



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(6): 839-845
Received: 02-04-2026
Accepted: 08-05-2026

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Evaluation of Okra [*Abelmoschus esculentus* (L.) Moench] Hybrids for fruit yield and yield attributing traits during Kharif Season

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6k.5794>

Abstract

Twenty-four okra [*Abelmoschus esculentus* (L.) Moench] hybrids, including one standard check hybrid, were evaluated in a randomized block design with three replications during the Kharif 2025 at CSAUA&T, Kanpur, Uttar Pradesh, to analyse genetic variability, correlation, path coefficient and genetic divergence for yield and yield-related traits. Considerable variations among hybrids were observed for all characters studied which showed the presence of significant genetic variability. Phenotypic coefficient of variation was higher than genotypic coefficient of variation for all traits, indicating environmental influence. Heritability was high for fruit yield per hectare, fruit yield per plant and number of fruits per plant. Similarly, traits like number of productive branches per plant, fruit yield per plant and fruit yield per hectare, showed high genetic advance, indicating the predominance of additive gene action. Correlation analysis revealed that fruit yield per plant exhibited strong positive association with number of fruits per plant, average fruit weight, and fruit length. Negative association of yield with days to flowering indicated that early flowering genotypes are more productive. Path analysis indicated that number of fruits per plant exerted the highest positive direct effect followed by average fruit weight, indicating their major contribution to yield. Cluster analysis divided the hybrids into five distinct clusters; Cluster III and Cluster V recorded the highest fruit yield per plant. Maximum inter-cluster distance was observed between Cluster I and Cluster V, indicating high genetic divergence. On the basis of overall performance, okra hybrids 2025/OKYVELHYBRES-11, 2025/OKYVELHYBRES-3 and 2024/OKYVELHYBRES-4 may be recommended for commercial cultivation in the Central Plain Zone of Uttar Pradesh.

Keywords: Okra, genetic variability, heritability, correlation, path analysis, yield, cluster analysis, genetic divergence

1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench], often referred to as bhindi or lady's finger, is a significant vegetable crop that is extensively grown in tropical and subtropical regions of the world. It is one of the most significant warm-season fruit vegetable, growing in both the spring (Zaid) and rainy (Kharif) seasons. With a chromosomal number of $2n = 130$, it is an amphidiploid and a significant vegetable crop in the Malvaceae family (Sheferie *et al.*, 2023) ^[1]. The succulent green pods of these herbaceous annual plants are used as a versatile vegetable in a variety of culinary dishes (Awasthi *et al.*, 2022) ^[2]. Okra, like its related wild species, is remarkably adaptable to changing environmental conditions. Several economically significant okra species have been identified, including *Abelmoschus manihot*, *A. tuberculatus*, *A. moschatus*, *A. ficulneus*, *A. crinitus*, *A. angulosus*, and *A. caillei*. Okra's geographic origin has been debated, with some claiming it is from South Asia and others claiming it is from Ethiopia or West Africa. The crop has significant morphological and genetic variability, resulting in a wide range of cultivars that varies in plant height, branching patterns, and pod properties, like shape, size, & diameter (AdeOluwa & Kehinde, 2011) ^[3]. Globally, okra is cultivated in numerous agro-ecological zones, with India, Nigeria, and Sudan being the primary producers (Kumar *et al.*, 2019) ^[4]. In world okra production, with a total annual production of about 11.52 million tonnes from an area of 2.92 million hectares and an average productivity of 3.95 tonnes per hectare (FAOSTAT, 2023) ^[5]. While okra output has continuously increased, the average productivity remains rather low,

particularly in underdeveloped countries. In India, okra is cultivated on approximately 557 thousand hectares of land, yielding around 7,305.41 thousand tonnes, with an average productivity of 13.12 tonnes per hectare. Okra is predominantly cultivated in the Indian states such as West Bengal, Gujarat, Bihar, Odisha, Jharkhand, Madhya Pradesh, Uttar Pradesh, Chhattisgarh, Andhra Pradesh, Haryana, Assam, and Tamil Nadu (Chaukhande *et al.*, 2011) ^[6]. Okra is a valuable crop valued for both its nutritional benefits and its industrial applications, consequently improving food security, nutrition, and economic growth in many nations (Sharma *et al.*, 2016) ^[7]. Its pods contain a large number of essential vitamins, minerals, and dietary fiber, making it an indispensable component of the human diet (Sharma *et al.*, 2020) ^[8]. The composition of okra fruit includes a high-water content (88%), carbohydrates (8%), protein (2.1%), fat (0.2%), fiber (1.7%), and ash (0.2%) per 100 g of edible portion (Kartina *et al.*, 2019) ^[9]. Okra fruits have high levels of thiamine, riboflavin, and ascorbic acid. Furthermore, okra has several therapeutic properties, including anti-inflammatory, antioxidant, and anti-diabetic benefits. It is also utilised to treat peptic ulcers and provide plasma replacement in human body fluids (Elkhalifa *et al.*, 2021) ^[10]. Okra seeds are also high in minerals including iron (Fe), potassium (K), and magnesium (Mg), as well as vitamins A, B, C, and K, folates, and antioxidants like xanthin and lutein etc. Genetic improvement plays an important role in increasing okra productivity and quality, with an emphasis on qualities such as yield potential, disease resistance, insect pest resistance, and nutritional content (Kumar *et al.*, 2019) ^[4]. Before starting any crop improvement programme, analysing the variation existing in the available materials is the need of an hour. Genetic studies, such as the assessment of genetic variability, heritability, and genetic advance, provide useful insights into the inheritance patterns of desirable traits and help to select an adequate breeding program. Genetic parameters, such as the genetic coefficient of variation, heritability, and genetic advance,

of horticultural and yield-related traits are thus critical for enhancing okra productivity and quality. Furthermore, studying the correlation among different characters and yield helps to identify potential traits for conducting selection or to provide greater emphasis during the selection of germplasm accessions. Furthermore, correlating more than one variable with yield may pose problems in selecting the most promising trait. In this context, path analysis helps to identify the direct and indirect contributions of various morphological and horticultural traits to yield. Keeping these aspects in mind, the current study was conducted to assess the genetic diversity, character association, path coefficients, and genetic divergence of 24 okra hybrids grown under the agro-climatic conditions of CSAUA&T, Kanpur, Uttar Pradesh. The objective of this study was to identify key selection traits and superior okra hybrids suitable for commercial cultivation under the agro-climatic conditions of Uttar Pradesh.

2. Materials and Methods

The present investigation was conducted at the Vegetable Research Farm (VRF), Department of Vegetable Science, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology (CSAUA&T), Kanpur, Uttar Pradesh during the Kharif season 2025. Kanpur is located in the upper Indo-Gangetic plain of India and is a part of the central region of Uttar Pradesh. With an elevation of roughly 125.9 meters above mean sea level, the precise geographic coordinates are 26°29'35' N latitude and 80°16'25' E longitude. It is located on the right bank of the sacred river Ganga and forms a part of the upper Indo-Gangetic plain region of India. The research material for this study comprised of 24 different okra hybrids (*Abelmoschus esculentus* L. Moench), sourced from ICAR- Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh. Since the hybrids are under evaluation and not yet released for commercial cultivation, they were identified using coded designations. The details of genotypes and their source of collection are given in the Table. 1.

Table 1: Details of experimental materials used in the present study

S. No.	Treatment	Okra Hybrids	Source
1.	H1	2025/OKYVELHYBRES-1	ICAR-IIVR, Varanasi, U.P.
2.	H2	2025/OKYVELHYBRES-2	ICAR-IIVR, Varanasi, U.P.
3.	H3	2025/OKYVELHYBRES-3	ICAR-IIVR, Varanasi, U.P.
4.	H4	2025/OKYVELHYBRES-4	ICAR-IIVR, Varanasi, U.P.
5.	H5	2025/OKYVELHYBRES-6	ICAR-IIVR, Varanasi, U.P.
6.	H6	2025/OKYVELHYBRES-7	ICAR-IIVR, Varanasi, U.P.
7.	H7	2025/OKYVELHYBRES-8	ICAR-IIVR, Varanasi, U.P.
8.	H8	2025/OKYVELHYBRES-9	ICAR-IIVR, Varanasi, U.P.
9.	H9	2025/OKYVELHYBRES-10	ICAR-IIVR, Varanasi, U.P.
10.	H10	2025/OKYVELHYBRES-11	ICAR-IIVR, Varanasi, U.P.
11.	H11	2025/OKYVELHYBRES-12	ICAR-IIVR, Varanasi, U.P.
12.	H12	AZAD HYBRID-1 (Check)	CSAUA&T, Kanpur, U.P.
13.	H13	2024/OKYVELHYBRES-1	ICAR-IIVR, Varanasi, U.P.
14.	H14	2024/OKYVELHYBRES-2	ICAR-IIVR, Varanasi, U.P.
15.	H15	2024/OKYVELHYBRES-3	ICAR-IIVR, Varanasi, U.P.
16.	H16	2024/OKYVELHYBRES-4	ICAR-IIVR, Varanasi, U.P.
17.	H17	2024/OKYVELHYBRES-5	ICAR-IIVR, Varanasi, U.P.
18.	H18	2024/OKYVELHYBRES-6	ICAR-IIVR, Varanasi, U.P.
19.	H19	2024/OKYVELHYBRES-7	ICAR-IIVR, Varanasi, U.P.
20.	H20	2024/OKYVELHYBRES-8	ICAR-IIVR, Varanasi, U.P.
21.	H21	2024/OKYVELHYBRES-9	ICAR-IIVR, Varanasi, U.P.
22.	H22	2024/OKYVELHYBRES-10	ICAR-IIVR, Varanasi, U.P.
23.	H23	2024/OKYVELHYBRES-11	ICAR-IIVR, Varanasi, U.P.
24.	H24	2024/OKYVELHYBRES-12	ICAR-IIVR, Varanasi, U.P.

The experiment was set up in a randomized block design with three replications and spacing of 60 × 30 cm between line to line

and plant to plant. Seeds were sown on 22 July 2025 at 2pm on the field by direct hand sowing. A recommended fertilizer dose of

FYM @25 tonnes per hectare and N: P₂O₅: K₂O @100:80:80 kg per hectare was given to the crop in two split doses. Observations were taken for eighteen quantitative traits such as plant height (cm) at 45 DAS & 90 DAS, stem diameter at 10 cm above the ground level (cm), stem node number at which first flower open, number of productive branches per plant, days to 50% flowering, days to first fruit initiation, leaf blade sinus depth (cm), leaf blade length (cm), leaf blade width (cm), number of locules per fruit, days to first picking, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruit per plant, fruit yield per plant (g) and fruit yield per hectare (quintal). Data was collected from three randomly selected plants within each plot that were averaged and used for statistical analysis, with the exception of yield traits which were recorded on plot basis. Analysis of variance (ANOVA) was performed to determine the significance of differences among twenty-four okra hybrids based on the linear model of a randomized block design as outlined by Panse & Sukhatme ^[11]. The extent of variability present in the

experimental material was assessed through estimation of phenotypic and genotypic coefficients of variation. Broad-sense heritability and genetic advance expressed as percentage of mean were calculated to evaluate the transmissibility and expected genetic gain of different traits using the methods proposed by Burton, 1953 ^[13]. The association among yield and its component characters was studied through correlation coefficient analysis as described by Johnson, 1955 ^[14]. Path coefficient analysis was employed to partition the correlation coefficients into direct and indirect effects of component traits on grain yield following the methodology of Dewey, 1959 ^[15]. Genetic divergence among the okra hybrids was estimated using Mahalanobis D² statistics, and the hybrids were grouped into clusters based on the degree of genetic divergence.

3. Results and Discussion

3.1. Analysis of Variance (ANOVA)

Table 2: Analysis of Variance of randomized block design for 18 characters in 24 genotypes of okra hybrids

Character	Replication (df = 2)	Treatment (df = 23)	Error (df = 46)	Total (df = 71)
Plant height (cm) (45 DAS)	0.98	31.93**	7.53	15.25
Plant height (cm) (90 DAS)	13.96	343.80**	12.22	119.68
Stem diameter at 10cm above the ground level (cm)	0.001	0.060**	0.006	0.023
Stem node no. at which first flower open	0.097	0.563**	0.125	0.266
No. of productive branches per plant	0.075	1.662**	0.058	0.578
Days to 50% flowering	0.06	10.58**	0.60	3.82
Days to first fruit initiation	0.35	10.48**	1.07	4.10
Leaf blade sinus depth of terminal lobe (cm)	0.78	9.01**	0.23	3.09
Leaf blade length (cm)	4.42	12.94**	0.26	4.48
Leaf blade width (cm)	2.12	10.13**	0.36	3.57
No. of locules per fruit	0.059	0.236**	0.056	0.114
Days to first picking	3.60	11.72**	1.73	5.02
Fruit length (cm)	3.31	3.14**	0.36	1.35
Fruit diameter (cm)	0.0010	0.0304**	0.0078	0.0149
Average fruit weight (g)	0.32	3.94**	0.29	1.47
No. of fruits per plant	5.60	44.35**	1.47	15.47
Fruit yield per plant (g)	205.92	12798.36**	128.70	4235.13
Fruit yield per hectare (q/ha)	20.34	3865.35**	20.37	1265.93

** Significant at 1% level of significance.

ANOVA for the randomized block design for twenty-four okra hybrids revealed highly significant differences ($p < 0.01$) among genotypes for all 18 quantitative traits as shown in Table 2. Additionally, the mean square due to blocks were significant for most traits, indicating that environmental heterogeneity among the plots was sizeable and was effectively overcome through replication. The variation with the check variety further established differential performance under Uttar Pradesh agro-climatic condition. Collectively, the results show significant genetic variation among okra hybrids, thus suitable for breeding programme. Similar findings were also reported by Faizan *et al.* (2023) ^[17] and Ranjani *et al.* (2019) ^[18].

3.2. Mean Performance of Genotypes

Substantial variability was observed across all traits when mean performance was analysed for twenty-four okra hybrids, including one standard check Table 3. The plant height at 45 DAS varied from 47.30cm (H10) to 59.97cm (H17) with the mean value of 53.34cm while plant height at 90 DAS varied from 72.97cm (H22) to 111.93 cm (H1) with the mean value of 93.87cm. Taller genotypes help in producing more vegetative biomass, whereas dwarf genotypes are preferred for lodging resistance. The stem diameter ranged from 1.41 cm (H10) to

1.89cm (H16) with the mean value of 1.63 cm. The node number at which first flower appeared ranged from 4.0 (H3) to 5.78 (H11 & H23) with an average of 5.15. Hybrids exhibiting a lower first flower node like H3 indicates strong physiological earliness. Days to 50% flowering ranged from 33.47 days (H3) to 40.30 days (H22), with the mean value of 36.95 days. Days to first fruit picking varied from 41.67 days (H13 & H15) to 48.67 days (H22 & H24), averaging 44.76 days. The number of fruits per plant ranged from 15 (H11) to 28.67 in (H16) with an average of 21.93 fruits per plant. Highly prolific lines like H16, H10, and H4 have a direct impact on total yield. Fruit length in okra ranged between 9.67cm (H14) and 13.33 cm (H6), with a mean of 11.86cm. Genotypes like H6 and H20 had long fruits, which is a key trait preferred by commercial consumers. Average single fruit weight varied from 11.67 g (H14) to 16.23 g (H13), averaging 14.58 g. Fruit yield per plant varied from 192.23 g (H22) to 397.67 g (H3), while its average was 318.24 g. Fruit yield per hectare ranged between 105.83 q/ha (H22) and 226.30 q/ha (H10), with an average of 178.12 q/ha. The top yielding hybrids were H10 (2025/OKYVELHYBRES-11), H3 (2025/OKYVELHYBRES-3), and H16 (2024/OKYVELHYBRES-4), all significantly outperformed the standard check hybrid H12 (Azad Hybrid-1, 153.70 q/ha), showing their potential for commercial cultivation.

3.3. Genetic Variability Parameters: PCV, GCV, Heritability and Genetic Advance

Various estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h^2 bs), and genetic advance as percentage of mean (GA%) for the observed 18 quantitative traits are being shown in Table 3. The estimates of genetic parameters revealed considerable variability among the studied traits. In general, the phenotypic coefficient of variation (PCV) was slightly higher than the corresponding genotypic coefficient of variation (GCV) for all characters, indicating a limited influence of environmental factors

on trait expression. High GCV and PCV values were observed for number of productive branches per plant (32.70% and 34.43%, respectively), fruit yield per plant (20.42% and 20.73%), fruit yield per hectare (20.10% and 20.26%) and number of fruits per plant (17.24% and 18.10%), suggesting the presence of substantial genetic variability for these traits. High heritability estimates were recorded for fruit yield per hectare (98.44%), fruit yield per plant (97.04%), leaf blade length (94.22%), leaf blade sinus depth of terminal lobe (92.83%), number of fruits per plant (90.69%), number of productive branches per plant (90.21%), leaf blade width (90.15%) and plant height at 90 DAS (90.05%).

Table 3: Estimates of range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance as% of mean, and their percent contribution

Characters	Mean	Min.	Max.	Heritability (%)	GA% mean	GCV (%)	PCV (%)	% Contribution
Plant Height (cm) (45 DAS)	53.34	47.30	59.97	51.90	7.93	5.35	7.42	7.80
Plant Height (cm) (90 DAS)	93.87	72.97	111.93	90.05	21.89	11.20	11.80	4.81
Stem diameter at 10 cm above ground level (cm) (60 DAS)	1.63	1.41	1.89	75.14	14.71	8.24	9.50	6.80
Stem node no. at which first flower open (45 DAS)	5.15	4.00	5.78	53.77	11.20	7.42	10.11	7.15
No. of Productive Branches per plant	2.24	1.11	3.78	90.21	63.98	32.70	34.43	5.06
Days to 50% flowering with at least one flower open	36.95	33.47	40.30	84.74	9.36	4.94	5.36	5.38
Days to first fruit initiation	44.76	41.67	48.67	74.52	7.03	3.96	4.58	6.29
Leaf blade sinus depth of terminal lobe (cm)	13.92	11.33	16.73	92.83	24.40	12.30	12.76	4.05
Leaf blade length (cm)	18.02	13.20	20.77	94.22	22.81	11.41	11.75	4.17
Leaf blade width (cm)	22.17	18.00	25.17	90.15	15.92	8.14	8.57	5.08
No. of locules per fruit	5.41	5.00	5.89	51.99	6.74	4.54	6.29	7.33
Days to first picking	48.90	46.33	52.67	65.86	6.24	3.73	4.60	6.40
Fruit length (cm)	11.86	9.67	13.33	72.00	14.20	8.12	9.57	6.13
Fruit diameter (cm)	1.62	1.43	1.81	49.29	7.75	5.36	7.63	7.49
Average fruit weight (gram)	14.58	11.67	16.23	80.64	13.99	7.56	8.42	5.52
No. of fruits per plant	21.93	15.00	28.67	90.69	33.82	17.24	18.10	3.18
Fruit yield per plant (gram)	318.24	192.23	397.67	97.04	41.44	20.42	20.73	5.51
Fruit yield per hectare (q/ha)	178.12	105.83	226.30	98.44	41.08	20.10	20.26	1.85

High heritability coupled with high genetic advance as per cent of mean was observed for number of productive branches per plant, fruit yield per plant, fruit yield per hectare and number of fruits per plant, indicating the predominance of additive gene action and suggesting that these traits can be effectively improved through direct selection. Comparable findings have also been reported by Sravanthi *et al.* (2021) ^[19], Rana *et al.* (2020) ^[20] and Reddy *et al.* (2022) ^[21].

3.4. Correlation Coefficient Analysis

The phenotypic correlation coefficient analysis is presented in Table 4. Phenotypic correlation analysis revealed that fruit yield per plant exhibited highly significant and positive association with number of fruits per plant (0.913**), average fruit weight (0.575**), fruit length (0.523**), number of productive branches per plant (0.415**) and fruit diameter (0.315*). Fruit yield per hectare also showed highly significant positive correlation with fruit yield per plant (0.978**), number of fruits per plant (0.902**), average fruit weight (0.563**), fruit length (0.522**), number of productive branches per plant (0.425**) and fruit diameter (0.335**). The strong positive association of fruit yield with number of fruits per plant and average fruit weight indicated that these traits are the major determinants of yield and can be effectively utilized as selection criteria in okra improvement programmes. Conversely, days to 50% flowering exhibited a significant negative correlation with average fruit weight (-0.303*), fruit yield per plant (-0.285*) and fruit yield per hectare (-0.260*), suggesting that delayed flowering may adversely affect yield performance. In general, the genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients, indicating the presence of strong inherent genetic associations among different traits which were partially

masked at the phenotypic level due to environmental influence. This suggested that selection based on phenotypic performance would be effective, although the actual genetic relationships among the traits were more pronounced at the genotypic level. Comparable findings have also been reported by Muluken *et al.* (2016) ^[22], Raval *et al.* (2018) ^[23] and Kumar *et al.* (2024) ^[24].

3.5. Path Coefficient Analysis

The phenotypic path coefficient analysis for different characters on fruit yield per plant are presented in Tables 5. Phenotypic path coefficient analysis revealed that the number of fruits per plant (0.8790), average fruit weight (0.4315), days to first fruit initiation (0.0283), stem diameter (0.0061), number of locules per fruit (0.0042) and leaf blade diameter (0.0036) exerted positive direct effects on fruit yield per plant. Among these traits, number of fruits per plant and average fruit weight exhibited the highest positive direct effects, indicating their major contribution towards fruit yield. Fruit yield per plant also showed significant positive association with fruit yield per hectare (0.978**), number of fruits per plant (0.913**), average fruit weight (0.575**), fruit length (0.523**), number of productive branches (0.415**) and fruit diameter (0.315**). Therefore, these traits may be considered as important selection criteria for the improvement of fruit yield in okra. The low residual effect (0.00272) indicated that the traits included in the study accounted for most of the variability in fruit yield per plant. In general, the genotypic path coefficients were higher than the corresponding phenotypic path coefficients, indicating the presence of strong inherent genetic association among the characters, though their expression was partly influenced by environmental factors at the phenotypic level. Similar findings were also reported earlier by Kumar *et al.* (2024) ^[24], Saroj *et al.* (2025) ^[25] and Bagwale *et al.* (2016) ^[26].

Table 4: Estimates of phenotypic correlation coefficients among different traits in okra hybrids

Traits	PH45	PH90	SD	SNFF	NPB	D50F	DFFI	LBD	LBL	LBW	NLF	DFP	FL	FD	AFW	NFP	FYP	FYH
PH45	1.000	0.478**	0.243*	0.192	-0.141	-0.009	-0.183	-0.142	-0.038	0.040	0.258*	-0.051	-0.137	-0.011	0.102	-0.256*	-0.186	-0.211
PH90			0.355**	0.013	-0.175	-0.190	-0.124	-0.133	-0.037	0.170	0.001	-0.087	-0.141	0.071	0.017	-0.066	-0.058	-0.061
SD				0.104	-0.099	0.055	0.112	0.047	-0.042	0.017	0.054	0.021	-0.005	-0.008	0.082	0.075	0.100	0.076
SNFF					0.209	0.316**	-0.089	0.159	0.228	0.307**	0.019	0.011	0.139	0.174	-0.103	-0.039	-0.086	-0.086
NPB						0.064	-0.054	0.428**	0.319**	0.267*	-0.228	0.270*	0.287*	0.310**	-0.017	0.524**	0.415**	0.425**
D50F							0.324**	0.084	-0.080	-0.137	-0.164	-0.034	-0.182	-0.108	-0.303**	-0.190	-0.285*	-0.260*
DFFI								-0.157	-0.252*	-0.183	-0.114	0.183	-0.076	-0.182	-0.174	-0.176	-0.191	-0.218
LBD									0.600**	0.603**	0.244*	0.158	0.330**	0.321**	-0.044	0.247*	0.179	0.182
LBL										0.532**	0.151	0.165	0.235*	0.205	-0.029	0.181	0.121	0.150
LBW											0.292*	0.107	0.308**	0.242*	0.053	0.272*	0.239*	0.230
NLF												-0.011	0.104	-0.019	-0.007	-0.073	-0.058	-0.114
DFP													0.392**	0.123	0.124	-0.050	-0.001	-0.006
FL														0.532**	0.463**	0.403**	0.523**	0.522**
FD															0.166	0.309**	0.315**	0.335**
AFW																0.201	0.575**	0.563**
NFP																	0.913**	0.902**
FYP																		0.978**
FYH																		1.000

PH45: Plant height at 45 DAS, PH90: Plant height at 90 DAS, SD: Stem diameter at 10 cm above the ground level, SNFF: Stem node number at which first flower opened, NPB: Number of productive branches per plant, D50F: Days to 50% flowering with atleast one flower open, DFFI: Days to first fruit initiation, LBD: Leaf blade sinus depth of terminal lobe, LBL: Leaf blade length, LBW: Leaf blade width, NLF: Number of locules per fruit, DFP: Days to first picking, FL: Fruit length, FD: Fruit diameter, AFW: Average fruit weight, NFP: Number of fruits per plant, FYP: Fruit yield per plant, FYH: Fruit yield per hectare (in quintals).

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

Table 5: Phenotypic path coefficient analysis showing direct and indirect effects of different traits on fruit yield per plant in okra

Traits	PH45	PH90	SD	SNFF	NPB	D50F	DFFI	LBD	LBL	LBW	NLF	DFP	FL	FD	AFW	NFP	FYH	FYP
PH45	-0.0116	-0.0037	0.0015	-0.0002	0.0011	0.0001	-0.0052	-0.0005	0.0004	0.0000	0.0011	0.0009	-0.0012	0.0000	0.0439	-0.2250	0.0122	-0.186
PH90	-0.0055	-0.0078	0.0022	0.0000	0.0014	0.0024	-0.0035	-0.0005	0.0004	0.0001	0.0000	0.0016	-0.0013	-0.0003	0.0072	-0.0578	0.0035	-0.058
SD	-0.0028	-0.0028	0.0061	-0.0001	0.0008	-0.0007	0.0032	0.0002	0.0004	0.0000	0.0002	-0.0004	0.0000	0.0000	0.0353	0.0655	-0.0044	0.100
SNFF	-0.0022	-0.0001	0.0006	-0.0012	-0.0017	-0.0040	-0.0025	0.0006	-0.0022	0.0002	0.0001	-0.0002	0.0012	-0.0006	-0.0446	-0.0347	0.0050	-0.086
NPB	0.0016	0.0014	-0.0006	-0.0003	-0.0081	-0.0008	-0.0015	0.0016	-0.0031	0.0001	-0.0010	-0.0049	0.0026	-0.0011	-0.0075	0.4608	-0.0247	0.415**
D50F	0.0001	0.0015	0.0003	-0.0004	-0.0005	-0.0127	0.0092	0.0003	0.0008	-0.0001	-0.0007	0.0006	-0.0016	0.0004	-0.1307	-0.1670	0.0151	-0.285*
DFFI	0.0021	0.0010	0.0007	0.0001	0.0004	-0.0041	0.0283	-0.0006	0.0024	-0.0001	-0.0005	-0.0033	-0.0007	0.0007	-0.0751	-0.1548	0.0127	-0.191
LBD	0.0017	0.0010	0.0003	-0.0002	-0.0035	-0.0011	-0.0045	0.0036	-0.0058	0.0003	0.0010	-0.0029	0.0030	-0.0012	-0.0188	0.2168	-0.0106	0.179
LBL	0.0004	0.0003	-0.0003	-0.0003	-0.0026	0.0010	-0.0072	0.0022	-0.0096	0.0003	0.0006	-0.0030	0.0021	-0.0007	-0.0127	0.1593	-0.0087	0.121
LBW	-0.0005	-0.0013	0.0001	-0.0004	-0.0022	0.0017	-0.0052	0.0022	-0.0051	0.0005	0.0012	-0.0019	0.0028	-0.0009	0.0227	0.2390	-0.0134	0.239*
NLF	-0.0030	0.0000	0.0003	0.0000	0.0018	0.0021	-0.0032	0.0009	-0.0015	0.0001	0.0042	0.0002	0.0009	0.0001	-0.0031	-0.0641	0.0066	-0.058
DFP	0.0006	0.0007	0.0001	0.0000	-0.0022	0.0004	0.0052	0.0006	-0.0016	0.0001	-0.0001	-0.0181	0.0035	-0.0004	0.0534	-0.0439	0.0003	-0.001
FL	0.0016	0.0011	0.0000	-0.0002	-0.0023	0.0023	-0.0022	0.0012	-0.0023	0.0002	0.0004	-0.0071	0.0090	-0.0019	0.1997	0.3539	-0.0303	0.523**
FD	0.0001	-0.0006	-0.0001	-0.0002	-0.0025	0.0014	-0.0052	0.0012	-0.0020	0.0001	-0.0001	-0.0022	0.0048	-0.0036	0.0715	0.2718	-0.0195	0.315**
AFW	-0.0012	-0.0001	0.0005	0.0001	0.0001	0.0039	-0.0049	-0.0002	0.0003	0.0000	0.0000	-0.0022	0.0041	-0.0006	0.4315	0.1767	-0.0327	0.575**
NFP	0.0030	0.0005	0.0005	0.0001	-0.0042	0.0024	-0.0050	0.0009	-0.0018	0.0001	-0.0003	0.0009	0.0036	-0.0011	0.0868	0.8790	-0.0524	0.913**
FYH	0.0024	0.0005	0.0005	0.0001	-0.0034	0.0033	-0.0062	0.0007	-0.0015	0.0001	-0.0005	0.0001	0.0047	-0.0012	0.2428	0.7932	-0.0580	0.978**

PH45: Plant height at 45 DAS, PH90: Plant height at 90 DAS, SD: Stem diameter at 10 cm above the ground level, SNFF: Stem node number at which first flower opened, NPB: Number of productive branches per plant, D50F: Days to 50% flowering with atleast one flower open, DFFI: Days to first fruit initiation, LBD: Leaf blade sinus depth of terminal lobe, LBL: Leaf blade length, LBW: Leaf blade width, NLF: Number of locules per fruit, DFP: Days to first picking, FL: Fruit length, FD: Fruit diameter, AFW: Average fruit weight, NFP: Number of fruits per plant, FYP: Fruit yield per plant, FYH: Fruit yield per hectare (in quintals).

Residual- 0.00272

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

3.6. Genetic Divergence Analysis

Based on multivariate analysis, the genotypes were grouped into five distinct clusters, indicating the presence of considerable genetic diversity among the hybrids studied. Among the five clusters, Cluster V contained the maximum number of genotypes (8), followed by Cluster III with 6 genotypes. Cluster II and Cluster IV each consisted of 4 genotypes, whereas Cluster I contained the minimum number of genotypes (2). The inter-cluster distance values among different clusters are presented in Table 6. The maximum inter-cluster distance was observed

between Cluster I and Cluster V (6.953), followed by Cluster I and Cluster III (6.387) and Cluster I and Cluster IV (6.302), indicating the presence of high genetic divergence among the genotypes grouped in these clusters. The minimum inter-cluster distance was observed between Cluster III and Cluster V (3.287), followed by Cluster II and Cluster IV (3.353), indicating relatively close genetic relationship among the genotypes present in these clusters. Comparable findings were also reported earlier by Rana *et al.* (2020) [20], Muluken *et al.* (2016) [22] and Raval *et al.* (2018) [23].

Table 6: Estimates of average inter-cluster distances for five clusters in okra hybrids

Clusters	I	II	III	IV	V
I	2.817				
II	5.033	2.992			
III	6.387	4.378	2.968		
IV	6.302	3.353	3.879	2.957	
V	6.953	4.684	3.287	3.998	3.284

4. Conclusion

A significant genetic variation among the okra hybrids exists for many morphological and yield-attributing variables. High genetic advance and high heritability for significant yield-contributing variables demonstrated the efficacy of selection for these traits' development. The number of fruits per plant and average fruit weight were found to be the most significant characteristics influencing fruit output; as a result, they may be regarded as a trustworthy selection criterion in okra breeding programs. The presence of sufficient diversity among the hybrids indicated the potential use of genetically diverse parents in developing these hybrids. Okra hybrids viz., 2025/OKYVELHYBRES-11, 2025/OKYVELHYBRES-3, and 2024/OKYVELHYBRES-4 were found to be superior genotypes in terms of fruit yield and yield-contributing traits based on overall performance. Above mentioned hybrids outperformed the check hybrid (Azad Hybrid-1) by more than 40% in terms of fruit yield. hence, these three hybrids may be recommended for commercial cultivation in the Central Plain Zone of Uttar Pradesh.

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