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An insight into the phenotypic correlation and path analysis for yield and yield contributing traits in the F₂ segregating population of okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract

Okra [*Abelmoschus esculentus* (L.) Moench] is a crop predominantly grown in tropical and subtropical regions. An experiment was conducted to assess the relationship between various traits influencing crop yield and their direct and indirect effects on yield. This study analyzed the F₂ segregating population of the cross OK-2017-006 x Pusa A4 during the summer of 2023 at the Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru. The correlation analysis indicated that plant height, number of branches per plant, number of nodes on the main stem, stem girth, fruit diameter, and the number of fruits per plant exhibited a significant and positive correlation with total yield per plant. However, a significant negative correlation was observed for days to the first flowering with total yield per plant. Path coefficient analysis further revealed that the number of fruits per plant and average fruit weight had strong positive direct effects on yield per plant. Therefore, these quantitative traits could be valuable in developing selection indices for improving okra yield.

Keywords: Correlation, path analysis, fruit yield, yield components and okra

Introduction

Okra, scientifically known as *Abelmoschus esculentus* (L.) Moench is an annual vegetable crop that primarily undergoes often cross-pollination. In India, it is commonly called Bhendi and belongs to the class Dicotyledonae, order Malvaceae. It is the only vegetable of significant importance within the Malvaceae family (Schippers 2000) ^[26] and is believed to have originated in Tropical Africa. The genus *Abelmoschus* exhibits notable variation in chromosome number and ploidy levels among different species. The lowest chromosome number reported is 2n=56 for *Abelmoschus angulosus* (Ford 1938) ^[7], while the highest, 2n=200, has been observed in *Abelmoschus manihot* var. *caillei* (Singh and Bhatnagar 1975) ^[29]. Okra is mainly cultivated during the spring-summer and rainy seasons for its tender green fruits in tropical, subtropical, and Mediterranean climates worldwide (Hammon and Van Stoles, 1989) ^[8]. The crop is in high commercial demand due to its exceptional nutritional content, particularly rich in vitamin C, calcium, and iron. Okra is highly valued in horticulture, with substantial export potential. In India alone, it covers an extensive cultivation area of 546 million hectares, producing 6.7 million metric tons annually, with a productivity of 12.27 tons per hectare (Anon., 2022) ^[3].

Yield in okra is a quantitative trait influenced by multiple genes and environmental factors. The success of any selection program in segregating generations depends on understanding the nature and extent of the correlation between independent and dependent variables, allowing for the simultaneous selection of multiple traits to enhance total fruit yield (Yogita et al., 2023) ^[35]. Studying correlation alongside path coefficient analysis, which divides the correlation into direct and indirect effects of contributing traits, is highly beneficial (Rahevar et al., 2023) ^[21]. With this in mind, the present investigation was undertaken to examine the nature and association of traits concerning fruit yield and its components, as well as the direct and indirect path coefficients of independent variables on fruit yield in the F₂ segregating population of the cross OK-2017-006 x Pusa A4.

Materials and Methods

This study focusing on correlation and path analysis of yield and yield-related traits in F_2 segregating population of okra was conducted at Research Block, Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru during the *summer* season of 2023. The experimental materials consisted of the 426 F_2 segregating progenies obtained selling of the F_1 hybrid OK-2017-006 x Pusa A4. The F_2 population was evaluated along with their parents, F_1 , and commercial check (Radhika). The seeds were sown with a spacing of 60 x 30 cm by adopting a standard package of practices and evaluated in an unreplicated trail. The observations were recorded on every plant in the F_2 segregating population for 13 traits as per the DUS guidelines by PPV&FRA. The characters studied are depicted below.

- **Plant height (cm):** The height of the plant was measured in centimeters from ground level to the tip of the main shoot at 90 days after sowing.
- **Internodal length (cm):** The length of the inter-node was measured using a scale on the 8th to 9th node from the bottom of the main stem and recorded in centimeters.
- **Number of branches per plant:** The number of fruiting branches arising from the main stem above the ground level was recorded 90 days after sowing.
- **Number of nodes on the main stem:** The number of nodes on the main stem was counted at 90 days after sowing.
- **Stem girth (cm):** Stem girth was measured at 10 cm above ground level at 60 days after sowing by using a vernier caliper.
- **Days to first flowering:** The number of days taken from the date of sowing to the time of first flower opening was recorded and days to early flowering were calculated.
- **Number of ridges on fruit surface:** The number of ridges present on the fruit surface was recorded at the edible maturity stage and the average of five fruits was worked out.
- **Fruit length (cm):** The length of the fruit was measured from the base of the fruit (basal cap) to its tip at the edible maturity stage. It is expressed in centimeters, and the average of five fruits was worked out.
- **Fruit diameter (mm):** The diameter of the fruit was measured 3 mm away from the fruit base (basal cap) at the edible maturity stage by using vernier calipers and recorded in millimeters. The average of five fruits was worked out.
- **Number of seeds per fruit:** The number of seeds per fruit was recorded after the crop was harvested and dried.
- **Average fruit weight (g):** The average fruit weight was calculated by adding the weight of fruits, dividing by the total number of fruits, and expressing it as grams per fruit.
- **Number of fruits per plant:** The number of fruits per plant was recorded during the full range of harvesting (added all pickings) up to the near maturity stage.
- **Total yield per plant (g):** Yield per plant was computed by adding the fruit weight of all the pickings in each plant and expressed in grams per plant.

The correlation coefficient among all trait combinations at a phenotypic level was estimated according to the formula given by Al-Jibouri *et al.* (1958)^[2]. Path coefficient analysis was carried out as given by Wright (1921)^[33] and Dewey and Lu (1959)^[6]. R software and packages are used for data visualization and correlation analysis (Version 0.92), (Wei and Simko, 2021)^[32].

Phenotypic correlation coefficient (rp)

$$r_p(xy) = \frac{Cov_p(xy)}{\sqrt{\sigma_p^2(x)\sigma_p^2(y)}}$$

Where,

$rp(xy)$ = phenotypic correlation coefficient between characters 'x' and 'y'

$Cov_p(xy)$ = phenotypic covariance of character 'x' and 'y'

$\sigma_p^2(x)$ = phenotypic variance of character 'x'

$\sigma_p^2(y)$ = phenotypic variance of character 'y'

Test of significance of correlation between the considered traits was carried out by comparing correlation coefficients- 'r' value at n-2 degree of freedom with the table values (Fisher and Yates, 1963) at (n-2) degrees of freedom at 5% and 1% level where "n" denotes the total number of pairs of observations used in the calculation.

$$t = \sqrt{r(n-2/1-r^2)}$$

Where n is the number of pairs of observations.

If the calculated value is greater than the tabulated value at (n-2) degrees of freedom at a given probability level, the coefficient of correlation is considered significant.

Path coefficient analysis

Path coefficient analysis was carried out independently to know both the direct and indirect effects of the important component traits on yield, as suggested by Wright (1921)^[33] and was illustrated by Dewey and Lu (1959)^[6].

The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$$R1y = a + r12b + r13c + \dots + r1li$$

$$r2y = a + r21a + b + r23c + \dots + r2li$$

$$r3y = r31a + r32b + c + \dots + r3li$$

$$rly = r11a + r12b + r13c + \dots + I$$

Where,

$r1y$ to $r1ly$ = Co-efficient of correlation between causal factors 1 to 1 with dependent characters y.

$r12$ to $r1li$ = Co-efficient of correlation among causal factors a, b, c...i = Direct effects of characters 'a' to 'i' on the dependent character 'y.'

The residual effect (r) was computed as follows.

Residual effect (r) = 1-

$$\sqrt{a^2 + b^2 + c^2 + \dots + e^2 + 2abr12 + 2acr13 + \dots}$$

Have suggested scales for path coefficient analysis.

0.00-0.09: Negligible

0.10-0.19: Low
 0.20-0.29: Moderate
 0.30-0.99: High
 >1.00: Very high

Results and Discussion

Correlation analysis

Understanding the connections between the factors affecting fruit production is crucial for developing a selection-based plant breeding program to boost yield. Yield, being a dependent trait, is influenced by numerous characteristics. Plant breeders can derive substantial advantages from positive associations among desirable traits. Positive correlations indicate that enhancing one specific trait often leads to the simultaneous improvement of related characteristics. The correlation analysis in F_2 segregating population of the biparental cross OK-2017-006 x Pusa A4 shows total yield per plant was highly significant and positive correlated with number of fruits per plant (0.94), plant height (0.54), stem girth (0.39), number of nodes on main stem (0.34), fruit diameter (0.27), number of branches per plant (0.25) (Table 1) (Figure 1); and days to first flowering exhibited significant and negative correlation (-0.19) with total yield per plant suggesting that single plant selections can be practiced in F_2 and advanced generations with these traits which lead to improvement in yield. These findings are in accordance with the reports of Alam *et al.* (2020) [1], Rana *et al.* (2020) [22], Sravanthi *et al.* (2021) [30], Saleem *et al.* (2023) [25] and Shinde *et al.* (2023) [28] for plant height and Shinde *et al.* (2023) [28] for the number of nodes on main stem and Saleem *et al.* (2023) [25] for stem girth; Alam *et al.* (2020) [1] for number of branches per plant; Jadhav *et al.* (2022) [9], Nbeaa *et al.* (2023) [16] and Saleem *et al.* (2023) [25] for fruit diameter, Alam *et al.* (2020) [1], Rana *et al.* (2020) [22], Sravanthi *et al.* (2021) [30], Saleem *et al.* (2023) [25], Shinde *et al.* (2023) [28] and Nbeaa *et al.* (2023) [16] for fruit length, average fruit weight and number of fruits per plant, Sravanthi *et al.* (2021) [30], Jadhav *et al.* (2022) [9] and Nbeaa *et al.* (2023) [16] for days to first flowering.

Path coefficient analysis

The main goal of breeder is to have traits with minimum defects while maximizing production potential. While some of them have a direct impact on yield, others do so indirectly

through the developmental behavior of other traits. Thus, it is preferable to comprehend the direct and indirect effects of other factors on yield. The relative importance of each feature has been determined and the total number of characteristics used in selection programs has been limited through the use of path analysis. Path coefficient analysis in the F_2 segregating population of the cross revealed that the maximum direct contribution to total yield per plant was made by the number of fruits per plant (0.99) and average fruit weight (0.23). (Table. 2). These findings are in line with the results obtained by Raval *et al.* (2019) [23], Pawar *et al.* (2020) [20], Rana *et al.* (2020) [22], Rynjah *et al.* (2020) [24], Karmata *et al.* (2023) [10], Lal., (2023) [13], Nayak *et al.* (2023) [15] which indicated that the considerable improvement may be brought about by selecting genotypes with more number of fruits per plant followed and average fruit weight. Further, these traits also had a significantly positive correlation with total yield per plant and positive inter-correlation among themselves.

Correlation analysis revealed that traits such as plant height, number of branches per plant, number of nodes on the main stem, stem girth, fruit length, fruit diameter, average fruit weight, and the number of fruits per plant demonstrated a significant and positive correlation with total fruit yield per plant suggesting these are the key selection traits for yield improvement in Okra. The positive correlation effect of these traits will be attributed to reasons such as an increased number of branches per plant and a number of nodes on the main stem (Figure 2) consequently resulting in a higher leaf count per plant this enhances photosynthetic activity which leads to the accumulation of photosynthetic materials and higher amount of photosynthates move from the source to the sink (Shah, 2019) [27] results in a positive effect on fruit length and fruit diameter, average fruit weight, more number of fruit production per plant results in increased total yield per plant (Lakshmi *et al.*, 2015) [12]. Conversely, days to first flowering exhibited a significant negative association with total fruit yield. This implies when plants produce early flowering it will produce fruits for a longer fruiting duration. Therefore, these traits may be crucial for enhancing fruit yield in okra. Path analysis further indicated that the trait number of fruits per plant followed by average fruit weight had the strongest direct positive effect on total fruit yield per plant.

Table 1: Phenotypic correlation coefficient among thirteen traits in F_2 population of cross OK-2017-006 x Pusa A4

Traits	PH	IL	NBPP	NNMS	SG	FL	FD	AFW	NFPP	NSPF	NR	DFP	TYPP
PH	1.000	0.181**	0.406**	0.368**	0.633**	-0.066	0.078	0.061	0.561**	-0.029	0.034	-0.083	0.542**
IL		1.000	0.223**	0.011 ^{NS}	0.044 ^{NS}	-0.038	-0.011	-0.023	0.062	-0.032	0.052	0.084	0.026
NBPP			1.000	0.188**	0.479**	-0.041	0.014	0.035	0.259**	-0.004	-0.019	-0.067	0.257**
NNMS				1.000	0.294**	-0.043	0.078	-0.067	0.361**	-0.023	0.018	0.007	0.341**
SG					1.000	-0.051	0.053	0.067	0.399**	-0.004	-0.004	-0.091	0.393**
FL						1.000	0.389**	0.109*	0.023	-0.006	-0.095*	-0.089	0.060
FD							1.000	0.040	0.250**	-0.040	-0.038	0.004	0.270**
AFW								1.000	-0.189**	-0.035	0.020	-0.125**	0.044
NFPP									1.000	0.007	0.040	-0.143**	0.944**
NSPF										1.000	0.020	-0.071	0.014
NR											1.000	0.070	0.031
DFP												1.000	-0.196**
TYPP													1.000

* Significant at 5% and ** Significant at 1%

PH : Plant height (cm)

IL : Inter nodal length (cm)

NBPP : Number of branches per plant

NNMS : Number of nodes on the main stem

SG : Stem girth (cm)

FL : Fruit length (cm)

FD : Fruit diameter (mm)

AFW : Average fruit weight (g)

NFPP : Number of fruits per plant

NSPF : Number of seeds per fruit

NR : Number of ridges per fruit

DFP : Days to first flowering

TYPP : Total yield per plant (g)

Table 2: Direct and indirect effect of different characters on fruit yield per plant in F₂ population of OK-2017-006 × Pusa A4

Traits	PH	NNMS	SG	FL	FD	AFW	NFPP	DFP	Correlation values
PH	-0.03656	0.00336	-0.00228	-0.00013	0.00098	0.01423	0.56041	0.00232	0.542**
NNMS	-0.01345	0.00913	-0.00106	-0.00008	0.00099	-0.01547	0.36115	-0.00020	0.341**
SG	-0.02315	0.00268	-0.00360	-0.00010	0.00067	0.01545	0.39842	0.00254	0.393**
FL	0.00241	-0.00039	0.00018	0.00191	0.00488	0.02526	0.02314	0.00248	0.060
FD	-0.00286	0.00072	-0.00019	0.00074	0.01256	0.00923	0.24957	-0.00011	0.270**
AFW	-0.00224	-0.00061	-0.00024	0.00021	0.00050	0.23194	-0.18924	0.00348	0.044
NFPP	-0.02050	0.00330	-0.00144	0.00004	0.00314	-0.04392	0.99935	0.00399	0.944**
DFP	0.00304	0.00007	0.00033	-0.00017	0.00005	-0.02898	-0.14293	-0.02787	-0.196**

* Significant at 5% and ** Significant at 1% (Residual effect: 0.05565)

PH : Plant height (cm)

SG : Stem girth (cm)

FD : Fruit diameter (mm)

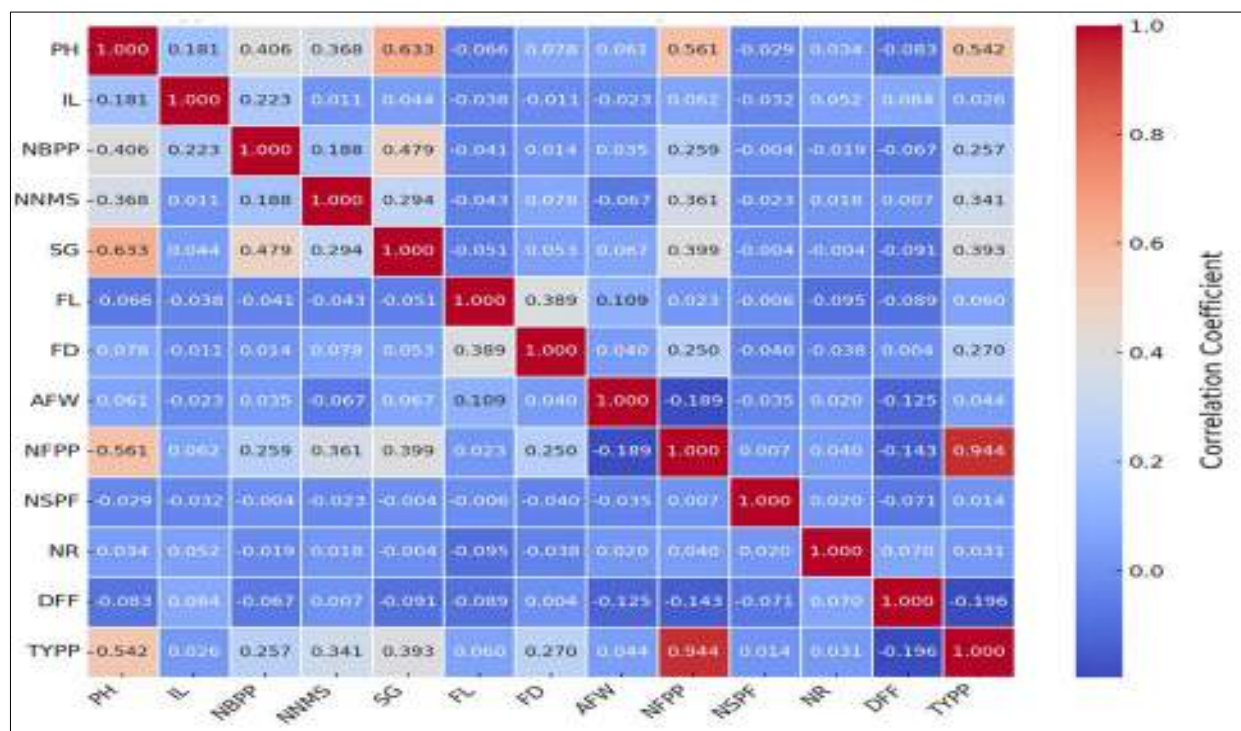
NFPP : Number of fruits per plant

NNMS : Number of nodes on main stem

FL : Fruit length (cm)

AFW : Average fruit weight (g)

DFP : Days to first flowering

**Fig 1:** Here is the heatmap showing the phenotypic correlation coefficients among thirteen traits in the F₂ population of the cross OK-2017-006 × Pusa A4. The annotations display the correlation coefficients, with a color gradient to emphasize the strength and direction of correlations**Fig 2:** Plants expressing significant and positive correlated traits a. Plant showing short internodal length and more number of internodes. b. Plant exhibiting more number of productive branches results in more no fruits per plant

Conclusion

This study evaluated the relationships between 13 key traits and their impact on yield in an F₂ segregating population of okra (*Abelmoschus esculentus* (L.) Moench), comprising 426 individuals. The results revealed that traits such as plant height, number of branches per plant, number of nodes on the main stem, stem girth, fruit length, fruit diameter, average fruit weight, number of fruits per plant, and days to first flowering significantly influenced yield. These findings suggest that selecting these traits can be an effective strategy to improve fruit yield in okra breeding programs.

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Conflict of interest

The authors have declared that no conflict of interest exists.

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