



## Assessment of organic manures and fertilizers on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench cv. 'Arka Anamika') in morang, Nepal using variability, correlation, and path analysis

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### ABSTRACT

Okra is an important culinary vegetable cultivated extensively in sub-tropical regions of Nepal and India. This study was conducted in Morang, Nepal, using a randomized complete block design (RCBD) to evaluate the impact of various organic manures and fertilizers on okra yield and to apply statistical tools for optimizing breeding practices. The treatments included NPK (recommended dose), farmyard manure (FYM), goat manure, vermicompost + FYM, jholmol, mustard seed cake, and a control. The results showed significant treatment effects, with goat manure yielding the highest fresh pod yield (52.15 g/plant), while the control showed the lowest (40.56 g/plant). Path coefficient analysis revealed that plant height (direct effect = 1.79) and the number of pods (direct effect = 0.96) had the strongest direct effects on fresh pod yield. Correlation analysis showed a strong positive correlation between fresh pod yield and the number of pods ( $r = 0.90$ ) and fresh pod weight ( $r = 0.84$ ). The study supports the use of organic fertilizers, especially goat manure, for sustainable okra production and highlights the value of path analysis in identifying indirect traits like plant height and pod number to enhance selection for yield in breeding programs.

### HIGHLIGHTS

- Goat manure gave the highest okra yield (52.15 g/plant)
- Strong correlations found between yield vs. pod number ( $r = 0.90$ )
- Plant height and pod number had strong direct effects on yield.
- Organic fertilizers enhance sustainable okra production.

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## 1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench), commonly known as lady's finger (English) or bhindi (South Asia) or gumbo (Wolof language in West Africa), is a vegetable crop of economic significance within the Malvaceae family. It originated in tropical Africa and spread to both tropical and subtropical regions of the world, grown for its tender green fruits (Harisha et al., 2022). It thrives best in hot, humid climates with nighttime highs of over 20°C (Anwar et al., 2011). It has a higher calorie content compared to other vegetable crops, including spinach, cabbage, and pumpkin (Babatunde et al., 2007). Globally, okra is valued for its versatility, with applications ranging from industrial and medicinal uses (due to its linoleic acid and nutritional fiber content) to culinary purposes, where it is consumed in both raw and cooked forms (Yadav & Dadhich, 2022). Additionally, it is rich in vitamins, amino acids, and carbohydrates (Kumar et al., 2017).

Okra is one of the important culinary vegetables mostly grown in the Terai region (sub-tropical) of Nepal. The total production throughout the country is 110,565 metric tonnes planted on 9,584 hectares of land with a productivity of 11.54 t/hac (STATISTICAL INFORMATION ON NEPALESE AGRICULTURE 2077/78 (2020/21), 2022). Although Nepal's productivity is comparable to

high-yielding nations like Egypt, Saudi Arabia, and India (Yadav & Dadhich, 2022), sustainable production remains a challenge due to long-term soil health degradation and over-reliance on inorganic fertilizers. To address these issues, the adoption of organic amendments suited to Nepal's unique agro-climate conditions is essential. Organic fertilizers are gaining popularity globally because they reduce fertilization costs and support sustainable energy practices (IPI, 1982; Tihamiyu et al., 2012). Moreover, the use of inorganic fertilizers late in the growing season can lead to reduced crop yields, soil acidification, and nutrient imbalances (Tihamiyu et al., 2012). In contrast, organic amendments significantly enhance okra yield (Aboyeji, 2022), and thus, to sustain agricultural output, it is essential to maintain soil fertility and nutrient availability (Jaja, 2015).

Organic manures are vital for sustainable agriculture as they improve soil's physical, chemical, and biological properties, retain moisture, boost crop yields, and ensure crop quality (Engball et al., 2002). Compared to inorganic fertilizers, manures offer long-term benefits for crop development and yield (Shiyam et al., 2016). Vermicompost, produced by earthworms from organic waste, enriches the soil with minerals like potassium, phosphate, and nitrogen, enhancing soil structure, nutrient content, and cation exchange capacity (Kumar et al., 2012). Increased quantities of goat manure have been shown to accelerate okra growth and pod

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production (Awodun, 2007). Additionally, plant-derived manures, such as sesame oil cakes, neem oil cakes, mustard oil cakes, and castor cakes, reduce Phyto nematode prevalence, thereby promoting plant growth and productivity (Sumbul et al., 2015). Beyond soil health and sustainability, organic produce is becoming increasingly popular among consumers, with organic agriculture practiced in 191 countries, including the USA, India, Germany, and Brazil (Willer et al., 2023). While previous studies have established the effect of organic fertilizers on okra yield, the comparison of their effects through path coefficient analysis and correlation has been limited in Nepal's subtropical climate. Even fewer studies have been implemented to identify key agronomic traits that have direct or indirect effects on yield improvement. This study addresses this gap by determining the direct and indirect effects of agronomic traits on yield and exploring the potential for indirect selection in breeding programs.

The primary objectives of this study were twofold. The first objective of this study was to evaluate the impact of selected organic amendments (e.g., goat manure, mustard seed cake, and jholmol) on the growth and yield of okra under Nepal's specific agro-climatic conditions. The second objective was to utilize correlation and path coefficient analysis to identify key traits influencing fresh pod yield. This approach, which examines both the direction and magnitude of trait correlations, provides a robust framework for improving breeding strategies. The results from this analysis aim to optimize organic farming practices and inform future breeding programs for okra cultivation in Nepal. The research is based on the hypothesis that organic fertilizers enhance soil nutrient availability, microbial activity, and plant growth, thereby leading to higher okra yields.

2. Materials and Methods

2.1. Experimental site

The field experiment was conducted at G.P. Koirala College of Agriculture and Research Centre (GPCAR) in Sundarharaicha, Morang, Nepal, from April 2 to July 29 (2023), aimed at assessing the yield of the "Arka Anamika" okra variety. The area has a tropical climate characterized by an annual rainfall of 858.75 mm and the mean annual temperature ranging from 18.81 to 33.46°C (Ishwar et al., 2024). The site coordinates are 26° 40' 49.9" N latitude, 87° 21' 16.7" E longitude, and 149 meters from sea level.

2.2. Materials

The materials used included organic manure and inorganic fertilizer as treatments (Table 1), which were collected from farmers, and okra seeds (*Arka Anamika*) as a planting material

Table 1. List of treatments along with corresponding doses

| S/N | Symbol | Treatments             | Doses                               |
|-----|--------|------------------------|-------------------------------------|
| 1   | T1     | NPK (Recommended dose) | 100:60:50 kg/ha                     |
| 2   | T2     | FYM                    | 20 t/ha                             |
| 3   | T3     | Goat Manure            | 3 t/ha                              |
| 4   | T4     | Vermicompost +FYM      | 5 t/ha (vermicompost)               |
| 5   | T5     | Jholmol                | 10 litter /plot (1jholmol: 5 water) |
| 6   | T6     | Seed Cake (Mustard)    | 2 t/ha                              |
| 7   | T7     | Control                | Untreated                           |

Abbreviation: FYM - Farmyard Manure, NPK - Nitrogen, Phosphorous, and Potassium

collected from the agrovet in Biratnagar. The preparation and application of these organic amendments are discussed below:

Jholmol: Jholmol, a traditional fermented organic liquid fertilizer, was prepared by fermenting cow urine, molasses, and water in a ratio of 1:1:5 for seven days in an airtight container under shade to enhance microbial activity. Before application, it was diluted at a 1:5 ratio with water and applied as a soil drench at 10 liters per plot.

Goat Manure: Goat manure was collected from a local farm, sun-dried for 15 days to reduce moisture content, and applied at a rate of 3 tons/ha. It was incorporated into the soil to a depth of 10 cm one day before planting to allow decomposition.

Mustard Seed Cake: Mustard seed cake was obtained from a processing unit, crushed into powder form, and applied at 2/ha. It was mixed with soil and left undisturbed for one week before planting to allow for the slow release of nutrients.

2.3. Experimental design, treatments, and agronomic practices

The experiment was laid out in a randomized complete block design (RCBD) with seven treatments, each replicated three times, totaling 21 experimental plots. Each plot measured 3 m x 1.5 m (4. 5m<sup>2</sup>) with a space of 0.5m between each plot within the block and 1m between each block, contributing to a total area of 14.5 m x 13m (188.5 m<sup>2</sup>). There were 25 plants per plot, planted 60 cm apart between rows and 30 cm between plants. The treatments were randomly assigned to each plot. Table 1 outlines the specifics of every treatment used in the study, along with the corresponding doses.

The soil was tilled to a fine tilth to prepare for sowing. One week prior to sowing, the organic manure was crushed and mixed into the soil, full doses of potassium and phosphorus and half of the nitrogen were applied during the sowing phase; the remaining half of the nitrogen dose was divided into 2 parts, first applied at three weeks after sowing and then at flowering stage (Jagdish, 2024). Four okra seeds were planted per hole. After germination, the seedlings were thinned to two plants per stand. The growth of the weeds was controlled by hand weeding, followed by irrigation. During the early stages of growth, flowering, and fruit development, irrigation was used. Neem oil was used as an insecticide.

2.4. Data collection

For every replication, the observations were made in five randomly selected and tagged plants on agronomic traits viz., plant height (cm), number of pods per plant, fresh pod diameter (cm), fresh pod yield per plant (gm), number of primary branches, fresh pod length (cm), and fresh weight per pod (gm) at a stage of 50% flowering and were continued in the interval of a week till harvest (Days after sowing: 40, 47, 54, 61, 68, 75, 82, 89, 96, 103, 110, and 117).

2.5. Statistical analysis

Microsoft Excel was used for data entry and tabulation. A two-way analysis of variance (ANOVA) was conducted in R Studio version 4.4.1 (R Core Team, 2024) after verifying the assumptions of homogeneity of variances (Levene's test) and normality (Shapiro-Wilk test). Post hoc analysis using Tukey's Honest Significant Difference (HSD) test (P < 0.05) was used for multiple comparisons, with significant differences among treatment means presented as superscripts in tables denoting statistically different means. Pearson correlation was used to assess relationships

**Table 2.** Effect of treatment application on different agronomic traits over time

| Mean for Treatment * Time | PH                        | NP                      | PD                      | PB                      | PW                       | FY                       |
|---------------------------|---------------------------|-------------------------|-------------------------|-------------------------|--------------------------|--------------------------|
| <b>NPK</b>                | <b>100.69<sup>a</sup></b> | 2.35 <sup>abc</sup>     | 7.08 <sup>ab</sup>      | <b>3.24<sup>a</sup></b> | 21.32 <sup>a</sup>       | 48.46 <sup>ab</sup>      |
| <b>Goat manure</b>        | 99.38 <sup>ab</sup>       | <b>2.70<sup>a</sup></b> | 6.93 <sup>ab</sup>      | 2.65 <sup>b</sup>       | 21.15 <sup>ab</sup>      | <b>52.15<sup>a</sup></b> |
| <b>Vermicompost + FYM</b> | 98.29 <sup>abc</sup>      | 1.94 <sup>c</sup>       | 6.89 <sup>ab</sup>      | 2.64 <sup>b</sup>       | 20.51 <sup>abc</sup>     | 43.41 <sup>bcd</sup>     |
| <b>Jholmol</b>            | 94.19 <sup>bcd</sup>      | 1.91 <sup>c</sup>       | 6.92 <sup>ab</sup>      | 2.76 <sup>b</sup>       | 18.01 <sup>c</sup>       | 38.65 <sup>d</sup>       |
| <b>FYM</b>                | 93.58 <sup>cde</sup>      | 2.46 <sup>ab</sup>      | 6.49 <sup>ab</sup>      | 2.92 <sup>ab</sup>      | 19.82 <sup>abc</sup>     | 46.82 <sup>abc</sup>     |
| <b>Seedcake</b>           | 92.38 <sup>de</sup>       | 2.64 <sup>a</sup>       | <b>7.37<sup>a</sup></b> | 2.87 <sup>ab</sup>      | <b>21.68<sup>a</sup></b> | 50.32 <sup>ab</sup>      |
| <b>Control</b>            | 88.01 <sup>e</sup>        | 2.06 <sup>bc</sup>      | 6.26 <sup>b</sup>       | 2.91 <sup>ab</sup>      | 18.22 <sup>bc</sup>      | 40.56 <sup>cd</sup>      |
| <b>CV %</b>               | 8.05                      | 21.35                   | 4.82                    | 6.03                    | 16.70                    | 21.35                    |

For each column, mean values with different letters are significantly different ( $P < 0.05$ ); Tukey HSD post hoc test; superscripts used only for significant differences according to ANOVA; **Bolded values** are the highest among the treatments; NPK = nitrogen, phosphorus, and potassium; PH = plant height; NP = number of pods per plant; PD = fresh pod diameter; PB = number of primary branches; PL = fresh pod length; PW = fresh weight per pod (gm); and FY = fresh pod yield per plant (gm).

among various agronomic traits, while path coefficient analysis, performed using semPlot (Epskamp, 2013), lavaan, and lavaanPlot (Gana & Broc, 2019) packages in R to elucidate the direct and indirect effects of the agronomic traits on fresh pod yield.

### 3. Results and Discussion

#### 3.1. Sources of variation analysis

Table 2 presents the results from the two-way ANOVA between treatment and time on traits. Both treatment and time significantly affected plant height, pods per plant, fresh pod yield per plant, fresh pod diameter, number of primary branches, and fresh weight per pod. Fresh pod length was only significantly affected by the timing of measurements, not by the treatments. However, the interaction between treatment and time also revealed noteworthy insights, indicating that certain treatments performed better at specific time intervals. This suggests that optimizing both the treatment applied and the timing of application could enhance overall fresh yield significantly. Treatment and time significantly affected fresh pod yield ( $p < 0.01$ ) and fresh weight per pod ( $p < 0.01$ ), showing varying changes across treatments. A similar impact was observed by Alam et al. (2020) and El-Shaieny & Bashandy (2022) in Okra. Goat manure resulted in the highest pod yield (52.15 g/plant), likely due to its sustained nutrient release and microbial activity, while jholmol had the lowest (35.65 g/plant), possibly due to rapid nutrient leaching (Alam et al., 2020). Similar improved performance was observed by Ojeniyi et al., 2007 when applying goat manure, as it improved soil organic matter and moisture retention in tomatoes. Similarly, a research by Gichangi et al., 2009 observed that goat manure addition increased soil microbial biomass phosphorus, indicating enhanced microbial activity. A research study on Mustard seed cake performed well in fresh weight per pod (21.68 g) but provided lower nitrogen than goat manure. The control consistently showed the lowest values across measured traits, aligning with findings from Bhattarai et al. (2020).

#### 3.2. Correlation analysis

The Pearson correlation coefficients for various agronomic traits, as presented in Table 3, were analyzed to understand their interrelationships. From the data, we can clearly observe that fresh pod yield (FY) showed a positive phenotypic correlation with all traits. Fresh pod yield showed the highest statistically significant correlation with the number of pods ( $r = 0.90$ ;  $p \leq 0.01$ ),

followed by a strong statistically significant correlation with fresh pod weight ( $r = 0.84$ ;  $p \leq 0.01$ ). Similar results on the high correlation between the number of pods and pod yield were obtained by Alam et al. (2020), Ejaz-UI-Hasan et al. (2013), Ghimire et al. (2020), and Yadav et al. (2017), and contrasting results of lower non-significant correlation were obtained in the West African region by Adeniji & Aremu (2007) in Okra.

Additionally, pod diameter ( $r = 0.49$ ;  $p \leq 0.05$ ) and plant height ( $r = 0.45$ ;  $p \leq 0.05$ ) also showed significant correlations with fresh pod yield. A similarly high significant correlation was observed by Ariyo et al. (1987) and Tilahun et al. (2022), whereas Yadav et al. (2017) observed a contrasting result, i.e., no correlation between pod diameter and fruit weight. A similar high correlation between fresh pod yield and plant height was obtained by Aman et al. (2020), Ejaz-UI-Hasan et al. (2013), Ghimire et al. (2020), and Yadav et al. (2017). Other than fresh pod yield, plant height (PH) showed moderate positive correlations with pod diameter (PD) ( $r = 0.47$ ;  $p \leq 0.05$ ), pod length (PL) ( $r = 0.44$ ;  $p \leq 0.05$ ), and fresh pod weight (PW) ( $r = 0.62$ ;  $p \leq 0.01$ ). Similar associations of plant height were observed by Ejaz-UI-Hasan et al. (2013) and Tilahun et al. (2022). Pod diameter (PD) was strongly positively correlated with fresh pod weight (PW) ( $r = 0.72$ ;  $p \leq 0.01$ ). The number of primary branches (PB) did not show significant correlations with most other traits, except for a weak positive correlation with pod length (PL) ( $r = 0.31$ ;  $p \leq 0.05$ ). Similar non-significant associations were observed by Tilahun et al. (2022) and R. K. Yadav et al. (2017). In summary, the traits influencing fresh pod yield, ranked from the highest to the lowest correlation, are the number of pods (NP), fresh pod weight (PW), pod diameter (PD), and plant height (PH). Understanding these relationships is crucial for selecting traits that contribute substantially to yield improvement.

PH - plant height, NP - number of pods per plant, PD - fresh pod diameter, PB - number of primary branches, PL - fresh pod

**Table 3.** Phenotypic Correlation between each agronomic trait

|    | PH | NP   | PD    | PB   | PL    | PW     | FY            |
|----|----|------|-------|------|-------|--------|---------------|
| PH | 1  | 0.11 | 0.47* | 0    | 0.44* | 0.62** | <b>0.45*</b>  |
| NP |    | 1    | 0.32* | 0.26 | 0.06  | 0.57*  | <b>0.90**</b> |
| PD |    |      | 1     | -0.1 | 0.42* | 0.72** | <b>0.49*</b>  |
| PB |    |      |       | 1    | 0.31* | 0.05   | 0.21          |
| PL |    |      |       |      | 1     | 0.48*  | 0.26          |
| PW |    |      |       |      |       | 1      | <b>0.84**</b> |
| FY |    |      |       |      |       |        | 1             |

length, PW - fresh weight per pod (gm), and FY - fresh pod yield per plant (gm). For the interpretation above, the correlation coefficients were interpreted as weak correlation for values between  $\pm 0.00$  and  $\pm 0.39$ , moderate correlation for values between  $\pm 0.40$  and  $\pm 0.59$ , and strong correlation for values above that.

### 3.3. Path Analysis

The results from path coefficient analysis are depicted in both Table 4 and the path diagram (Figure 1). The table represents the path coefficient analysis for the relationships among six traits: Plant Height (PH), Number of Pods (NP), Pod Diameter (PD), Pod Breadth (PB), Pod Length (PL), and Fresh Pod Yield (FY). Our results from the path coefficient analysis revealed that all traits studied (with weight per pod (PW) omitted from the path analysis as it is an intermediary step, and its association is determined by other variables) had a positive direct effect on fresh pod yield (referred to as yield in this path analysis). Some of the researchers, Adeniji & Aremu (2007) and Yadav et al. (2017), observed similar positive direct effects of all similar traits on pod yield.

The highest direct effect on yield was exhibited by plant height (1.79). This implies that plant height has a much higher direct effect than its moderate correlation coefficient (0.45), indicating that selection for taller plants is likely to significantly boost yield. A similar high direct effect was reported by (Adeniji & Aremu, 2007; Aman et al., 2020; Ejaz-Ul-Hasan et al., 2013)). Contrasting negative direct effects were reported by (Al-Juboori, 2021; Aman et al., 2020). However, it's important to recognize that the negative effects reported by Aman et al., 2020 were observed in maize, which could potentially be the case in other crops. The number of pods exhibited the second highest direct effect on yield (0.96), which is higher than its correlation coefficient with yield (0.90). This implies that selection for yield based on the number of pods would be effective. A similar higher direct effect was observed by (Al-Juboori, 2021). Pod diameter (PD) contributed a high direct effect on yield (0.45), which is similar to the correlation coefficient (0.49), suggesting that thicker pods contribute moderately to yield. Usman et al. (2017) also reported similar results of the positive impact of pod diameter on yield. Pod Length (PL) had an equal direct effect on yield (0.26) and correlation with yield (0.26), suggesting a positive impact but not significant on yield improvement. A similar positive direct impact of PL was also reported by (Alam et al., 2020). The number of primary branches (PB) had a lower direct effect on yield (0.14), similar to its correlation coefficient (0.21). This implies that PB doesn't contribute as much to yield improvement as shown by the correlation coefficient, highlighting the importance of using path

**Table 4.** Direct (**boldface**) and indirect effects of different traits on fresh pod yield.

|    | PH           | NP           | PD           | PB           | PL           | FY           |
|----|--------------|--------------|--------------|--------------|--------------|--------------|
| PH | <b>0.321</b> | 0.106        | 0.212        | 0.001        | 0.114        | 0.450        |
| NP | 0.197        | <b>0.132</b> | 0.144        | 0.036        | 0.016        | 0.900        |
| PD | 0.841        | 0.307        | <b>0.576</b> | -0.014       | 0.109        | 0.490        |
| PB | 0.010        | 0.250        | -0.045       | <b>0.883</b> | 0.081        | 0.210        |
| PL | 0.788        | 0.058        | 0.189        | 0.043        | <b>0.933</b> | 0.260        |
| FY | 0.806        | 0.864        | 0.221        | 0.029        | 0.067        | <b>1.000</b> |

Each value in the table indicates the strength and direction of the direct and indirect effects of one trait on another; PH = plant height; NP = number of pods per plant; PD = fresh pod diameter; PB = number of primary branches; PL = fresh pod length; and FY = fresh pod yield per plant (gm)

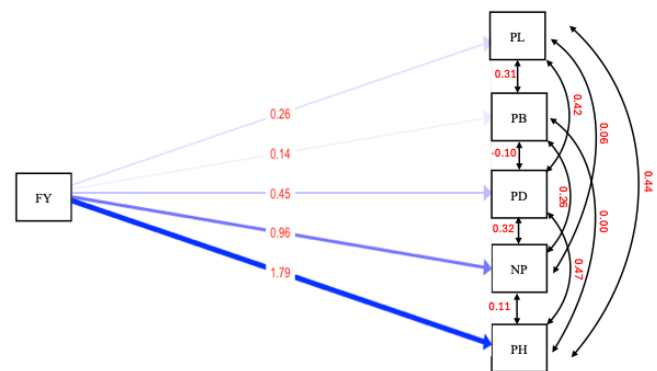
coefficient analysis for trait selection. Alam et al. (2020) reported a similar higher correlation but lower impact of PB on yield.

The analysis of indirect effects revealed that pod diameter (PD) had the highest indirect effects on yield (FY) through plant height (PH) (0.84), followed by pod length (PL) through plant height (0.788). Yield itself had a high indirect effect through plant height (0.806) and through the number of pods (0.864). The number of pods (NP) also contributed to yield indirectly through plant height (0.197). Plant height (PH) exhibited moderate indirect effects through pod diameter (0.212), pod length (0.114), and number of pods (0.11). Similar higher indirect effects of NP on yield through plant height were observed by (R. K. Yadav et al., 2017). Combining the direct and indirect effects, the integrated analysis reveals that plant height (PH) and number of pods (NP) are the most influential traits for improving fresh pod yield (FY). Pod diameter (PD) also significantly impacts FY, both directly and indirectly, through its relationships with PH and NP. If only correlation coefficients were considered, pod diameter ranked better than the number of pods, but NP has a much greater direct and indirect impact on yield than PD, as shown from this path analysis.

A major limitation in conventional selection approaches in plant breeding is the overemphasis on direct effects, often neglecting the complex interactions among correlated traits (Falconer & Mackay, 1996). Indirect selection has been widely used in animal breeding, but its application in plant breeding is less common. The role of these indirect effects as secondary traits can be crucial in breeding programs, where multi-trait selection strategies could be more effective than focusing on individual traits (Bernardo, 2020). This opens an avenue for selection of genotypes based on correlated traits. In this scenario, the okra varieties could be selected for yield based on their plant height and number of pods. This would reduce the breeding cycle and improve response to selection.

The findings here suggest that although PD alone may not be the strongest predictor of yield, its interaction with PW, NP, and PH plays a crucial role in yield improvement. Breeding programs should consider these indirect pathways in their selection decisions for maximizing fresh pod yield potential. By understanding the intricate interrelationships among traits, breeders can develop more effective strategies for enhancing yield in agricultural practices. This can be achieved by allocating correlation coefficients into direct and indirect effects using path analysis (Dewey & Lu, 1959; Ghimire et al., 2020).

The double-headed lines (black lines) indicate correlation coefficients between two traits, and the single-headed lines (blue



**Figure 1.** Diagrammatic representation of path coefficient for fresh pod yield in okra.

lines) represent the direct influence of each trait on fresh pod yield (FY). The thickness and color intensity of the blue lines represent the strength of the direct effect.

### 3.4. Possible Cofounding Factors and Future Directions

Environmental conditions, such as temperature fluctuations and soil moisture levels, may have influenced the treatment efficiencies. The superior performance of goat manure could be attributed to its solid and coarse texture, which enhances soil moisture retention and stimulates microbial activity, thereby promoting nutrient availability (Gichangi et al., 2009; Ojeniyi et al., 2007). In contrast, the liquid nature of jholmol makes it more prone to leaching during heavy rainfall and limits its capacity for sustained nutrient release over time.

This study was conducted over a single season with a limited sample size, which may affect the generalizability of the findings. Future studies should incorporate multi-seasonal experiments, optimize application timing, and assess the economic feasibility of large-scale application of organic amendments. Additional studies on the microbial dynamics of soil under different organic treatments can also provide insights for long-term soil fertility management. For selection and breeding purposes, future research should focus on identifying key agronomic traits, understanding trait heritability, and genotype-by-environment interactions under organic management systems to aid in developing high-yielding okra varieties. Furthermore, considering resource availability, integrating advanced genomic selection for yield-related quantitative traits could further enhance breeding efforts and improve selection efficiency.

## 4. Conclusion

This study confirms that goat manure is a viable alternative to inorganic fertilizers, significantly enhancing both okra yield and soil health. Among the treatments, goat manure resulted in the highest fresh pod yield, likely due to its high nitrogen content, improved microbial activity, and better soil structure. Correlation and path coefficient analysis identified plant height and the number of pods per plant as key traits influencing yield, highlighting their importance for breeding programs. However, the confounding environmental factors, limited trial size, and single-season study may have affected the generalizability of the results. Further research should incorporate multi-season trials, compare organic treatments with NPK at farmer-recommended doses, explore varying application rates of organic amendments, and assess the economic sustainability of organic farming practices.

## CRedit authorship contribution statement

**BKS:** Resources, field work, methodology, data collection and entry, writing draft, funding acquisition. **AKS:** Data entry, writing draft, supervision, editing, visualization. **AC:** Field work, data collection and entry, methodology. **RI:** Field work, data collection and entry, methodology. **SG:** Data analysis, writing draft, reviewing and editing. **DG:** Data curation, data analysis, writing draft, visualization, editing, reviewing, Resources.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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