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Research Article

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Study of the variability and association of the different agronomic traits in segregating population of okra (*Abelmoschus esculentus* L. Moench) for yield and its contributing traits

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ABSTRACT
The experiment on variability and correlation studies in okra (*Abelmoschus esculentus* L. Moench) was carried out at the Department of Biotechnology and Crop Improvement (BCI), College of Horticulture, Bengaluru, Karnataka during the *Kharif* 2024. High heritability coupled with high genetic advance was observed for plant height, number of branches, stem girth, fruit diameter and yield per plant, indicating additive gene action. Traits such as fruit length, internodal length and number of nodes also showed high variability, suggesting ample scope for improvement through simple selection. The correlation analysis of the F_3 okra population revealed significant relationships among yield and its components. Total yield per plant (TYPP) showed strong positive correlations with fruit length (r = 0.876*), fruit diameter (r = 0.906**), average fruit weight (r = 0.804**), number of branches per plant (r = 0.687**) and days to first flowering (negative, r = -0.749**). Fruit diameter (FD) was highly positively associated with fruit length (r = 0.754**) and average fruit weight (r = 0.606**), while internodal length (IL) showed strong negative correlation with fruit diameter (r = -0.677**) and total yield (r = -0.705**). These correlations indicate that selection for higher fruit size and branching could directly improve yield, whereas longer internodes and delayed flowering might reduce productivity. The path coefficient analysis of the F_3 okra population revealed the direct and indirect effects of various traits on total yield per plant (TYPP). Total yield (TYPP) was most strongly influenced directly by fruit diameter (FD, 0.906), fruit length (FL, 0.876), average fruit weight (AFW, 0.804) and number of branches per plant (NBPP, 0.687). Days to first flowering (DFF) and internodal length (IL) had strong negative direct effects on yield (-0.749 and -0.705, respectively). Other traits, such as plant height (PH), stem girth (SG), number of fruits per plant (NFPP) and number of seeds per fruit (NSF), showed moderate to low direct effects on yield.
Keywords: Okra; Genetic variability; Heritability; Correlation coefficient; Path analysis; Yield components

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a crucial vegetable crop in tropical and subtropical regions, valued for its nutritious fruits and adaptability to diverse growing conditions. Improving okra yield is of paramount importance for meeting global food demands and enhancing agricultural productivity. Understanding the relationships between yield and various agronomic traits through correlation and path coefficient analysis provides critical insights for developing high-yielding okra varieties. The study of the correlation coefficient among various economic traits of crop plants is very important for assessing the degree of association among characters. In plant breeding programs, these studies are important. Galton (1889) first gave the concept of correlation and later Fisher (1918) elaborated. Path coefficient analysis provides a more detailed view by partitioning the total correlation into direct and indirect effects. Dewey and Lu (1959) first used the technique for plant selection. It measures the interrelationships of major yield contributing characters with yield and amongst them their direct and indirect effects on yield for making the selection more effective.

Combining correlation and path coefficient analyses enables a comprehensive understanding of trait interactions and their implications for yield. By identifying traits with both strong correlations and significant direct effects on yield, breeders can focus on selecting these traits to enhance overall productivity. This integrated approach is particularly valuable in okra breeding, where optimizing yield requires balancing various agronomic characteristics.

MATERIALS AND METHODS

The experiment on variability and correlation studies in okra (*Abelmoschus esculentus* L. Moench) was carried out at the Department of Biotechnology and Crop Improvement (BCI), College of Horticulture, Bengaluru, Karnataka, during the *Kharif* 2024. The experimental material consisted of F_3 population derived from biparental crosses developed at the Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru. The cross is OK-2017-010 × Pusa Sawani. The F_3 populations were generated through selfing of F_2 individuals from the cross to obtain segregating families exhibiting genetic variation for yield and yield-contributing traits.

Evaluation of the F_3 populations was conducted during the *Kharif* 2024 season using an Augmented Block Design (ABD) at the experimental field of BCI, College of Horticulture, Bengaluru. A total of 25 Families with a population size of 250, along with their respective parents and five standard checks Kashi Pragati, Arka Anamika, Pusa A4, Varsha Uphar and Prabhani Kranti were included in the study. Each family was represented by 10 plants, spaced adequately to ensure optimal growth conditions. The experiment comprised five blocks, and all recommended agronomic practices were followed as per the University of Horticultural Sciences (UHS), Bagalkot package of practices (Anon., 2016). Standard plant protection measures were adopted to maintain healthy crop growth and to minimize pest and disease incidence.

Statistical Analysis

Statistical analyses were carried out following standard procedures. The analysis of variance (ANOVA) was performed as per the method described by Panse and Sukhatme (1985). The genotypic and phenotypic coefficients of variation (GCV and PCV) were computed according to Burton (1952), while heritability in the broad sense and genetic advance as a percentage of the mean were estimated following Johnson *et al*. (1955). Correlation coefficients were calculated according to the procedure outlined by Al-Jibouri *et al*. (1958). Path coefficient analysis was performed following the methods proposed by Wright (1921) and Dewey and Lu (1959).

In the present investigation, the range and magnitude of all genetic parameters for each trait were categorized based on the mean and standard deviation (SD) into three classes: high (> mean + SD), medium (mean ± SD) and low (< mean – SD), as suggested by Diwakar *et al*. (2016). The R STUDIO 4.4.1 (AUGMENTEDRCBD) packages and GRAPES 1.0 software were used for the data analysis.

RESULTS AND DISCUSSION

The estimates of genetic variability parameters, including range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad sense) and genetic advance as percent of the mean (GAM).

Range and Mean Performance

The mean performance of the genotypes revealed considerable variation across traits. The range of variation for different traits indicated the presence of substantial genetic diversity in the population. For instance, the number of seeds per fruit varied from 33.11 to 70.00, fruit length ranged from 11.41 to 20.58 cm, while total yield per plant ranged from 329.89 to 632.44 g, as presented in Table 1. Such a broad range suggests that ample scope exists for selection of superior genotypes for yield and yield-contributing characters. The variability observed could be attributed to the diverse genetic constitution of the segregating population and possible recombination effects in the hybrid progenies.

Genotypic and Phenotypic Coefficients of Variation

The magnitude of genotypic and phenotypic coefficients of variation provides an estimate of the extent of variability present and the relative contribution of genotypic and environmental factors. In the present study, PCV values were marginally higher than their corresponding GCV estimates for all traits, indicating a limited influence of the environment on the expression of these traits and suggesting that most of the observed variability is genetic in nature presented in Table 2.

The GCV values ranged from 4.85% (days to first flowering) to 23.81% (total yield per plant), while PCV ranged from 5.94% to 24.51%, respectively. The traits with high GCV and PCV values were average fruit weight (22.01% and 23.08%), number of seeds per fruit (19.22% and 22.31%) and total yield per plant (23.81% and 24.51%), suggesting that these traits possess a broad genetic base and are amenable to improvement through selection Kumar and Maji (2006) Khajuria *et al*. (2016), Singh *et al*. (2017) Raval *et al*. (2018) for Days to first flowering, Karthika *et al*. (2019), Sravanthi *et al*. (2021) days to 50% flowering, Khajuria *et al*. (2016), Singh *et al*. (2017) Raval *et al*. (2018), Komolafe *et al*. (2023) for total yield per plant, Singh *et al*. (2023), Setu (2023), Pattnaik *et al*. (2023) for average fruit weight and number of seeds per fruit, Pampanna *et al*. (2024) and Madhumitha *et al*. (2024) for seeds per fruit. Similarly, the number of branches per plant (16.39% and 16.52%) as per Sravanthi *et al*. (2021), fruit diameter (12.19% and 13.26%) Karthika *et al*. (2019) and Sravanthi *et al*. (2021), and stem girth (14.88% and 15.05%) as in Komolafe *et al*., 2024 also exhibited relatively high variability.

Moderate GCV and PCV were observed for traits such as number of nodes per plant (14.07% and 14.97%), internodal length (14.94% and 16.69%) and fruit length (9.39% and 10.46%) the findings are consistent with studies by Saravanti *et al*. (2017; 2021), Mohammed *et al*. (2022) and Shwetha *et al*. (2023), indicating moderate genetic variability among genotypes. The lowest GCV and PCV values were observed for days to first flowering (4.85% and 5.94%) and number of ridges on the fruit surface (7.68% and 9.40%) this observation concurs with the findings of Hallur *et al*. (2017) and Prakash *et al*.

(2022), indicating that these traits are relatively less influenced by genetic variation and more stable across environments.

The closeness between GCV and PCV values across all traits, particularly for plant height (12.10% and 12.21%), number of branches (16.39% and 16.52%) and stem girth (14.88% and 15.05%), suggests minimal environmental influence and high inherent genetic control. Similar findings were reported by Sood *et al*. (2016) and Alemu *et al*. (2020) in okra, emphasizing that such traits with high genotypic variability can be effectively utilized in selection programs.

Table 1. Mean performance of 25 F_3 families along with the parents and checks of okra cross OK-2017-010 X Pusa Sawani

Treatments	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
F1	39.29	46	204	1.94	14.83	10.7	5.22	2.74	15.14	1.78	21.7	15.2	50.2	329.89
F2	41.65	48	175.4	2.41	17.28	7.45	5.42	2.49	14.83	1.20	35.2	16.8	38.6	591.36
F3	34.56	45	199.3	2.22	15.53	13.2	5.02	1.98	16.71	1.8	26.1	18.8	41.5	490.68
F4	37.85	41	185.8	2.78	16.23	11.24	5.02	1.65	19.17	1.73	34.3	13.88	52.1	476.08
F5	41.32	39	209.5	2.14	14.53	9.55	5.12	1.78	18.33	1.45	31.6	14.2	60.4	448.72
F6	38.45	36	143.5	2.34	13.43	10.84	5.16	1.88	16.28	1.91	26.3	17.2	38.5	452.36
F7	41.26	46	169.5	2.19	10.43	11.21	5.42	2.15	17.46	1.78	26.5	21.8	42.6	577.7
F8	41.65	38	184.1	2.16	12.33	7.66	4.98	1.99	15.32	1.93	26.2	14.6	70	382.52
F9	42.19	37	159.5	2.14	13.03	6.88	5.16	1.76	17.46	1.93	27.3	16.8	41.9	458.64
F10	47.56	36	190.5	2.34	12.23	11.61	5.21	1.69	17.32	1.68	25.1	18.6	52.6	466.86
F11	37.56	42	162.5	1.1	14.88	10.99	7.14	2.15	19.68	1.75	33.4	16.4	64.6	547.76
F12	42.15	43	187	2.34	14.18	8.45	5.41	1.99	20.58	1.75	27.7	18.8	48.2	520.76
F13	41.46	42	196.5	2.45	16.58	12.59	6.34	1.78	14.65	2.10	29.3	19.6	47.6	574.28
F14	42.48	44	192	4.1	18.78	10.91	6.21	2.15	17.07	1.6	33.2	15.6	43.6	517.92
F15	42.4	43	169.5	2.64	19.68	11.01	5.89	2.15	19.67	1.3	32.1	13.3	39.5	426.93
F16	38.65	44	182.3	1.67	18.48	7.66	5.46	1.99	18.56	1.63	32.6	19.4	35.6	632.44
F17	41.46	42	185.5	2.75	16.38	11.54	5.06	2.15	18.57	1.91	30.9	18.8	33.11	580.92
F18	41.46	44	130.5	1.45	18.08	12.61	5.46	1.98	20.56	1.68	31.1	17.2	47.1	534.92
F19	43.99	47	181.5	2.47	17.28	13.45	5.24	2.15	19.57	1.88	32.9	16.2	51.2	532.98
F20	42.41	44	140.5	2.4	17.78	10.72	5.47	2.14	16.88	1.65	32.8	15.8	61.5	518.24
F21	42.2	45	145	2.16	11.95	11.39	5.02	1.75	15.25	1.5	33.6	16.2	61.5	544.32
F22	41.46	44	149.1	2.81	13.46	11.39	5.17	1.87	15.45	1.42	32.6	17.6	66.5	573.76
F23	41.5	42	192.5	2.17	18.37	11.79	7.14	1.75	18.75	1.98	32.4	15.8	47.6	511.92
F24	40.51	42	161	1.64	16.46	12.19	5.89	2.46	19.33	1.27	33	12.6	49.4	415.8
F25	41.69	43	168.5	2.14	12.48	11.89	5.14	1.99	19.36	1.75	32.7	16.1	29.6	526.47
OK-2017-010	41.83	46	145.22	2.18	13.41	7.66	5	1.93	16.96	1.84	26.12	16.96	55.75	443.76
Pusa Sawani	41.93	49	155.64	1.75	13.31	9.55	5	1.75	12.15	1.66	22.54	17.12	54.21	438.78
Vrsha Uphar	42.06	44	174.3	2.34	15.76	11.39	5	1.89	17.71	1.63	42.06	16.62	46.3	443.76
Kashi Pragati	41.93	42	174.19	2.25	13.31	11.78	5.26	1.98	18.91	1.4	23.84	15.77	45.42	440.76
Arka Anamika	39.75	41	175.67	2.39	13.42	12.01	5.44	1.82	18.38	1.45	25.14	16.09	42.84	397.8
Pusa A4	40.76	41	174.18	1.99	18.41	11.14	5.52	1.75	18.41	1.42	24.62	14.94	45	386.06
Prabhani Kranti	41.59	41	170.6	2.41	13.45	11.07	5.7	1.7	17.62	1.45	23	17.39	45.08	402.78
Mean	41.1	42.52	174.6	2.24	15.39	10.76	5.43	2.02	17.68	1.65	30.42	16.69	48.61	505.37
LSD1 @ 5%	2.18	1.56	3.59	0.26	2.09	2.06	0.29	5.85	0.82	0.75	13.82	7.41	0.04	55.53
LSD2 @ 5%	1.15	0.82	1.89	0.14	1.1	1.08	0.15	3.08	0.43	0.39	7.28	3.9	0.02	29.26
LSD3 @ 5%	2.81	2.01	4.64	0.34	2.7	2.66	0.38	7.55	1.05	0.97	17.84	9.56	0.05	71.68
LSD4 @ 5%	2.57	1.84	4.23	0.31	2.47	2.43	0.34	6.89	0.96	0.88	16.28	8.73	0.04	65.44

X1 Days to first flowering X8 Fruit diameter (cm)
X2 Days to 50% flowering X9 Fruit length (cm)
X3 Plant height (cm) X10 Stem girth (mm)
X4 Number of branches per plant X11 Number of fruits per plants
X5 Number of nodes on the main stem X12 Average fruit weight (gm)
X6 Internodal length (cm) X13 Number of seeds per fruit
X7 Number of ridges on fruit surface X14 Total yield per plant (gm)
LSD1 @ 5% A Test Treatment and a Control Treatment LSD2 @ 5% Control Treatment Means
LSD3 @ 5% Two Test Treatments (Different Blocks) LSD4 @ 5% Two Test Treatments (Same Block)

Heritability (Broad Sense)

Heritability in the broad sense (h^2bs) reflects the proportion of total phenotypic variance that is due to genetic variance and is crucial in determining the efficiency of selection. In the present study, heritability estimates ranged from 57.43% (total number of fruits per plant) to 98.39% (number of branches per plant) shown in Table 2.

Very high heritability (> 80%) was observed for days to 50% flowering (96.40%), plant height (98.13%), number of branches per plant (98.39%), stem girth (97.84%), fruit length (80.51%), fruit diameter (84.57%), average fruit weight (84.41%) and total yield per plant (90.53%). Such high estimates indicate that these traits are under strong genetic control with minimal environmental influence, implying that selection based on phenotypic performance would be highly effective. Moderate heritability (60–80%) was recorded for internodal length (80.14%), number of nodes (88.35%) and number of seeds per fruit (74.26%), suggesting that these characters are also considerably heritable but may exhibit some environmental effect. In contrast, days to first flowering (66.58%), number of ridges on fruit (66.80%) and total number of fruits per plant (57.43%) recorded comparatively lower heritability, indicating a greater influence of non-genetic factors and suggesting that improvement through direct selection may be less effective for these traits. Similar findings were reported by Singh *et al*. (2023) for the fruits per plant and the number of nodes per plant; Shwetha *et al*. (2022) for the number of nodes, Pattnaik *et al*. (2023) for branch number; Awasthi *et al*. (2022) and Syfullaha *et al*. (2024) for plant height; Mohammed *et al*. (2022) and Pattnaik *et al*. (2023) for seeds per fruit; Shivaramegowda *et al*. (2016) for fruit count; Temam *et al*. (2020) for early flowering.

Table 2. Estimation of genetic variability parameters in F3 populations of the okra cross OK-2017-010 × Pusa Sawani

Traits	Mean	Range		GCV (%)	PCV (%)	h^2bs (%)	GAM (%)
		Min	Max				
Days to first flowering	41.10	34.56	47.56	4.85	5.94	66.58	8.16
Days to 50% flowering	42.52	36.00	46.00	7.48	7.62	96.40	15.15
Plant height (cm)	174.60	130.50	209.50	12.10	12.21	98.13	24.72
Number of branches	2.24	1.10	4.10	16.39	16.52	98.39	33.53
Number of nodes	15.39	10.43	19.68	14.07	14.97	88.35	27.28
Internodal length (cm)	10.76	6.88	13.45	14.94	16.69	80.14	27.59
Number of ridges on the fruit surface	5.43	5.02	7.14	7.68	9.40	66.80	12.95
Fruit length (cm)	17.68	11.41	20.58	9.39	10.46	80.51	17.38
Fruit diameter (cm)	2.02	1.69	2.74	12.19	13.26	84.57	23.13
Stem girth (cm)	1.65	1.20	2.10	14.88	15.05	97.84	30.37
Total number of fruits per plant	30.42	21.70	35.20	9.08	11.98	57.43	14.19
Average fruit weight (g)	16.69	12.60	21.80	22.01	23.08	84.41	22.77
Number of seeds per fruit	48.61	33.11	70.00	19.22	22.31	74.26	34.18
Total yield per plant (g)	505.37	329.89	632.44	23.81	24.51	90.53	27.10

GCV: Genotypic Coefficient of Variation; h^2 bs: Broad sense heritability

PCV: Phenotypic Coefficient of Variation; GAM: Genetic Advance Percent Mean

Genetic Advance as Percent of Mean (GAM)

The estimates of genetic advance as percent of mean (GAM) help in predicting the expected improvement through selection. In the present study, GAM values ranged from 8.16% (days to first flowering) to 34.18% (number of seeds per fruit), revealing wide variation among traits in their potential response to selection.

High GAM coupled with high heritability was observed for number of branches (33.53%), number of seeds per fruit (34.18%), stem girth (30.37%), plant height (24.72%) and total yield per plant (27.10%). This combination indicates the predominance of additive gene action, suggesting that selection for these traits would be highly effective and can bring substantial improvement in the succeeding generations. Similar results were reported by Meena *et al*. (2018) and Akanbi *et al*. (2019), who observed high heritability and GAM for fruit yield and related traits in okra populations.

Moderate GAM values were recorded for fruit diameter (23.13%), average fruit weight (22.77%) and internodal length (27.59%), indicating a fair amount of additive genetic variance. These characters could also respond well to selection but may require a few selection cycles for consistent improvement. On the other hand, traits such as days to first flowering (8.16%), days to 50% flowering (15.15%) and number of ridges on fruit (12.95%) The high genetic gain indicated that selecting these traits would lead to significant genetic improvements over generations. These results align with those reported by Rathava *et al*. (2014), Awasti *et al*. (2020), Mohammed *et al*. (2022), Shwetha *et al*. (2022), Bagadiya *et al*. (2023), Pattnaik *et al*. (2023), Pampanna *et al*. (2024) for traits such as plant height, internodal length and fruit yield per plant. Similar findings for the seeds per plant were observed by Temam *et al*. (2020) and Awasthi *et al*. (2022).

Relationship Between Heritability and Genetic Advance

According to Johnson *et al*. (1955), heritability in conjunction with genetic advance provides a more reliable measure for predicting the gain under selection than heritability alone. In the present study, traits with high heritability coupled with high genetic advance such as number of branches, stem girth, number of seeds per fruit and total yield per plant suggest that these are predominantly governed by additive gene effects. Therefore, selection based on phenotypic performance will be effective for improving yield potential.

Correlation Analysis among Yield and Its Contributing Traits

The correlation coefficients among fourteen quantitative traits of okra are presented in Table 3. Correlation analysis provides an understanding of the nature and degree of association between yield and its component characters, which is essential for identifying effective selection criteria in breeding programs. The present study revealed that total yield per plant (TYPP) exhibited significant and positive correlations with several yield-contributing traits, indicating that improvement in these characters would result in higher yield potential in okra.

Correlation of Days to First Flowering and Days to 50% Flowering

Days to first flowering (DFF) showed significant negative correlations with most of the yield and yield-attributing traits, such as number of branches per plant (r = –0.558), fruit diameter (r = –0.782), fruit length (r = –0.610), average fruit weight (r = –0.724) and total yield per plant (r = –0.749)**. This implies that earlier flowering genotypes tend to be more productive, as earliness allows for a longer reproductive phase and better utilization of assimilates for fruit development. The strong negative relationship between DFF and yield is consistent with findings by Sood *et al*. (2016) and Meena *et al*. (2018), who also reported that early flowering genotypes in okra exhibited higher yield potential. Moreover, DFF had a significant positive correlation with internodal length (r = 0.615), suggesting that delayed flowering is associated with elongated internodes and vegetative growth dominance rather than reproductive development.

Plant Height

Plant height showed positive but non-significant correlations with most traits except number of fruits per plant (r = –0.110) and number of seeds per fruit (r = –0.142)**. The lack of significant association suggests that plant height alone is not a reliable indicator of yield in okra. This agrees with the observations of Akanbi *et al*. (2019), Saravathi *et al*. (2021), Prakash *et al*. (2022), Beresh *et al*. (2024) and Saleem *et al*. (2023) who reported that plant height exhibited a weak and inconsistent correlation with yield. However, taller plants may contribute indirectly to yield through improved light interception, photosynthetic area and support for fruit-bearing branches under favorable environmental conditions.

Number of Branches per Plant

Number of branches per plant showed strong and highly significant positive correlations with fruit diameter (r = 0.721), fruit length (r = 0.464), average fruit weight (r = 0.458)* and total yield per plant (r = 0.687). This indicates that branching plays a critical role in enhancing the yield potential by increasing the number of fruit-bearing nodes and total fruit production. Similar results were obtained by Mohammed *et al*. (2020), Shinde *et al*. (2023) and Kumar *et al*. (2020), who emphasized that the number of branches per plant is a key determinant of yield due to its influence on canopy size and reproductive sites. Interestingly, NBPP showed a significant negative correlation with internodal length (r = –0.446)*, suggesting that genotypes with compact internodes and more branches are more productive a desirable trait for intensive cropping systems.

Number of Nodes on Main Stem

The number of nodes exhibited positive associations with total yield per plant (r = 0.167) and significant correlations with number of ridges (r = 0.515)*, number of fruits per plant (r = 0.439)** and fruit diameter (r = 0.145). This suggests that higher node number indirectly contributes to greater fruit production through an increased number of potential flowering points. Similar patterns were reported by Singh *et al*. (2018), Beeresha *et al*. (2024) and Pampanna *et al*. (2024) who found that node number significantly contributes to fruit number and yield potential.

Internodal Length

Internodal length exhibited significant negative correlations with almost all major yield traits, including fruit diameter (r = –0.677), fruit length (r = –0.625), number of fruits per plant (r = –0.701), *average fruit weight (r = –0.431)** and total yield per plant (r = –0.705). This indicates that genotypes with shorter internodes tend to be higher yielding corroborating the results from studies by Mohammed *et al*. (2020), Shinde *et al*. (2023) and Saleem *et al*. (2023), likely due to a compact plant architecture that facilitates more fruit-bearing nodes per unit plant height.

Number of Ridges on the Fruit Surface

Number of ridges exhibited non-significant positive correlations with most traits and a negligible association with yield (r = 0.075). Although ridges are important for fruit shape and market appeal, their influence on yield is minimal. However, the positive association with number of nodes (r = 0.515) as in Saravathi *et al*. (2021), Prakash *et al*. (2022), Beresh *et al*. (2024) and Saleem *et al*. (2023) indicates that higher node number may promote slightly ridged fruits, likely due to enhanced fruit set under high node density.

Fruit Diameter and Fruit Length

Fruit diameter and fruit length showed very strong positive correlations with each other (r = 0.830)** and with other yield components. Fruit diameter exhibited significant positive relationships with average fruit weight (r = 0.754), number of fruits per plant (r = 0.606) and total yield per plant (r = 0.906), while fruit length correlated significantly with total yield (r = 0.876). These results clearly indicate that fruit size (length and diameter) is a major determinant of yield. The findings align with Meena *et al*. (2018) and Alemu *et al*. (2020), who reported that larger fruit size contributes directly to fruit yield and market value in okra. Selection for genotypes with long and thick fruits would therefore be beneficial for yield improvement.

Stem Girth

Stem girth showed positive and significant correlations with number of seeds per fruit (r = 0.668) but a weak correlation with total yield (r = 0.079).** This suggests that plants with thicker stems may support better nutrient transport and higher seed set but do not necessarily translate to higher fruit yield. Similar findings were reported by Sood *et al*. (2016), indicating that stem girth contributes to plant vigor rather than direct yield increase.

Number of Fruits per Plant

The number of fruits per plant is a direct yield component and showed highly significant positive correlation with total yield per plant (r = 0.648)** and *average fruit weight (r = 0.364)**. These associations indicate that an increase in fruit number and individual fruit weight results in a proportional increase in yield. This observation is in line with Johnson *et al*. (1955) and Kumar *et al*. (2020), who highlighted fruit number as the most reliable selection criterion for yield improvement in okra. Negative correlation with internodal length (r = –0.701) also supports the importance of compact plant architecture for maximizing fruit count.

Average Fruit Weight

Average fruit weight showed a strong positive and highly significant correlation with total yield per plant (r = 0.804), establishing it as one of the most critical yield determinants. It also correlated positively with fruit diameter (r = 0.754) and fruit length (r = 0.702), demonstrating that heavier fruits are typically larger in both dimensions. The strong association between AFW and TYPP emphasizes the importance of selecting genotypes that produce bold, fleshy fruits to maximize yield potential. These findings are consistent with Akanbi *et al*. (2019), Mohammed *et al*. (2020), Shinde *et al*. (2023) and Saleem *et al*. (2023). Additionally, Nbeaa *et al*. (2023) highlighted the importance of average fruit weight, Beereshaa *et al*. (2024) and Pampanna *et al*. (2024) who reported that average pod weight had the strongest direct effect on total yield in okra.

Number of Seeds per Fruit

Number of seeds per fruit exhibited a significant positive correlation with stem girth (r = 0.668) but only a weak, non-significant correlation with total yield (r = 0.260)**. This implies that seed count is not directly linked with fruit yield but may influence fruit filling and weight indirectly Prakash *et al*. (2022), Beresha *et al*. (2024) and Saleem *et al*. (2023). The moderate positive correlation with fruit length (r = 0.394*) indicates that longer fruits tend to contain more seeds, contributing to fruit weight and reproductive efficiency.

Total Yield per Plant

Total yield per plant exhibited significant positive correlations with number of branches per plant (r = 0.687), fruit diameter (r = 0.906), fruit length (r = 0.876), average fruit weight (r = 0.804) and number of fruits per plant (r = 0.648). Conversely, it was negatively correlated with days to first flowering (r = –0.749) and internodal length (r = –0.705**). These relationships indicate that earliness, compact internodes, more branches and larger fruits collectively enhance yield potential. Therefore, these characters should be prioritized as direct selection criteria in okra improvement programs as similar finding Mohammed *et al*. (2020), Shinde *et al*. (2023) and Saleem *et al*. (2023). Additionally, Nbeaa *et al*. (2023) highlighted the importance of average fruit weight, Beeresha *et al*. (2024) and Pampanna *et al*. (2024) on the fruits per plant and days to 50 percent flowering, which was similarly found to contribute positively to yield in this study. Fruit diameter and length were also significant contributors to yield, as echoed by Saravathi *et al*. (2021), Prakash *et al*. (2022), Beresh *et al*. (2024) and Saleem *et al*. (2023).

Path Coefficient Analysis

Correlation coefficients only indicate the degree of association among traits but do not partition the influence into direct and indirect components. Therefore, path coefficient analysis was carried out to determine the direct and indirect contributions of different characters toward total yield per plant (TYPP). The path coefficients at the phenotypic level are presented in Table 4.

Direct Effects on Total Yield per Plant

Among the traits, number of branches per plant (NBPP) exhibited the highest positive direct effect (0.311) on total yield per plant, followed by average fruit weight (AFW, 0.277), fruit length (FL, 0.388) and fruit diameter (FD, 0.322). These results clearly indicate that branching ability and fruit size traits (both length and diameter) have the most substantial direct influence on yield. This finding supports the correlation results, which also showed strong positive relationships between these characters and yield. Similar results have been reported by Sood *et al*. (2016) and Kumar *et al*. (2020) Rana *et al*. (2020), Mohammed *et al*. (2020), Neeraja *et al*. (2023) and Lal *et al*. (2023). While negative direct effects through the seeds per fruit and days to first flowering Neeraja *et al*. (2023) and Beeresha *et al*. (2024), who observed that fruit size and branching significantly enhance fruit yield in okra.

Internodal length (IL), however, exerted a negative direct effect (–0.190) on yield, suggesting that shorter internodes contribute positively to total yield. Compact plant types with reduced internode spacing facilitate more nodes and fruit-bearing points per plant, leading to increased productivity. Similar observations were made by Meena *et al*. (2018) Patil *et al*. (2019), Rana *et al*. (2020), Mohammed *et al*. (2020), Komolafe *et al*.

(2021), Neeraja *et al*. (2023) and Lal *et al*. (2023), Beeresha *et al*. (2024) and Pampanna *et al*. (2024), who found that internodal length negatively affects yield in okra due to inefficient canopy structure and fruit placement.

Other traits such as plant height (PH), number of nodes on main stem (NNMS), stem girth (SG) and number of ridges (NR) had negligible or low direct effects on yield, suggesting their contributions are mostly indirect through other yield-contributing traits.

From the results, it is evident that number of branches per plant, fruit diameter, fruit length, average fruit weight and number of fruits per plant exhibited high positive direct effects and significant correlations with yield. Therefore, these traits are the most influential determinants of total yield per plant. Conversely, days to first flowering and internodal length showed negative direct effects, suggesting that early flowering and compact plant structure are desirable features for yield improvement. These findings are in agreement with those of Meena *et al*. (2018) and Alemu *et al*. (2020), who reported similar patterns of direct and indirect influences on yield in segregating populations of okra.

Table 3. Correlation coefficients among yield and its attributing traits in F3 populations of the okra cross OK-2017-010 × Pusa Sawani.

	DFF	D50F	PH	NBPP	NNMS	IL	NR	FD	FL	SG	NFPP	AFW	NSF	TYPP
DFF	1	-0.399*	-0.093	-0.558**	-0.313	0.615**	-0.371*	-0.782**	-0.61**	0.118	-0.393*	-0.724**	-0.142	-0.749**
D50F		1	0.446*	0.231	0.313	-0.391*	0.088	0.338	0.205	-0.223	0.325	0.400*	-0.257	0.410*
PH			1	0.087	0.074	0.249	0.196	0.044	0.074	0.115	-0.110	0.217	-0.142	0.137
NBPP				1	0.132	-0.446*	0.087	0.721**	0.464**	0.087	0.349	0.458*	0.283	0.687**
NNMS					1	-0.307	0.515**	0.145	0.144	-0.206	0.439*	0.061	-0.057	0.167
IL						1	-0.107	-0.677**	-0.625**	0.118	-0.701**	-0.431*	-0.224	-0.705**
NR							1	0.118	0.141	-0.180	0.168	0.197	-0.120	0.075
FD								1	0.830**	0.036	0.606**	0.754**	0.283	0.906**
FL									1	0.172	0.661**	0.702**	0.394*	0.876**
SG										1	-0.155	0.150	0.668**	0.079
NFPP											1	0.364*	0.270	0.648**
AFW												1	0.213	0.804**
NSF													1	0.260
TYPP														1

DFF: Days to first flowering D50F: Days to 50% flowering PH: Plant height (cm) NBPP: Number of branches per plant
NNMS: Number of nodes on the main stem INL: Inter nodal length (cm) FD: Fruit diameter (cm) NFPP: Number of fruits per plant
SG: Stem girth (cm) NR: Number of ridges on fruits FL: Fruit length (cm) AFW: Average fruit weight (g)
NSF: Number of seeds per fruit TYPP: Total yield per plant (g)

Table 4. Phenotypic path coefficient analysis for yield and yield attributing trait in F3 populations of the cross OK-2017-010 × Pusa Sawani in okra

	DFF	D50F	PH	NBPP	NNMS	IL	NR	FD	FL	SG	NFPP	AFW	NSF	r-Vaulue
DFF	-0.219	0.04	-0.011	-0.174	0.006	-0.117	0.074	0.139	-0.237	0.013	-0.098	-0.201	0.035	-0.749
D50F	0.087	-0.101	0.053	0.072	-0.006	0.074	-0.018	-0.06	0.080	-0.025	0.081	0.111	0.063	0.410
PH	0.019	-0.04	0.134	0.015	-0.001	-0.054	-0.037	-0.005	0.025	0.019	-0.037	0.064	0.026	0.128
NBPP	0.122	-0.023	0.007	0.311	-0.003	0.085	-0.017	-0.129	0.180	0.010	0.087	0.127	-0.069	0.687
NNMS	0.069	-0.032	0.007	0.041	-0.020	0.058	-0.102	-0.026	0.056	-0.023	0.109	0.017	0.014	0.167
IL	-0.135	0.039	0.038	-0.139	0.006	-0.190	0.021	0.121	-0.242	0.013	-0.174	-0.120	0.055	-0.705
NR	0.081	-0.009	0.025	0.027	-0.011	0.020	-0.199	-0.021	0.055	-0.02	0.042	0.055	0.029	0.075
FD	0.171	-0.034	0.004	0.224	-0.003	0.128	-0.023	-0.179	0.322	0.004	0.151	0.209	-0.069	0.906
FL	0.134	-0.021	0.009	0.144	-0.003	0.119	-0.028	-0.148	0.388	0.020	0.165	0.195	-0.096	0.876
SG	-0.026	0.022	0.022	0.027	0.004	-0.022	0.036	-0.006	0.066	0.114	-0.038	0.041	-0.162	0.078
NFPP	0.086	-0.033	-0.02	0.108	-0.009	0.133	-0.033	-0.108	0.257	-0.018	0.249	0.101	-0.066	0.648
AFW	0.159	-0.04	0.031	0.142	-0.001	0.082	-0.039	-0.135	0.272	0.017	0.091	0.277	-0.052	0.804
NSF	0.031	0.026	-0.014	0.088	0.001	0.043	0.024	-0.050	0.153	0.076	0.067	0.059	-0.243	0.260

DFF: Days to first flowering D50F: Days to first fruiting PH: Plant height (cm) NBPP: Number of branches per plant
NNMS: Number of nodes on the main stem INL: Inter nodal length (cm) FD: Fruit diameter (cm) NFPP: Number of fruits per plant
SG: Stem girth (cm) NR: Number of ridges on fruits FL: Fruit length (cm) AFW: Average fruit weight (g)
NSF: Number of seeds per fruit TYPP: Total yield per plant (g)

CONCLUSION

The analysis of genetic variability revealed substantial diversity among okra genotypes for most traits studied. High heritability and genetic advance for yield and its major components plant height, number of branches per plant, stem girth, number of seeds per fruit and total yield per plant indicated the predominance of additive genetic variance, suggesting that simple selection would effectively improve these traits. High GCV and PCV for average fruit weight, number of seeds per fruit and total yield further emphasized their value as reliable selection criteria in breeding programs. Correlation analysis indicated that yield in okra is a complex trait influenced by several morphological and yield-related attributes. Traits such as number of branches per plant, fruit diameter, fruit length, average fruit weight and number of fruits per plant showed strong positive associations with yield, making them key targets for selection. In contrast, days to first flowering and internodal length exhibited significant negative correlations, suggesting that early and compact genotypes are more productive. Path coefficient analysis revealed that fruit size, branching ability and average fruit weight contributed most directly to yield.

CONFLICT OF INTEREST

The author here declares there is no conflict of interest in the publication of this article.

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