable in okra because of its potential contribution to higher yield. Hence, positive heterotic effects are desirable for this character. The heterobeltiosis estimates ranged from 20.62 percent (JOL-22-17 × KS-404) to 13.58 percent (JOL-24-113 × GAO-8), whereas standard heterosis varied from 14.66% (JOL-24-113 × KS-404) to 20.7% (JOL-22-17 × GJO-3). None of the crosses exhibited positive and significant heterosis over the standard check (GJOH-4) for fruit length. The present findings were in accordance with those reported by Sabesan *et al.* (2016) ^[34], Punia and Garg (2017) ^[29], Samindre *et al.* (2022) ^[36], Chaudhary *et al.* (2023) ^[4] and Ranga *et al.* (2024) ^[33].

For fruit girth in okra, negative heterosis is considered desirable. The heterobeltiosis values ranged from 5.8 (JOL-22-17 × KS-404) to 6.36 percent (SKNOL-23-03 × Kashi Lalima), while standard heterosis ranged from 7.36 (JOL-22-17 × GAO-8) to 6.86 percent (JOL-12-13 × GJO-3). The findings were in agreement with the results reported by Ram *et al.* (2016) ^[32], Joshi *et al.* (2019) ^[11], Abinaya *et al.* (2020) ^[2], Chaudhary *et al.* (2023) ^[4] and Pathania *et al.* (2024) ^[27].

For average fruit weight, heterobeltiosis estimates varied from 14.96 (AOL-22-16 × GJO-3) to 11.94 percent (JOL-22-17 × GJO-3), whereas standard heterosis ranged from 17.31 (SKNOL-23-03 × Kashi Lalima) to 23.95 percent (JOL-22-17 × GJO-3). Positive heterotic effects for this trait have also been reported by Sabesan *et al.* (2016) ^[34], Mahajan *et al.* (2017) ^[16], Joshi *et al.* (2019) ^[11], Poluru *et al.* (2023) ^[30] and Pathania *et al.* (2024) ^[27].

For days to last picking, the heterobeltiosis estimates varied from 5.57 percent (JOL-12-13 × KS-404) to 4.98 percent (SKNOL-23-03 × GAO-8), whereas standard heterosis ranged from 9.97 percent (JOL-12-13 × KS-404) to 10.63 percent (JOL-22-17 × GJO-3). The present results were comparable with the findings reported by Nagesh *et al.* (2014) ^[19], Tiwari *et al.* (2016) ^[40], Punia and Garg (2017) ^[29], Chaudhary *et al.* (2023) ^[4] and Vekariya *et al.* (2025) ^[42].

For number of pickings, heterobeltiosis estimates ranged from 22.58 percent (SKNOL-23-03 × Kashi Lalima) to

15.63 percent (SKNOL-23-03 × GAO-8). Standard heterosis showed a range of 25.00 percent (SKNOL-23-03 × Kashi Lalima) to 40.63 percent (JOL-21-106 × GJO-3). The results obtained in the present investigation were in agreement with the observations reported by Nagesh *et al.* (2014) ^[19], Pithiya *et al.* (2019) ^[28], Patel *et al.* (2020) ^[23] and Ranga *et al.* (2024) ^[33].

For fruit yield per plant, heterobeltiosis estimates ranged from 19.64 (AOL-22-16 × GJO-3) to 20.07 percent (JOL-22-17 × GJO-3). The highest significant and desirable heterobeltiosis was observed in JOL-22-17 × GJO-3 (20.07%), followed by JOL-24-113 × GAO-8 (18.04%) and JOL-12-13 × GJO-3 (15.33%). Standard heterosis ranged from 23.62 (AOL-22-16 × GAO-8) to 45.33 percent (JOL-22-17 × GJO-3). Among the crosses, JOL-22-17 × GJO-3 recorded the highest significant standard heterosis in the desirable direction (45.33%), followed by JOL-12-13 × GJO-3 (39.59%) and JOL-21-106 × GJO-3 (35.10%). The present findings were in agreement with the results reported by Nagesh *et al.* (2014) ^[19], Neetu *et al.* (2015) ^[20], Bhatt *et al.* (2016) ^[3], Mahajan *et al.* (2017) ^[16], Gavint *et al.* (2018) ^[8], Pithiya *et al.* (2019) ^[28], Sapavadiya *et al.* (2019) ^[38], Samindre *et al.* (2022) ^[36], Chaudhary *et al.* (2023) ^[4], Gawai and Patel (2023) ^[9], Pathania *et al.* (2024) ^[27], Ranga *et al.* (2024) ^[33] and Vani *et al.* (2024) ^[41].

The cross JOL-22-17 × GJO-3 emerged as a superior hybrid and expressed significant standard heterosis in the desirable direction for nodal position for first flowering, number of primary branches per plant, number of fruits per plant, fruit length (cm), average fruit weight (g), days to last picking, number of pickings and total fruit yield per plant (g). This performance indicated the important contribution of these traits to fruit yield per plant. The same cross also exhibited significant heterobeltiosis in the desirable direction for nodal position for first flowering, number of primary branches per plant, number of fruits per plant, fruit length (cm), average fruit weight (g), days to last picking, number of pickings and total fruit yield per plant (g). (Table 4)

The second most heterotic cross JOL-12-13 × GJO-3 exhibited significant standard heterosis in the desirable direction for plant height (cm), number of primary branches per plant, number of fruits per plant, average fruit weight (g), fruit girth (cm), average fruit weight (g), days to last picking, number of pickings and total fruit yield per plant (g). The cross also showed significant heterobeltiosis in the desirable direction for nodal position for first flowering, days to first flowering, days to first picking, plant height (cm), number of fruits per plant, average fruit weight (g), number of pickings and total fruit yield per plant (g). (Table 4)

The third highest heterotic cross JOL-21-106 × GJO-3 demonstrated significant standard heterosis in the desirable direction over the standard check for nodal position for first flowering, days to first flowering, days to first picking, number of fruits per plant, days to last picking, number of pickings and total fruit yield per plant (g). The same cross also expressed significant heterobeltiosis in the desirable direction for nodal position for first flowering, number of fruits per plant, days to last picking, number of pickings and total fruit yield per plant (g). (Table 4)

It is interesting to note that the crosses exhibiting high heterosis for fruit yield per plant did not necessarily express high heterosis for all the associated yield components (Table 4). Nevertheless, the present investigation revealed that

significant and positive heterosis for fruit yield was generally accompanied by desirable and significant heterotic effects for two or more yield contributing characters. Such a combined influence of heterosis in multiple yield components contributing to fruit yield per plant has also

been reported by Nagesh *et al.* (2014) ^[19], Patel and Patel (2016) ^[24], Pithiya *et al.* (2019) ^[28], Kharat *et al.* (2022) ^[12], Poluru *et al.* (2023) ^[30], Sakriya *et al.* (2023) ^[35] and Ranga *et al.* (2024) ^[33].

Table 1: Detailed characterization of parental lines utilized in the crossing programme

Sr. No.	Parents	Salient features
Females (Lines)		
1	JOL-24-108	Tall plant stature, elongated internodes, broad leaves and light-green pods
2	JOL-24-113	Tall plant, long internodes, broad-striped leaves and dark-green pods
3	JOL-21-106	Dwarf plant, broad leaves, short internodes and light green shining pod
4	JOL-12-13	Tall plant, long internodes and red-coloured pods
5	AOL-22-16	Dwarf plant, short internodes, broad leaves and dark-green pods
6	SKNOL-23-03	Dwarf plant, broad-striped leaves and dark-green pods
7	JOL-22-17	Tall plant, long internodes, broad leaves and light-green pods
Males (Tester)		
1	GJO-3	Tall plant, long internodes, broad leaves and light-green pods
2	KASHI LALIMA	Tall plant, long internodes, broad-striped leaves and bright red, glossy pods
3	GAO-8	Tall plant, short internodes, broad leaves and dark-green pods
4	KS-404	Dwarf plant, broad leaves, short internodes and light-green pods
Standard check		
1	GJOH-4	Tall plant with dark-green, tender, long and attractive pods, tolerant to YVMV

Table 2: Analysis of variance presenting mean squares for various characters in okra

Source	d. f.	Nodal position for first flowering	Days to first flowering	Days to first picking	Plant height (cm)	Number of Primary branches per plant	Number of fruits per plant
Replications	2	0.13	2.68	2.60	0.28	0.06	0.21
Genotypes	38	2.51**	19.66**	21.40**	391.32**	1.02**	10.15**
Parents	10	2.90**	17.94**	14.34**	381.72**	1.23**	5.17**
Lines	6	4.40**	40.72**	48.52**	601.07**	0.57**	7.77**
Testers	3	10.33**	76.10**	90.21**	1095.21**	3.24**	55.80**
L. vs T.	1	0.46**	5.25*	5.61*	192.97**	0.66**	5.87**
P. vs H.	1	0.66**	0.45	6.99	687.38**	1.46**	14.39**
Hybrids	27	2.43**	21.01**	24.55**	383.91**	0.93**	11.84**
Error	76	0.07	2.97	2.79	28.86	0.06	1.04

Source	d. f.	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Days to last picking	Number of pickings	Total fruit yield per plant (g)
Replications	2	0.28	0.05	85.60	3.44	0.52	161.65
Genotypes	38	3.14**	0.10**	659.24**	94.29**	9.96**	2776.30**
Parents	10	1.66**	0.08**	396.54**	70.08**	5.23**	1213.10**
Lines	6	1.68**	0.22**	802.97**	111.52**	12.01**	2529.31**
Testers	3	8.62**	0.14**	2717.04**	532.35**	53.60**	20625.21**
L. vs T.	1	3.57**	0.07**	436.56**	22.94**	3.96**	761.43**
P. vs H.	1	2.63*	0.01	258.54	202.90**	21.78**	2611.16**
Hybrids	27	3.71**	0.11**	771.37**	99.23**	11.27**	3361.38**
Error	76	0.51	0.02	102.36	3.11	1.03	198.42

*, ** Significant at 5% and 1% levels, respectively

Table 3: Range and frequency of heterobeltiosis (H₁) and standard heterosis (H₂) among crosses for different traits in okra

Sr. No.	Characters	Range of heterosis (%)						Number of crosses with significant heterosis			
		Heterobeltiosis (H ₁)			Standard heterosis (H ₂)			H ₁		H ₂	
								+ Ve	-Ve	+ Ve	-Ve
1	Nodal position for first flowering	-26.85	to	4.46	-32.32	to	18.18	1	13	6	9
2	Days to first flowering	-9.88	to	5.30	-11.11	to	6.54	0	7	2	7
3	Days to first picking	-9.64	to	5.56	-11.59	to	6.71	1	7	3	6
4	Plant height (cm)	-24.98	to	15.83	-21.67	to	20.74	7	5	10	3
5	Number of primary branches per plant	-46.51	to	33.33	-40.54	to	45.95	6	7	12	4
6	Number of fruits per plant	-22.01	to	21.33	-27.42	to	37.63	5	4	8	4
7	Fruit length (cm)	-20.62	to	13.58	-14.66	to	20.70	4	4	8	2
8	Fruit girth (cm)	-5.80	to	6.36	-7.36	to	6.86	3	7	2	6
9	Average fruit weight (g)	-14.96	to	11.94	-17.31	to	23.95	4	1	6	2
10	Days to last picking	-5.57	to	4.98	-9.97	to	10.63	6	4	11	6
11	Number of pickings	-22.58	to	15.63	-25.00	to	40.63	7	4	12	5
12	Total fruit yield per plant (g)	-19.64	to	20.07	-23.62	to	45.33	6	5	7	4

Table 4: Evaluation of three superior heterotic crosses for fruit yield per plant and their heterotic response for yield contributing traits in okra

Heterotic crosses	Fruit yield per plant (g)	Per cent heterosis for fruit yield per plant over		sca effect for fruit yield per plant	Significant and desirable heterosis for component traits over	
		Better parent	Standard check (GJOH-4)		Better parent	Standard check (GJOH-4)
JOL-22-17 × GJO-3	211.89	20.07*	45.33**	24.19**	1, 6, 7, 9, 10, 11, 12	1, 5, 6, 7, 9, 10, 11, 12
JOL-12-13 × GJO-3	191.78	15.33**	39.59**	0.05	1, 2, 3, 4, 6, 9, 11, 12	4, 5, 6, 8, 9, 10, 11, 12
JOL-21-106 × GJO-3	184.81	11.62	35.10**	-5.82	1, 6, 10, 11, 12,	1, 2, 3, 6, 10, 11, 12

Where, *, ** Significant at 5% and 1% levels, respectively

1 = Nodal position for first flowering; 2 = Days to first flowering; 3 = Days first picking; 4 = Plant height (cm); 5 = Number of primary branches per plant; 6 = Number of fruits per plant; 7 = Fruit length (cm); 8 = Fruit girth (cm); 9 = Average fruit weight (g); 10 = Days to last picking; 11 = Number of pickings; 12 = Total fruit yield per plant (g);

Conclusion

From ongoing discussion, the three most promising crosses, namely JOL-22-17 × GJO-3, JOL-12-13 × GJO-3 and JOL-21-106 × GJO-3 exhibited superior *per se* performance along with significant and positive heterobeltiosis and standard heterosis in the desirable direction for fruit yield per plant and several yield contributing traits. Hence, these promising cross combinations may be subjected to further evaluation across different years and locations for their potential commercial exploitation through heterosis breeding. Alternatively, they may be utilized in future breeding programmes to generate desirable transgressive segregants and facilitate the identification of superior high yielding inbreds.

References

- Abdelkader MF, Mahmoud MH, Diyasty MZ, Sukar NA, Farag MI, Mohamed NN, *et al.* Genetic components derived parameters and heterosis in okra under Saudi Arabia conditions. *Genetics Research*. 2024;6(1):6432560.
- Abinaya S, Saravanan KR, Thangavel P, Madhubala R, Pushpanathan KR. Studies and heterosis and combining ability analysis in okra [*Abelmoschus esculentus* (L.) Moench]. *Plant Archives*. 2020;20(1):1340-1342.
- Bhatt JP, Patel NA, Acharya RR, Kathiria KB. Heterosis for yield and its related traits in okra [*Abelmoschus esculentus* (L.) Moench]. *Electronic Journal of Plant Breeding*. 2016;7(1):189-196.
- Chaudhary PL, Kumar B, Kumar R. 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*. 2023;35(11):84-98.
- Das A, Yadav R, Choudhary H, Singh S, Khade YP, Chandel R. Determining genetic combining ability, heterotic potential and gene action for yield contributing traits and yellow vein mosaic virus resistance in okra [*Abelmoschus esculentus* (L.) Moench]. *Plant Genetic Resources: Characterisation and Utilisation*. 2020;18(5):316-329.
- Dutta PC, Naug A. A few strains of *Abelmoschus esculentus* (L.) Moench: their karyological study in relation to phylogeny and organ development. *Beitrage zur Biologie der Pflanzen*. 1968;45:113-126.
- Fonseca S, Patterson F. Hybrid vigour in a seven-parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Science*. 1968;8(1):85-88.
- Gavint KN, Vadodariya KV, Bilwal BB. To study the nature and magnitude of heterosis for fruit yield and yield attributes in okra [*Abelmoschus esculentus* (L.) Moench]. *Journal of Pharmacognosy and Phytochemistry*. 2018;7(1):2583-2587.
- Gawai MP, Patel BN. Studies on heterobeltiosis and inbreeding depression for fruit yield and its attributing traits in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2023;12(7):741-745.
- Jain N, Jain R, Jain V, Jain S. A review on *Abelmoschus esculentus* (L.) Moench. *Pharmacia*. 2012;1(3):84-89.
- Joshi JL, Jayalakshmi G, Rajan REB, Muralidharan A. Studies on gene action and combining ability for earliness, fruit yield and yield contributing characters in bhendi [*Abelmoschus esculentus* (L.) Moench]. *Plant Archives*. 2019;19(2):2964-2966.
- Kharat MA, Bhalerao RV, Bhise DR, Sasane PA. Heterosis studies for yield and yield component in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2022;11(12):2251-2258.
- Kumar A, Kumar P, Nadendla R. A review on *Abelmoschus esculentus* (L.) Moench. *International Research Journal of Pharmaceutical and Applied Sciences*. 2013;3(4):129-132.
- Lamont WJ. Okra—a versatile vegetable crop. *Horticulture Technology*. 1999;9(2):179-184.
- Lyngdoh YA, Mulge R, Shadap A, Singh J, Sangwan S. Combining ability analysis in near homozygous lines of okra [*Abelmoschus esculentus* (L.) Moench] for yield and yield attributing parameters. *Journal of Applied and Natural Science*. 2017;9(1):324-331.
- Mahajan RC, Sonawane DJ, Yamgar SV. Estimation of heterosis, inbreeding depression and heritability for fruit yield and its attributing traits in okra [*Abelmoschus esculentus* (L.) Moench]. *Journal of Pharmacognosy and Phytochemistry*. 2017;6(6):2174-2177.
- Makdoomi MI, Wani KP, Dar ZA, Hussain K, Nabi A, Mushtaq F, *et al.* Heterosis studies in okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Current Microbiology and Applied Sciences*. 2018;7(2):3297-3304.
- Meredith WR, Bridge RR. Heterosis and gene action in cotton, *Gossypium hirsutum* L. *Crop Science*. 1972;12(3):304-310.
- Nagesh GC, Mulge R, Rathod V, Basavaraj LB, Mahaveer SM. Heterosis and combining ability studies in okra [*Abelmoschus esculentus* (L.) Moench] for yield and quality parameters. *The Bioscan*. 2014;9(4):1717-1723.
- Neetu A, Kumar R, Pal M. Heterosis and inbreeding depression in okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Scientific and Innovative Research*. 2015;3(2):15-24.

21. Padadalli S, Satish D, Babu AG, Chittapur R, Prabhuling G, Peerjade D. Studies on combining ability in okra [*Abelmoschus esculentus* (L.) Moench] through line $\times$ tester analysis for productivity and quality traits. *Journal of Pharmacognosy and Phytochemistry*. 2019;8(4):639-643.
22. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. 4th revised ed. New Delhi: ICAR; 1995.
23. Patel AA, Patel AI, Parekh VB, Patel RK, Mali SC, Vekariya RD. Estimation of standard heterosis over environments for fruit yield and its attributes in okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Chemical Studies*. 2020;8(6):2542-2547.
24. Patel BG, Patel AI. Heterosis studies in okra [*Abelmoschus esculentus* (L.) Moench]. *Annals of Agricultural and Environmental Medicine*. 2016;1(1):15-20.
25. Patel DD, Delvadiya IR, Kumar R. Analysis of heterotic potential for earliness, yield and its attributing traits in okra [*Abelmoschus esculentus* L. Moench]. *International Journal of Bio-resource and Stress Management*. 2024;15(2):1-9.
26. Patel HB, Bhandari DR, Patel AI, Tank RV, Kumar A. Magnitude of heterosis for pod yield and its contributing characters in okra [*Abelmoschus esculentus* (L.) Moench]. *The Bioscan Journal*. 2015;10(2):939-942.
27. Pathania R, Mehta DK, Bhardwaj RK, Dogra RK, Singh K, Kaplex A, *et al.* Exploitation of heterosis, combining ability and gene action potential for improvement in okra [*Abelmoschus esculentus* (L.) Moench]. *Indian Journal of Agricultural Sciences*. 2024;94(12):1340-1348.
28. Pithiya DJ, Pithiya KR, Jethava AS, Sapovadiya MH, Vachhani JH. Heterosis studies in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2019;8(12):461-465.
29. Punia M, Garg DK, Burdak A. Heterosis for fruit yield and its contributing traits in okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Chemical Studies*. 2017;5(5):2238-2242.
30. Poluru P, Pandya MM, Sakure AA, Patel NA. Heterosis studies of fruit yield and its component traits in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2023;12(10):1194-1199.
31. Rameshkumar D, Gunasekar R, Sankar R. Gene action studies for quantitative and qualitative traits in okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Chemical Studies*. 2017;5(5):2309-2312.
32. Ram B, Acharya RR, Patil K. Evaluation of diallel crosses for estimation of components of genetic variance and graphical analysis in okra. *Journal of Hill Agriculture*. 2016;7(1):68-74.
33. Ranga AD, Vikram A, Kumar R, Dogra RK, Sharma R, Sharma HR. Exploitation of heterosis and combining ability potential for improvement in okra [*Abelmoschus esculentus* L. Moench]. *Scientific Reports*. 2024;90(1):25-31.
34. Sabesan T, Saravanan K, Satheeshkumar P. Studies on heterosis, inbreeding depression and residual heterosis for fruit yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]. *Plant Archives*. 2016;16(2):669-674.
35. Sakriya SG, Vaja SJ, Patel S, Vaghela K, Mahesha KN, Saravaiya SN. Exploitation of heterosis for yield and yield attributes in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2023;12(6):4008-4013.
36. Samindre S, Jagtap V, Sargar P, Deokar S, Pisal S. Heterosis and inbreeding depression analysis for fruit yield and its related attributes in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2022;11(12):5754-5757.
37. Sood S. Assessment of combining ability for yield and yield component traits in okra [*Abelmoschus esculentus* (L.) Moench] genotypes using line $\times$ tester analysis. *Vegetos*. 2025;1-11.
38. Sapavadiya SB, Kachhadia VH, Savaliya JJ, Sapovadiya MH, Singh SV. Heterosis studies in okra [*Abelmoschus esculentus* (L.) Moench]. *The Pharma Innovation Journal*. 2019;8(6):408-411.
39. Subhakar Ivin JJ, Jessica GR, Williams G, Vennila S, Anbuselvam Y. Study of line $\times$ tester analysis for combining ability in bhendi [*Abelmoschus esculentus* (L.) Moench]. *Crop Research*. 2022;57(1):38.
40. Tiwari JN, Kumar S, Ahlawat TR. Combining ability studies for various horticultural traits in okra [*Abelmoschus esculentus* (L.) Moench] under South-Gujarat conditions. *Journal of Farm Sciences*. 2016;29(1):53-56.
41. Vani VM, Singh BK, Raju SVS, Singh AK, Jaiswal DK. Genomic expression of heterosis for yield and seed parameters of okra [*Abelmoschus esculentus* (L.) Moench]. *Plant Archives*. 2024;24(2):2273-2281.
42. Vekariya RG, Patel NB, Patel PC, Patel DR, Patel RD, Ravat KBJP. Combining ability and gene action analysis in okra [*Abelmoschus esculentus* (L.) Moench] over different environments. *Plant Archive*. 2025;25(1):3052-3067.