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ASSESSMENT OF HETEROSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN OKRA *[ABELMOSCHUS ESCULENTUS* (L.) MOENCH]

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ABSTRACT
Okra [*Abelmoschus esculentus* (L.) Moench] is an economically important vegetable crop valued for its high nutritional and medicinal properties. Enhancing its productivity is essential to meet growing global demand. This study evaluated standard heterosis for yield and yield-contributing traits in okra to identify superior hybrid combinations suitable for commercial exploitation. Eight genetically diverse parental lines were crossed in a half-diallel design (excluding reciprocals) to generate twenty-eight F1 hybrids. The parents, hybrids, and a standard check variety (‘Parbhani Kranti’) were evaluated across three distinct environments during the *kharif* season using a randomized block design (RBD) with three replications. Observations were recorded for eleven morpho-physiological characters, encompassing flowering, maturity, vegetative growth parameters, yield components, and seed traits. Significant variations in standard heterosis were observed across environments for most traits, indicating a pronounced genotype x environment (G × E) interaction. Desirable negative standard heterosis for earliness was recorded for days to 50% flowering and days to edible maturity, whereas positive heterosis was observed for primary yield components. The hybrid ‘Phule Utkarsh × GJO-3’ exhibited the highest and most stable positive standard heterosis for fruit yield per plant across all environments, paired with significant fruit weight. Similarly, ‘AKOV-107 × GJO-3’ demonstrated stable, highly desirable heterosis for total yield and fruit weight. In contrast, seed-related traits generally exhibited negative heterosis, confirming the competitive superiority of the check variety for those specific traits. The promising hybrids identified in this study hold substantial potential for commercial cultivation and integration into future okra improvement programmes.
KEYWORDS: *Abelmoschus esculentus*; earliness; hybrid breeding; okra; standard heterosis; yield.

1. INTRODUCTION

Food and nutritional security remain major global challenges, with the conceptual framework of food security gradually shifting from mere calorie sufficiency to nutritional adequacy and dietary diversity. Vegetables are indispensable components of a balanced and sustainable diet due to their richness in dietary fiber, vitamins, minerals, and bioactive compounds, such as phenols and flavonoids, which play a significant role in human health (1). Rising incidences of lifestyle-related disorders, including diabetes, coronary heart diseases, and hypercholesterolemia, have increased consumer awareness regarding healthy dietary practices, thereby promoting higher consumption of vegetables and fruits. Among vegetable crops, okra [*Abelmoschus esculentus* (L.) Moench], a prominent member of the family Malvaceae, is recognized globally for its high nutritional and medicinal value. Okra pods are exceptionally rich in carbohydrates, dietary fiber, vitamins (particularly vitamin C and folate), minerals such as calcium, potassium, and zinc, and essential unsaturated fatty acids, including linoleic and oleic acids (2). The crop is considered highly multipurpose, as its leaves, flowers, buds, stems, and seeds are also utilized commercially. Okra mucilage, a polysaccharide-rich compound extracted from the pods, exhibits several health-promoting properties, such as antitumor, antioxidant, antimicrobial, antiulcerogenic, and hypoglycemic effects, while also enhancing cholesterol binding to aid in detoxification processes (3). India is the largest producer of okra worldwide, accounting for a major share of global production; however, regional productivity levels have stagnated due to the predominance of traditional open-pollinated varieties and the limited exploitation of hybrid vigour (4). Yield in okra is a complex quantitative trait influenced by several yield-contributing characters and environmental factors. Direct selection for yield alone is often ineffective; hence, genetic improvement requires simultaneous selection for associated component traits with high heritability and genetic variability. The ultimate effectiveness of such selection programs depends largely on the extent of genetic diversity present within the baseline breeding material (5). Heterosis breeding has been widely recognized as a powerful genetic approach for significantly enhancing productivity in vegetable crops. The first foundational report on heterosis in okra was documented by Vijayaraghavan and Warrier (6), and subsequent studies have confirmed significant hybrid vigour for yield and its contributing traits. The floral biology of okra, characterized by large solitary flowers that offer ease of manual emasculation and a high fruit-set percentage, further facilitates the commercial exploitation of heterosis. Assessment of the magnitude and direction of heterosis is therefore essential for identifying superior hybrid combinations and for their potential commercial utilization in crop breeding programs. Hence, the present investigation was undertaken to assess heterosis for yield and yield-contributing traits in okra, with the explicit aim of enhancing productivity through effective hybrid breeding strategies.

2. MATERIALS AND METHODS

2.1 Experimental site

The field experiment was carried out at the Research Farm of K. V. Patel College of Agriculture, Shahada, District Nandurbar, Maharashtra, India (21.5454° N, 74.4711° E), under representative monsoonal conditions. During the cropping season, afternoon maximum temperatures ranged from 30.6 to 31.0 °C and night minimums from 24.5 to 25.7 °C. The district receives most of its average annual rainfall 767 mm per year during the south-west monsoon (June–September).

2.2 Experimental units, design and evaluation

The experimental material comprised eight genetically diverse parental okra genotypes, their twenty-eight F1 hybrids developed through a half-diallel mating design (excluding reciprocals), and one standard check variety (‘Parbhani Kranti’). Hybridization was performed during the preceding season using manual emasculation and hand-pollination techniques. The resulting 37 genotypes (8 parents, 28 F1 hybrids, and 1 check) were evaluated across three distinct environments during the *kharif* season using a Randomized Block Design (RBD) with three replications.

2.3 Planting geometry

Each genotype was grown in a single 6 m long row with a spacing configuration of 60 × 45 cm. Guard rows were systematically provided around the experimental blocks to minimize border effects. Standard recommended agronomic practices and plant protection measures were uniformly adopted across all environments to ensure optimal crop growth.

2.4 Observations recorded

Observations were recorded from five randomly selected, competitive plants per plot for eleven morpho-physiological traits: days to 50% flowering, plant height (cm), number of branches per plant, number of fruits per plant, fruit length (cm), fruit diameter (cm), average fruit weight (g), fruit yield per plant (g), number of seeds per fruit, seed index (100-seed weight in g), and days to edible maturity.

2.5 Statistical analysis

The mean values calculated from these traits were subjected to statistical analysis. The magnitude of standard heterosis, expressed as the percentage increase or decrease in the mean performance of the F1 hybrids over the standard check variety, was estimated following the biometric methodologies suggested by Hayes et al. (7).

3. RESULTS AND DISCUSSION

The estimates of heterosis measured as per cent increase or decrease over the standard check 'Parbhani Kranti' (standard heterosis) evaluated for various charcaters in individual environments and on a pooled basis are presented in Table 1-4. The estimates of standard heterosis for days to 50% flowering indicated expressions for both earliness and lateness across environments. These values ranged from -6.71% (Phule Utkarsha × AKOV-107) to 7.95% (GJO-3 × GO-6) in E1, -9.65% to 8.05% for the same crosses in E2, -11.33% (GOA-5 × Konkan Bhendi) to 7.03% (AKOV-107 × GJO-3) in E3, and -7.63% to 7.64% on a pooled basis. This range suggests a moderate scope for genetic improvement in flowering time. Standard heterosis for the number of branches per plant showed wide variation, ranging from -10.12% to 20.77% in E1, -12.15% to 19.16% in E2, -12.85% to 16.24% in E3, and -10.27% to 18.72% on a pooled basis. The hybrid Konkan Bhendi × GO-6 consistently outperformed the standard check across all three environments. For the number of fruits per plant, standard heterosis was generally low, varying from -30.59% to 2.78% in E1, -28.09% to 3.89% in E2, -31.31% to 1.68% in E3, and -29.59% to 2.71% on a pooled basis, indicating limited heterotic expression for this trait. Similar low heterotic expressions for fruit count have been reported previously (8, 9, 10).

Plant height exhibited substantial variability, with standard heterosis ranging from -30.19% to -6.02% in E1, -33.07% to -8.80% in E2, -28.76% to -7.45% in E3, and -30.05% to -7.42% on a pooled basis, reflecting considerable genetic diversity among the generated crosses. Fruit yield per plant expressed pronounced and consistent positive standard heterosis over the standard check 'Parbhani Kranti'. This was particularly evident in the hybrid Phule Utkarsha × GJO-3, which recorded highly desirable standard heterosis values of 51.22%, 56.44%, and 57.57% in E1, E2, and E3, respectively, resulting in a pooled heterosis value of 55.08%.

Conversely, some crosses, such as GOA-5 × GO-6, exhibited negative heterosis in specific environments, emphasizing the significant role of genotype × environment (G × E) interactions on final yield performance. For fruit length, standard heterosis was predominantly negative in GOA-5-based crosses, especially GOA-5 × GOA-8 (-27.15% to -24.67% across environments; -25.67% pooled). Meanwhile, Phule Utkarsha × GJO-3 exhibited the least negative heterosis (-4.94% to -0.84% across environments and -3.48% on a pooled basis). The lowest pooled heterosis for fruit length (-33.27%) was observed in GOA-8 × AKOV-107. These trends correspond closely with findings from earlier heterosis studies in okra (11, 12, 13, 14, 15).

Standard heterosis for fruit diameter ranged from -22.09% to 9.21% in E1, -24.30% to 6.91% in E2, -23.94% to 6.88% in E3, and -22.51% to 7.21% on a pooled basis, with Konkan Bhendi × GJO-3 consistently showing superiority over the check variety. For average fruit weight, the cross AKOV-107 × GJO-3 recorded the highest and most stable standard heterosis values (40.02%, 41.25%, and 40.95% across E1 to E3; 40.74% pooled). Moderate positive heterotic responses for fruit weight were also observed in Phule Utkarsha × AKOV-107 and GJO-3 × GO-6. However, some crosses, such as Phule Utkarsha × Konkan Bhendi, exhibited negative heterosis in specific environments, as noted in comparable regional evaluations (1). Days to edible maturity showed very high and consistent negative standard heterosis, indicating highly desirable earliness. This trend was prominent in GOA-5 × Phule Utkarsha (-57.65% to -58.44%; -57.99% pooled), GOA-5 × Konkan Bhendi, and GOA-5 × GOA-8, with even the least early hybrids recording more than -50% heterosis over the standard check.

Standard heterosis for the number of seeds per fruit was predominantly negative across environments, ranging from approximately -0.73% to -42.50%, indicating the distinct superiority of the standard check for seed-filling capacity. Similarly, the 100-seed weight (seed index) exhibited uniformly negative standard heterosis across all test environments and hybrid combinations (-0.88% to -36.23%), with GOA-5 × GOA-8 recording the most negative pooled value (-32.63%). This confirms the overall commercial superiority of 'Parbhani Kranti' regarding individual seed traits. Parallel negative heterotic values for seed-related traits in okra crosses have been highlighted in previous diallel evaluations (16, 17, 18).

4. SUMMARY AND CONCLUSION

The present investigation revealed substantial variability in standard heterosis for fruit yield and its component traits in okra across distinct agro-ecological environments, indicating strong potential for commercial exploitation of hybrid vigour. Evaluated diallel crosses exhibited desirable negative heterosis for earliness and significant positive heterosis for key productivity traits, although phenotypic expression was strongly modulated by environmental fluctuations. Among all crosses, Phule Utkarsh × GJO-3 emerged as the most stable and high-yielding hybrid, showing consistent positive standard heterosis for fruit yield per plant across environments and superior individual fruit weight. The cross AKOV-107 × GJO-3 also displayed reliable positive heterosis for secondary agronomic traits, particularly branch development and fruit mass density. In contrast, standard heterosis for seed index traits was predominantly negative across environments, underscoring the performance limits of these genotypes relative to the check variety ‘Parbhani Kranti’. Overall, results highlight the pronounced influence of genotype × environment (G × E) interactions on heterotic expression in okra. The identified superior hybrids, especially Phule Utkarsh × GJO-3, constitute promising candidates for commercial release and for use as elite parents in breeding programmes targeting early-maturing, high-yielding okra cultivars.

REFERENCES:

1. Ulger TG, Songur AN, Cirak O, Cakiroglu FP. Role of Vegetables in Human Nutrition and Disease Prevention. InTech. 2018. https://doi.org/10.5772/intechopen.77038
2. Gemede HF, Negussie R, Gulelat DH, Woldegiorgis AZ, Fekadu B. Nutritional quality and health benefits of okra (*Abelmoschus esculentus* L.). International Journal of Nutrition and Food Sciences. 2015;4(2):208-215. https://doi.org/10.11648/j.ijnfs.20150402.22
3. Dantas TL, Alonso Buriti FC, Florentino ER. Okra (*Abelmoschus esculentus* L.) as a Potential Functional Food Source of Mucilage and Bioactive Compounds with Technological Applications and Health Benefits. Plants. 2021;10(8):1683. https://doi.org/10.3390/plants10081683
4. Anonymous. Indian Institute of Food Processing Technology, Thanjavur. Detailed Project Report. www.iifpt.edu.in. 2022;4.
5. Adugna W, Labuschagne MT. Association of linseed characters and its variability in different environments. Journal of Agricultural Sciences. 2003;14:285-296.
6. Vijayaraghavan C, Warrier VA. Evolution of high yielding hybrid bhindi (*Hibiscus esculentus* L.). Proceedings of the 33rd Indian Science Congress; Bangalore, India. 1946:163.
7. Hayes HK, Immer F, Smith DC. Methods of Plant Breeding. New York: McGraw-Hill Book Co., Inc.; 1955:52-66.
8. Chavan SS, Jagtap VS, Dhakne VR, Veer DR, Sargar PR. Heterosis studies in okra (*Abelmoschus esculentus* L. Moench). The Pharma Innovation Journal. 2021;10(10):749-753.
9. Mundhe SS, Pole SP, Khandebharad PR, Patil AR. Heterosis studies for yield and yield component traits in okra (*Abelmoschus esculentus* L. Moench). The Pharma Innovation Journal. 2022;11(12):837-842.

10. Shinde SL, Zate DK, Rathod AH, Cheke SA. Heterosis studies by using L × T design for yield and yield contributing traits in okra (*Abelmoschus esculentus* (L.) Moench). The Pharma Innovation Journal. 2023;12(1):228-237.
11. Kumar S, Chowdhury S. Exploitation of heterosis for yield and yield attributes in okra (*Abelmoschus esculentus* L. Moench). International Journal of Chemical Studies. 2019;7(4):853-857.
12. Kerure P, Pitchaimuthu M, Srinivasa V, Venugopalan R. Heterosis for yield and its components in okra (*Abelmoschus esculentus* L. Moench). International Journal of Current Microbiology and Applied Sciences. 2019;8(1):353-367. https://doi.org/10.20546/ijcmas.2019.801.038
13. Ranjani PS, Rajan REB, Kumar CPS, Joshi JL, Muralidharan A. Estimation of standard heterosis in bhendi (*Abelmoschus esculentus* L. Moench). Plant Archives. 2020;20(1):2070-2072.
14. Panchal KN, Bhalekar MN, Kshirsagar DB, Joshi VR, Kute NS. Heterosis for fruit yield and its components traits in okra (*Abelmoschus esculentus* L. Moench). The Pharma Innovation Journal. 2021;10(8):1192-1200.
15. Shwetha A, Mulge R, Raju KK. Heterosis studies in okra (*Abelmoschus esculentus* L. Moench) for growth and earliness parameters through half diallel analysis. The Pharma Innovation Journal. 2011;10(6):1250-1254.
16. Shashank SS, Singh AK. Manifestation of heterosis in relation to seasonal variation in okra (*Abelmoschus esculentus* (L.) Moench). Vegetable Science. 2011; 38: 107-110.
17. Patel BG, Patel AI. Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench). Annals of Agricultural and Environmental Sciences. 2016;1(1):15-20.
18. Satish K, Bhatt K, Suresh K, Prajapati DB, Agalodiya AV. Heterosis study in okra (*Abelmoschus esculentus* L. Moench). Multilogic in Science. 2017;7(24):85-89.

Table 1. Estimates of standard heterosis (%) for days to 50 per cent flowering and no. of branches per plant in okra under different environments

Hybrids	Days to 50 per cent flowering				No. of branches per plant				No of fruits per plant			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled
GOA-5 × GOA-8	2.19	3.81	2.28	2.76	-1.06	-2.93	-2.47	-2.15	-9.59	-8.29	-10.05	-9.31
GOA-5 × Phule Utkarsha	0.48	-2.30	3.54	0.57	-10.12 *	-7.85	-12.85 **	-10.27 *	-20.96 **	-21.03 **	-20.79 **	-20.93 **
GOA-5 × Phule Vimukta	0.66	-1.61	-0.02	-0.32	15.97 **	12.25 *	7.19	11.81 **	-9.69	-11.23	-8.81	-9.91
GOA-5 × AKOV-107	-3.22	-2.21	-3.19	-2.87	-2.34	-3.98	-6.27	-4.20	-0.17	0.33	-0.30	-0.04
GOA-5 × Konkan Bhendi	-6.52	-4.20	-11.33 **	-7.35	5.75	6.07	1.64	4.49	-15.00	-12.86	-18.03	-15.30
GOA-5 × GJO-3	2.89	1.93	2.82	2.55	10.54 **	13.19 *	1.95	8.56 **	-27.96 **	-27.85 **	-31.23 **	-29.01 **
GOA-5 × GO-6	0.53	6.44	3.77	3.58	3.73	3.46	0.72	2.63	-17.90 **	-19.03	-16.34	-17.76
GOA-8 × Phule Utkarsha	-3.09	-3.08	-7.97*	-4.71	12.89 **	10.05	21.17 **	14.70 **	-15.51 **	-13.08 **	-13.31 **	-13.97 **
GOA-8 × Phule Vimukta	-4.07	-4.62	-3.95	-4.21	6.60	0.21	2.57	3.13	-12.09 **	-7.14	-14.13	-11.12
GOA-8 × AKOV-107	-1.85	-1.14	-2.00	-1.66	13.42 **	11.83 *	9.66 *	11.64 **	2.10	0.95	1.68	1.58
GOA-8 × Konkan Bhendi	2.45	-0.59	1.52	1.13	10.44 **	11.73 *	5.65	9.27 **	-9.57	-9.53	-10.19	-9.76
GOA-8 × GJO-3	2.53	5.06	-4.50	1.03	15.12 **	7.54	8.02	10.23 **	-26.79 **	-27.39 **	-27.27 **	-27.15 **
GOA-8 × GO-6	-2.75	1.05	0.98	-0.24	-2.56	-6.81	-1.54	-3.63	-20.47 **	-15.78 **	-19.07 **	-18.44 **
Phule Utkarsha × Phule Vimukta	-2.02	-1.15	-2.66	-1.95	1.81	-0.63	-1.95	-0.26	-18.65 **	-20.29 **	-19.19 **	-19.38 **
Phule Utkarsha × AKOV-107	-6.71	-9.65*	-6.54	-7.63	17.68 **	24.40 **	18.81 **	20.29 **	-2.57	-5.44	-2.68	-3.57
Phule Utkarsha × Konkan Bhendi	-2.76	1.61	-2.22	-1.13	1.17	-2.62	-3.80	-1.75	-13.39 **	-11.96 **	-13.79 **	-13.05 **
Phule Utkarsha × GJO-3	0.47	-2.66	3.38	0.40	-0.21	4.50	0.10	1.46	-25.51 **	-26.09 **	-24.28 **	-25.29 **
Phule Utkarsha × GO-6	-1.21	-0.52	2.30	0.19	-7.88 *	-9.11	-11.51 **	-9.50 *	-15.05 **	-17.86 **	-20.34 **	-17.75 **
Phule Vimukta × AKOV-107	-3.84	-5.02	-1.09	-3.32	15.02 **	13.51 *	8.22 *	12.25 **	2.78	3.89	1.44	2.71
Phule Vimukta × Konkan Bhendi	-0.87	0.77	1.65	0.52	2.02	-0.94	-0.10	0.33	-11.77 **	-9.14 **	-12.04 **	-10.99 **
Phule Vimukta × GJO-3	-2.7	-4.03	-0.62	-2.46	14.91 **	14.87 **	10.79 *	13.52 **	-24.4	-25.12	-25.6	-25.0

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Phule Vimukta × GO-6	1.15	-0.68	-4.57	-1.37	-5.86	-12.15 *	-5.34	-7.78	-16.06 **	-17.26 **	-23.18 **	-18.83 **
AKOV-107 × Konkan Bhendi	-1.73	-3.33	0.46	-1.53	1.81	-0.63	-2.47	-0.43	2.52	-1.33	0.40	0.53
AKOV-107 × GJO-3	3.90	2.20	7.03	4.38	-5.32	-8.27	-8.02	-7.20	-14.84 **	-14.04 **	-16.00 **	-14.96 **
AKOV-107 × GO-6	-2.62	-8.18	-5.15	-5.32	15.97 **	17.07 **	15.72 **	16.26 **	-2.81	-5.04	-3.72	-3.86
Konkan Bhendi × GJO-3	4.06	5.58	3.98	4.54	-1.92	-3.14	-4.62	-3.23	-28.35 **	-28.09 **	-31.31 **	-29.25 **
Konkan Bhendi × GO-6	-2.52	-6.81	-1.91	-3.75	20.77 **	19.16 **	16.24 **	18.72 **	-17.42 **	-14.91 **	-15.42 **	-15.92 **
GJO-3 × GO-6	7.95*	8.05*	6.91	7.64*	14.48 **	15.18 **	10.07 *	13.25 **	-30.59 **	-27.91 **	-30.27 **	-29.59 **

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

Table 2. Estimates of standard heterosis (%) for plant height (cm), yield per plant (g) and fruit length (cm) in okra under different environments

Hybrids	Plant height (cm)				Yield per plant (g)				Fruit length (cm)			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled
GOA-5 × GOA-8	-27.22	-28.44	-27.61	-27.76	-12.27 **	-11.69 **	-11.97 **	-11.97 **	-27.15 **	-24.67	-25.18	-25.67
GOA-5 × Phule Utkarsha	-21.22 **	-18.78 **	-26.68 **	-22.23 **	23.38 **	27.69 **	22.87 **	24.64 **	-8.22	-13.49	-11.56	-11.09
GOA-5 × Phule Vimukta	-27.88	-27.10	-25.53	-26.84	-10.15 **	-10.36 *	-9.52 *	-10.01 **	-29.37	-31.17	-27.37	-29.30
GOA-5 × AKOV-107	-24.55	-26.68	-25.73	-25.66	-5.81	-8.03	-5.31	-6.38	-27.96	-29.95	-29.42	-29.11 **
GOA-5 × Konkan Bhendi	-29.72	-33.07	-27.36	-30.05	-5.22	-8.32	-7.46	-7.00	-32.29 **	-28.28 **	-32.92 **	-31.16 **
GOA-5 × GJO-3	-19.67 **	-19.67 **	-19.24 **	-19.53 **	-1.49	-3.38	-1.01	-1.96	-26.91 **	-24.89 **	-28.03 **	-26.61 **
GOA-5 × GO-6	-30.19	-28.63	-26.92	-28.58	-10.54 **	-13.24 **	-6.23	-10.00 **	-32.94 **	-29.59 **	-36.52 **	-33.02 **
GOA-8 × Phule Utkarsha	-17.22 **	-18.16 **	-17.76 **	-17.71 **	15.66 **	16.94 **	14.33 **	15.64 **	-5.87 *	-2.86	-5.92	-4.88 *
GOA-8 × Phule Vimukta	-27.23	-29.61	-22.87	-26.57	-19.78 **	-20.37 **	-21.20 **	-20.45 **	-27.89	-25.84	-26.89	-26.88
GOA-8 × AKOV-107	-23.87	-31.16	-28.76	-27.93	-12.81 **	-11.85 **	-13.14 **	-12.60 **	-34.66 **	-27.22 **	-37.93 **	-33.27 **
GOA-8 × Konkan Bhendi	-28.29	-29.17	-27.05	-28.17	-8.52 *	-9.19 *	-8.78 *	-8.83 *	-29.31	-28.17	-30.69	-29.39
GOA-8 × GJO-3	-13.71	-10.16	-10.76 **	-11.54 **	10.94 **	11.32 **	7.03	9.76 **	-24.67 **	-23.94 **	-23.00 **	-23.87 **
GOA-8 × GO-6	-27.0	-27.74	-28.36	-27.71	-17.86	-15.79	-18.41	-17.36 **	-31.1	-26.26	-32.9	-30.1

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Phule Utkarsha × Phule Vimukta	-14.49	-14.97	-14.30 **	-14.59 **	24.53 **	18.31 **	21.73 **	21.52 **	-7.14 *	-5.90	-8.25 *	-7.10 *
Phule Utkarsha × AKOV-107	-16.84 **	-16.60 **	-16.85 **	-16.76 **	30.21 **	30.60 **	29.54 **	30.12 **	-12.10 **	-10.47 **	-14.77 **	-12.45 **
Phule Utkarsha × Konkan Bhendi	-17.02 **	-14.26 **	-12.49 **	-14.59 **	20.87 **	18.43 **	22.94 **	20.75 **	-6.57 *	-7.19 *	-6.46	-6.74 *
Phule Utkarsha × GJO-3	-6.02	-8.80	-7.45	-7.42	51.22 **	56.44 **	57.57 **	55.08 **	-4.94	-0.84	-4.64	-3.48
Phule Utkarsha × GO-6	-14.48	-14.40	-22.89	-17.25	16.81 **	17.16 **	15.22 **	16.40 **	-9.57 **	-7.45 *	-9.46 **	-8.83 **
Phule Vimukta × AKOV-107	-24.55	-22.70	-25.37	-24.21	-6.22	0.24	-11.15 *	-5.71	-30.59	-25.31	-31.36	-29.09
Phule Vimukta × Konkan Bhendi	-28.18	-23.93	-24.34	-25.48	-25.02 **	-16.59 **	-28.13 **	-23.25 **	-26.68	-25.20	-27.17	-26.35
Phule Vimukta × GJO-3	-17.85	-17.43	-18.11	-17.80 **	16.12 **	17.37 **	16.50 **	16.66 **	-24.98	-24.11	-28.77	-25.95
Phule Vimukta × GO-6	-25.40 **	-24.08	-26.91	-25.46 **	-10.36 **	-6.83	-7.82	-8.34 **	-27.96	-23.45	-33.61	-28.34
AKOV-107 × Konkan Bhendi	-25.50 **	-25.82 **	-23.94 **	-25.09 **	-8.79 *	-10.99 *	-8.70 *	-9.49 *	-26.28	-23.23	-27.15	-25.55
AKOV-107 × GJO-3	-12.03 **	-14.34 **	-9.75 **	-12.04 **	13.10 **	12.44 **	13.67 **	13.07 **	-27.59 **	-25.93 **	-35.55 **	-29.69 **
AKOV-107 × GO-6	-23.04 **	-23.77 **	-20.82 **	-22.54 **	-4.62	-5.50	-6.27	-5.47	-26.07	-27.77	-26.44	-26.76
Konkan Bhendi × GJO-3	-16.59 **	-14.52 **	-12.57 **	-14.56 **	17.59 **	16.84 **	14.83 **	16.42 **	-25.59	-24.82	-23.65	-24.69
Konkan Bhendi × GO-6	-22.02 **	-24.24 **	-22.88 **	-23.05 **	-17.25 **	-17.20 **	-17.50 **	-17.32 **	-25.78	-23.74	-25.23	-24.92
GJO-3 × GO-6	-18.90 **	-18.62 **	-17.58 **	-18.37 **	-7.05	-4.91	-4.68	-5.54	-22.13	-18.77	-21.75	-20.88

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

Table 3. Estimates of standard heterosis (%) for fruit diameter (cm), fruit weight (g) and days to edible maturity in okra under different environments

Hybrids	Fruit diameter (cm)				Fruit weight (g)				Days to edible maturity			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled
GOA-5 × GOA-8	-21.27 **	-23.24 **	-23.02 **	-22.51 **	18.86 **	14.97 **	22.42 **	18.75 **	-54.87	-54.81	-54.15	-54.61
GOA-5 × Phule Utkarsha	-12.74 **	-14.74 **	-16.01 **	-14.49 **	6.03	-13.58 **	-1.38	-2.98	-57.65	-57.87	-58.44	-57.99
GOA-5 × Phule Vimukta	-18.83 **	-21.91 **	-20.90 **	-20.55 **	23.72 **	23.19 **	23.85 **	23.59 **	-54.37	-55.54	-52.59	-54.17
GOA-5 × AKOV-107	0.00	-2.79	-10.05 *	-4.28	28.80 **	31.61 **	23.88 **	28.10 **	-52.21	-51.78	-54.48	-52.82
GOA-5 ×	-	-	-	-	6.03	7.84	7.46	7.11	-	-	-	-

Konkan Bhendi	22.09 **	20.45 **	23.94 **	22.16 **		*			57.35	56.64	56.93	56.97
GOA-5 × GJO-3	2.17	4.38	2.91	3.15	13.68 **	13.85 **	4.13	10.55 **	-53.55	-53.10	-55.30	-53.98
GOA-5 × GO-6	2.30	-3.45	-1.19	-0.78	6.37	7.47 *	5.30	6.38	-51.06 **	-51.17 **	-50.68 **	-50.97 **
GOA-8 × Phule Utkarsha	3.79	5.18	4.89	4.62	-7.97	-0.29	-8.62 *	-5.63	-54.08	-53.80	-54.35	-54.08
GOA-8 × Phule Vimukta	9.21 *	5.31	6.48	7.00 *	9.19 *	9.39 *	10.74 **	9.77 *	-52.70 *	-53.36	-52.73 *	-52.93
GOA-8 × AKOV-107	-7.45	-10.23 *	-10.58 *	-9.42	15.24 **	14.24 **	14.11 **	14.53 **	-51.99	-51.73 **	-53.19 **	-52.30 **
GOA-8 × Konkan Bhendi	5.83	6.77	2.78	5.13	-3.99	1.14	-1.19	-1.34	-53.65	-54.46	-55.40	-54.51
GOA-8 × GJO-3	-17.34 **	-18.86 **	-17.72 **	-17.98 **	9.91 *	11.93 **	2.60	8.15 *	-54.45 **	-54.54 **	-54.15 **	-54.38 **
GOA-8 × GO-6	1.76	-0.27	2.65	1.38	24.67 **	22.90 **	24.92 **	24.16 **	-52.80	-52.76	-52.51	-52.69
Phule Utkarsha × Phule Vimukta	-13.96 **	-15.41 **	-18.78 **	-16.05 **	18.01 **	16.72 **	19.67 **	18.13 **	-55.82 **	-55.98 **	-55.97 **	-55.92 **
Phule Utkarsha × AKOV-107	6.37	3.85	4.50	4.91	16.84 **	16.84 **	13.55 **	15.75 **	-56.33 **	-56.35 **	-51.03 **	-54.57 **
Phule Utkarsha × Konkan Bhendi	-16.26 **	-15.80 **	-18.12 **	-16.73 **	-6.15	-8.91 *	-5.15	-6.73	-59.02 **	-58.17 **	-58.11 **	-58.43 **
Phule Utkarsha × GJO-3	8.67 *	3.45	-3.97	2.72 *	18.49 **	19.23 **	18.85 **	18.86 **	-57.09 **	-58.95 **	-58.32 **	-58.12 **
Phule Utkarsha × GO-6	-4.34	-7.57	-5.69	-5.86	21.34 **	16.77 **	22.01 **	20.04 **	-52.55 **	-52.95 **	-58.43 **	-54.64 **
Phule Vimukta × AKOV-107	-5.69	-24.30 **	-6.35	-12.11	32.10 **	32.25 **	31.09 **	31.81 **	-52.83 **	-54.00 **	-52.69 **	-53.17 **
Phule Vimukta × Konkan Bhendi	-0.95	-5.84	3.57	-1.07	3.67	3.82	2.53	3.34	-54.04	-53.99	-53.49	-53.84
Phule Vimukta × GJO-3	0.14	-7.97	-1.59	-3.14	12.13 **	13.39 **	13.82 **	13.11 **	-50.67	-49.81	-51.72	-50.73
Phule Vimukta × GO-6	-2.85	-4.91	-4.50	-4.09	3.43	3.38	2.38	3.06	-55.66 **	-56.41 **	-54.46 **	-55.51 **
AKOV-107 × Konkan Bhendi	-9.35 *	-9.69 *	-12.17 **	-10.40 *	33.78 **	34.80 **	38.74 **	35.77 **	-56.85 **	-57.40 **	-56.37 **	-56.87 **
AKOV-107 × GJO-3	-13.01 **	-14.08 **	-11.90 **	-13.00 **	40.02 **	41.25 **	40.95 **	40.74 **	-51.13	-51.01	-51.40	-51.18
AKOV-107 × GO-6	-1.49	-2.66	-2.78	-2.31	12.59 **	3.46	12.82 **	9.62 **	-54.94 **	-54.73 **	-55.22 **	-54.96 **

Konkan Bhendi × GJO-3	7.86 *	6.91	6.88	7.21 *	20.70 **	25.55 **	21.40 **	22.55 **	-56.57 **	-58.55 **	-56.75 **	-57.29 **
Konkan Bhendi × GO-6	-12.20 **	-15.01 **	-13.62 **	-13.61 **	-4.71	-4.82	-5.95	-5.16	-52.17	-52.04	-51.75	-51.98
GJO-3 × GO-6	-13.14 **	-17.13 **	-15.21 **	-15.16 **	19.93 **	19.35 **	18.41 **	19.23 **	-55.62 **	-59.92 **	-56.59 **	-57.38 **

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

Table 4. Estimates of standard heterosis (%) for number of seeds per fruit and 100-seed weight (g) in okra under different environments

Hybrids	Number of seeds per fruit				100-seed weight (g)			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled
GOA-5 × GOA-8	-24.58 **	-26.92 **	-20.28 **	-23.92 **	-30.50	-36.23	-31.17	-32.63
GOA-5 × Phule Utkarsha	-32.91	-33.92	-29.69	-32.17	-19.89 **	-21.76 **	-18.53 **	-20.06 **
GOA-5 × Phule Vimukta	-28.64 **	-30.25 **	-28.42 **	-29.10 **	-28.59	-23.27	-32.40	-28.08
GOA-5 × AKOV-107	-20.14 **	-12.18 **	-17.88 **	-16.73 **	-19.01	-18.22	-19.40	-18.87
GOA-5 × Konkan Bhendi	-30.85	-30.61	-34.51	-31.99	-30.76	-29.93	-30.81	-30.50
GOA-5 × GJO-3	-18.05	-22.03	-17.92 **	-19.33 **	-15.23	-16.50	-22.67	-18.13
GOA-5 × GO-6	-30.54 **	-32.04 **	-28.64 **	-30.41 **	-16.78 **	-14.52 **	-17.81 **	-16.37 **
GOA-8 × Phule Utkarsha	-30.12	-29.04	-31.82	-30.32	-23.87 **	-22.28 **	-22.11 **	-22.75 **
GOA-8 × Phule Vimukta	-24.79 **	-23.00 **	-25.41 **	-24.40 **	-23.56	-22.59	-23.59	-23.25
GOA-8 × AKOV-107	-26.84	-24.67	-27.44	-26.32	-22.58	-20.15	-18.88	-20.54
GOA-8 × Konkan Bhendi	-32.39 **	-25.33 **	-28.70 **	-28.80 **	-22.73 **	-22.75 **	-22.52 **	-22.67 **
GOA-8 × GJO-3	-12.66 **	-14.89 **	-9.39 *	-12.31 **	-19.21 **	-18.27 **	-16.79 **	-18.09 **
GOA-8 × GO-6	-24.92 **	-24.51 **	-24.13 **	-24.52 **	-28.85	-26.97	-28.71	-28.17
Phule Utkarsha × Phule Vimukta	-28.20 **	-28.62 **	-28.77 **	-28.53 **	-18.54 **	-17.75 **	-19.55 **	-18.61 **
Phule Utkarsha × AKOV-107	-23.69 **	-24.14 **	-22.12 **	-23.32 **	-20.61	-18.84	-22.52	-20.66
Phule Utkarsha × Konkan Bhendi	-35.35	-39.08	-35.09	-36.51	-19.89 **	-20.87 **	-23.03 **	-21.26 **
Phule Utkarsha × GJO-3	-19.25 **	-19.25 **	-18.42 **	-18.97 **	-7.51	-8.07	-7.11	-7.56
Phule Utkarsha × GO-6	-28.62 **	-28.07 **	-27.83 **	-28.17 **	-23.67	-23.37	-25.18	-24.07
Phule Vimukta × AKOV-107	-19.10 **	-18.40 **	-18.81 **	-18.77 **	-20.35	-19.83	-21.65	-20.61
Phule Vimukta × Konkan Bhendi	-32.77	-34.36	-28.90	-32.01	-18.49 **	-19.05 **	-17.96 **	-18.50 **
Phule Vimukta × GJO-3	-20.12 **	-19.61 **	-20.55 **	-20.09 **	-7.46 **	-7.50	-8.75 **	-7.90 **
Phule Vimukta × GO-6	-29.99	-31.87	-29.51	-30.46	-17.97 **	-17.23 **	-17.25 **	-17.48 **
AKOV-107 × Konkan	-19.58	-20.09	-13.94	-17.87	-16.83	-17.33	-17.60	-17.26

Bhendi	**	**	**	**	**	**	**	**
AKOV-107 × GJO-3	-2.92	-0.73	-1.42	-1.69	-0.88	-5.36	-2.46	-2.90
AKOV-107 × GO-6	-31.00 **	-25.57 **	-42.50 **	-33.03 **	-16.16 **	-16.87 **	-12.23 **	-15.08 **
Konkan Bhendi × GJO-3	-10.51 **	-6.19 *	-10.39 **	-9.03 **	-16.83 **	-19.94 **	-15.56 **	-17.44 **
Konkan Bhendi × GO-6	-33.46 **	-30.21 **	-36.78 **	-33.48 **	-20.56 **	-21.45 **	-21.24 **	-21.08 **
GJO-3 × GO-6	-13.24 **	-12.56 **	-17.34 **	-14.38 **	-15.85 **	-13.07 **	-19.86 **	-16.26 **

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