Original Research Article

**Phosphorus Application improved Growth and Yield of Okra (*Abelmoschus esculentus* L.) During the *Kharif* Season in Bangladesh**

**ABSTRACT**

|  |
| --- |
| Okra (*Abelmoschus esculentus* L.) plays a prominent role in the culinary traditions of various tropical and subtropical regions, such as the Southern United States, India, West Africa, and the Middle East.The nutritional contribution of okra extends to being a rich source of dietary fibre, vitamins and minerals like potassium and magnesium. Understanding the relation between okra growth and phosphorus levels can help increase agricultural yield while reducing the adverse environmental impacts. In order to support sustainable agricultural practices, this study intends to investigate the effects of varying phosphorus levels on the growth attributes and productivity of okra. The experiment was conducted at the field experimental station of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the *Kharif* season (April to August) of 2023 to investigate the influence of different phosphorus levels on the growth, yield attributes, and yield of okra (*Abelmoschus esculentus* L.). This experiment was conducted using a randomised complete block design (RCBD) with four replications. The experimental treatments consisted of two okra varieties, namely 'BARI Dherosh-2' and 'Chamak' and four levels of phosphorus, viz., 0.0, 70.0, 90.0, and 110 kg P₂O₅ ha⁻¹. Data on plant height, leaves per plant, petiole length, stem diameter, internode length, and branches per plant were recorded at 20, 40, 60, 80, and 100 days after sowing (DAS). Days required to first flowering, number of floral buds per plant, number of pods per plant, individual pod weight, pod length and diameter, pod yield, and dry matter accumulation in different plant parts were also recorded. The result indicated that the vegetative growth parameters and yield-contributing characters were significantly improved with phosphorus fertilisation. The ‘BARI Dherosh-2’ when treated with 90 P₂O₅ ha⁻¹ resulted in maximum plant height (99.27 cm at 100 DAS), branches per plant (4.68 at 100 DAS), fruits per plant (36.65), and fruit yield (14.94 t ha⁻¹). The results were statistically similar to those obtained with the treatment combination using the same variety at 110 P₂O₅ ha⁻¹. It has been concluded that 'BARI Dherosh-2', along with a dosage of 90 kg P₂O₅ per hectare, could be a suitable dose for cultivating okra during the kharif season in Bangladesh. |

***Keywords****: Okra; BARI Dherosh-2; kharif* season*; sustainable agriculture, yield, productivity*

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a vegetable crop typically cultivated for its tender, green fruits, which are prized for their culinary versatility and nutritional value. It plays a prominent role in the culinary traditions of various tropical and subtropical regions, such as the Southern United States, India, West Africa, and the Middle East. It is an annual vegetable that grows quickly and has become a popular choice. It is a crop with many uses. It is primarily important for its immature fruits, which are consumed as cooked vegetables (Singh et al., 2025). A key ingredient in dishes like gumbo, a popular Creole creation, and featured in soups, stews, and curries, okra's mild, slightly nutty flavour and distinctive texture make it a favourite across diverse culinary landscapes (Reed, 2006).

The nutritional contribution of okra extends to being a rich source of dietary fibre, vitamins and minerals like potassium and magnesium. With dietitians recommending a daily vegetable intake of 285g for adults (Rampal and Gill, 1990), okra proves to be a healthy addition. Its antioxidant content, low-calorie nature, and potential health benefits, including blood sugar regulation and digestive health support, make it a favourable choice.

Traditionally, okra has found use in various cultures for its perceived health benefits. It is thought to regulate blood sugar, aid in digestive health, and offer relief from conditions like constipation. Being heat-tolerant and drought-resistant, okra is well-suited for cultivation in hot and dry climates (Singh et al., 2024). Its short growing cycle and high yield potential make it a crucial cash crop for small-scale farmers in many developing nations.

Phosphorus, an essential macronutrient, plays a vital role in various plant physiological processes such as photosynthesis, energy transfer, and nucleic acid synthesis (Raghothama, 1999). It is crucial for root development, flowering, and fruiting (Schachtman *et al*.,1998). Phosphorus deficiency in okra can lead to reduced root growth, delayed flowering, and poor fruit formation, impacting fruit yield and quality (Patel at al., 2024). Maity et al. (2022) observed a 75 per cent yield increase with phosphorus application at 56 kg ha-1, highlighting its importance in fruiting development.

Referred to as "the life key," phosphorus plays a critical role in numerous physiological processes. Achieving high-quality okra green fruit yields necessitates the right fertiliser amounts, with phosphorus fertiliser holding significance in this context (Kumari et al., 2025). Despite varying outcomes in research reports, understanding the specific impact of phosphorus levels on okra's growth is crucial for tailoring nutrient management practices. This becomes especially important amid increasing global demand for nutritious and sustainable food sources.

In recent years, increasing focus on sustainability has raised serious concerns about the long-term effects of chemical fertiliser application on soil fertility and environmental integrity (Ingle et al., 2024; Pradhan et al., 2025) (Syers et al., 2008). Inorganic fertilisers pose a threat to the ecosystem, while organic ones are eco-friendly. Due to the deleterious effects of inorganic fertilisers, there is a need to explore the use of organic-based fertilisers, which are environmentally friendly (Oluleye et al., 2023). Due to its limited soil availability and potential for environmental runoff, phosphorus management requires optimisation (Cordell et al., 2009). Understanding the relation between okra growth and phosphorus levels can help increase agricultural yield while reducing the adverse environmental impacts. In order to support sustainable agricultural practices, this study intends to investigate the effects of varying phosphorus levels on the growth attributes and productivity of okra. Besides, the study aims to find out a suitable combination of phosphorus and okra varieties for ensuring a higher yield of the crop, which could ultimately help the growers.

2. material and methods

2.1 Experimental Site

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh, during the *Kharif* season (April 2023 to August 2023). Geographically, the experiment site was located at 23°74’N latitude and 90°35’E longitude, with an elevation of 8.1 m above sea level. The experimental site had a subtropical climate and was a part of the Modhupur Tract (AEZ-28). The soil was shallow red-brown terrace soil with a silty clay texture. Before transplanting, four 0-20 cm topsoil cores were collected from the experimental field using a standard auger for analysis of physicochemical properties. The properties of topsoil are shown in Table 1.

2.2 Planting Material

Two okra varieties were used as planting materials, viz. (i) BARI Dherosh-2 and (ii) ACI Okra “Chamak”. The seeds were obtained from the Bangladesh Agricultural Research Institute in Joydebpur, Gazipur and Siddiq Bazar, respectively.

**Table 1. Physical and chemical properties of experimental soil (0-20 cm)**

|  |  |  |
| --- | --- | --- |
| Particulars | Value | Methods |
| Sand (%)Silt (%)Clay (%) | 165628 | Hydrometer meter method (Gee and Bauder, 1986) |
| Bulk density, g c m-3 | 1.23-1.45 | Core Sampler methods (Blake and Hartge, 1986) |
| pH (1: 2.5: Soil: Water) | 5.56 | Glass Electrode method |
| Organic carbon (g kg-1) | 0.45 | K2Cr2O7oxidation-titration method (Blake, 1965) |
| Extractable P (g kg-1)Total N, % | 0.0430.064 | Olsen method Modified Kjeldahl Method (Bremner and Mulvaney,1982) |

**2.3 Experimental design and Treatments**

The experiment was conducted under field conditions using a 2×4 factorial randomised complete block design (RCBD) with four replications. Four levels of phosphorus (P) fertiliser were applied, viz, T0: 0 kg P2O5 ha-1 (control), T1: 70 kg P2O5 ha-1, T2: 90 kg P2O5 ha-1, and T3: 110 kg P2O5 ha-1. The total experimental area was 300 m2 (30 m length × 10 m width divided into 4 blocks. Each block had 8 treatments placed randomly, making 32 treatment plots in total. Each unit plot was 3.0 m long and 2.0 m wide, maintaining a 1.0-meter spacing between blocks and a 0.5-meter spacing between two plots.

**2.4 Growth Conditions and Management**

The okra seeds were sown on 6th April, 2023, in the main field. To manage soil-borne diseases, Bavistin was applied as a treatment for the seeds were treated with Bavistin to prevent soil-borne disease. Seeds were placed in rows at a depth of 2-3 cm, with 30 cm spacing between plants and 60 cm between rows. After seedling germination, Intercultural operations such as gap filling, weeding, earthing up, irrigation, and pests and diseases control were conducted to promote healthy growth and enhance yield whenever necessary. Cinocarb 3 G was applied during the final land preparation, and mechanical methods and the application of Darsban 29 EC at a 3% concentration were used to manage cutworms. Diseased, discoloured and yellowish leaves were also removed to ensure healthy plant growth and development. The okra fruits were harvested at intervals of every 4 days based on eating quality. Harvesting commenced on May 22, 2023, and continued till July 15 2023, to ensure optimal ripeness and quality for consumption or processing.

**2.5 Data Collection**

To assess the impact of various treatments in the experiment on plant growth, yield attributes, and overall yield, data were collected systematically. Five plants were randomly chosen from the middle rows of each unit plot to avoid any border effects. Data were collected on the following parameters: plant height, number of leaves, length of petiole, diameter of stem, length of leaf, number of branches per plant, length of internode, diameter of fruit, fresh weight of plant, dry weight of plant, yield/plot, and yield/hectare.

These parameters were recorded at four different time points: 20, 40, 60, 80 and 100 days after sowing (DAS). Additionally, the fresh weight of leaves per plant and the dry weight per plant were measured at 100 DAS. Other crucial yield-related characteristics and parameters were also documented, such as: The number of days required for flowering to occur, the Number of flowers per plant, the Number of fruits per plant, the Weight of individual fruits, the Length of fruits, the Diameter of fruits, and Yield per plot.

**2.5 Data Analysis**

The collected data were statistically analysed using Statistix 10 software. Mean for treatments were calculated, and analysis of variance and difference between treatment means was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

3. results and discussion

**3.1 Plant height**

Plant height of okra exhibited significant variations at 20, 40, 60, 80, and 100 days after sowing (DAS) in response to different phosphorus levels (Table 1). Phosphorus application increased plant height by 11.1 to 35.9% over the control. At each time point, T2 treatment yielded the tallest plants, which were statistically similar to T3 treatment. T1 treatment showed intermediate heights, while the shortest plants were observed under T0 (control). The interaction effect of P doses and varieties on plant height also indicated similar trends. The combination V1T3 exhibited the highest plant heights (18.0, 40.52, 74.97,

86.65, and 99.27 cm at 20, 40, 60, 80, and 100 DAS). Conversely, the V2T0 treatment produced the lowest plant height. Increases in plant height attributed to phosphorus application were also documented by Uddin *et al.* (2014). This trend also aligns with the findings of Bhai and Singh (1998).

**Fig. 1.** Bar graph showing interaction effects of phosphorus doses and varieties on plant height of okra at different days after sowing (DAS). In a bar, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. V1, BARI Dherosh-2; V2, Chamak. T0, 0 kg P2O5 ha-1, T1, 70 kg P2O5 ha-1; T2, 90 kg P2O5 ha-1; T3, 110 kg P2O5 ha-1. DAS, days after sowing.

**3.2 Internode length**

Phosphorus application significantly improved the average internode length of okra recorded at final harvest (100 DAS) (Table 2). BARI Dherosh-2 and Chamak varieties showed 8.13 to 40.08% and 13.5 to 29.41% improvements with selected phosphorus treatments, respectively. The longest average internode (14.73 cm) was produced by BARI Dherosh-2 with T2 (90 kg P2O5 ha-1) treatment, which was statistically similar to the internode length of the same variety under T3 (110 kg P2O5 ha-1). The Chamak variety also produced the longest internode with T2 treatment; however, compared to BARI Dherosh-2, its average internode length was 14.9% shorter at similar phosphorus levels. Both varieties produced the shortest internode length under T0 (0 kg P2O5 ha, i.e., control condition). These findings underscore that both the variety and the application of phosphorus can influence internode length. Previous studies suggested that the application of phosphorus significantly increases internode length of okra (Uddin et al., 2014; Bhai and Singh,1998).

**Fig. 2.** Bar graph showing interaction effects of phosphorus doses and varieties on average internode length of okra at final harvest (100 DAS). In a bar, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. V1, BARI Dherosh-2; V2, Chamak. T0, 0 kg P2O5 ha-1; T1, 70 kg P2O5 ha-1; T2, 90 kg P2O5 ha-1; T3, 110 kg P2O5 ha-1. DAS, days after sowing.

**3.3 Leaves number**

Phosphorus application significantly improved the leaf number of okra recorded at 20, 40, 60, 80, and 100 days after sowing (DAS) in response to different phosphorus levels (Table 3). The highest leaf number (49.47plant-1) of okra was observed from T2 (90 kg P2O5 ha-1) treatment, which was statistically similar to T3 (110 kg P2O5 ha-1) treatment. Interaction effects of variety and phosphorus level also showed significant variation in okra leaf production. The V1T2 produced the maximum leaf number at different days after sowing, which were 17.8 to 22.6% and 16.3 to 28.2% greater than the V1T0 and V2T0 treatments, respectively. Okra leaf production per plant at different DAS under V2T2 treatment was significantly higher than V2T0 treatment and statistically identical with V2T3 treatment, but **11.6 to 13 % less** compared to V1T2 treatment. Overall, data indicated that phosphorus improves leaf production in okra. The result aligns with those reported by Uddin et al. (2014), who observed that better phosphorus-nourished okra plants show higher growth, as reported for number of leaves, leaf size and branch numbers. However, V1 (BARI Dherosh-2) produced more leaves than V2 (Chamak), highlighting its superior photosynthetic potential.

**Table 2. Effect of** phosphorus doses  **on leaves number of okra at different days after sowing**

|  |  |
| --- | --- |
| **Treatments** | **Leaves number** |
| **20 DAS** | **40 DAS** | **60 DAS** | **80 DAS** | **100 DAS** |
| **T0** | 6.21b | 16.83b | 31.07a | 39.30c | 42.00b |
| **T1** | 6.01b | 17.47b | 33.63bc | 40.78bc | 44.56b |
| **T2** | 6.88a | 21.36a | 37.06a | 45.58a | 49.47a |
| **T3** | 7.02a | 20.78a | 36.63ab | 43.80ab | 49.18a |
| LSD (0.05) | 0.50 | 1.89 | 3.29 | 3.22 | 3.31 |
| CV (%) | 7.37 | 9.54 | 6.71 | 6.46 | 6.20 |

 In a column, means having similar letter(s) are statistically similar, and those having dissimilar letter(s) differ significantly at the 0.05 level of probability. T0, 0 kg P2O5 ha-1; T1, 70 kg P2O5 ha-1; T2, 90 kg P2O5 ha-1; T3, 110 kg P2O5 ha-1. DAS, days after sowing.

**Table 3. Interaction effect of** phosphorus **doses and varieties on leaves number of okra at different days after sowing**

|  |  |
| --- | --- |
| **Treatments** | **Leaves number** |
| **20 DAS** | **40 DAS** | **60 DAS** | **80 DAS** | **100 DAS** |
| **V1T0** | 6.17cd | 16.77c | 35.70bc | 40.75cde | 42.82bc |
| **V1T1** | 5.80d | 17.75bc | 37.62ab | 42.67bcd | 46.00b |
| **V1T2** | 7.27a | 22.62a | 39.90a | 46.72a | 52.50a |
| **V1T3** | 7.17ab | 22.42a | 39.72a | 45.15ab | 52.00a |
| **V2T0** | 6.25cd | 16.90c | 27.67d | 38.10e | 40.92c |
| **V2T1** | 6.22cd | 17.20c | 29.65d | 38.90de | 43.37bc |
| **V2T2** | 6.50bcd | 20.10ab | 35.22bc | 44.45abc | 46.45b |
| **V2T3** | 6.87abc | 19.15bc | 34.12c | 42.45bcd | 46.37b |
| **LSD (0.05)** | 0.70 | 2.68 | 3.43 | 4.03 | 4.22 |
| **CV (%)** | 7.37 | 9.54 | 6.71 | 6.46 | 6.20 |

In a column, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. V1, BARI Dherosh-2; V2, Chamak. T0, 0 kg P2O5 ha-1; T1, 70 kg P2O5 ha-1; T2, 90 kg P2O5 ha-1; T3, 110 kg P2O5 ha-1. DAS, days after sowing.

**3.4 Leaf dry matter content**

Biomass content reflects carbohydrate partitioning in a plant. Application of different levels of phosphorus in selected Okra varieties showed significant variation in the total biomass content of leaves (Table 4). The biomass content of leaves of BARI Dherosh-2 was maximum (26.35 g plant-1) with T2 (90 kg P2O5 ha-1) treatment, which was 26.1% and 28.5% greater than V1T0 and V2T0 treatments, respectively. The variation in leaf biomass content of V1T2, V1T3, V2T2, and V2T3 treatments was statistically identical. Lowest leaf biomass content (20.51 g plant-1) observed in V2T0 treatment, which was statistically similar to V1T0 but 21.15% and 22% lower than V2T2 and V2T3 treatments, respectively.

Singh et al. (2022) reported that plants receiving 90–100 kg P₂O₅/ha recorded a 20–30% increase in leaf dry matter compared to unfertilized controls. Our result found up to a 28.5% increase in leaf biomass content with 90 kg P₂O₅ ha-1. Kumar et al. (2021) reported that phosphorus fertilisation improved dry matter production in multiple plant parts of okra, with leaf dry matter being most responsive due to higher source-sink activity. Phosphorus fertilisation significantly increased dry matter content in okra by promoting chloroplast development and photosynthetic efficiency (Singh et al. 2022). Phosphorus deficiency reduced leaf dry matter by up to 35%, primarily due to impaired root function and reduced leaf expansion.

**3.5. Branches per plant**

The combination of BARI Dherosh-2 with 90 kg P₂O₅ ha⁻¹ (V1T2) recorded the highest number of branches per plant (4.68), which was a 44% increase over the control (V1T0). The V2T2 treatment had 37.4% height number of branches per plant compared to V2T0 but statistically similar with V2T1 and V2T3 treatments. Conversely, the combination V2T0 showed the lowest number of branches (2.43). These results indicate that the application of phosphorus can influence branching of okra, however, responses could vary with variety selection.

**Table 4. Interaction effect of phosphorus doses and varieties on Dry leaf biomass, branches number of okra at final harvest**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Dry leaf biomass****(g plant-1)** | **Branches number (plant-1)** | **Stem base diameter (cm)** | **Days of first flowering** |
| **V1T0** | 20.89d | 3.25c | 1.75c | 44.25a |
| **V1T1** | 23.29c | 4.26b | 1.81c | 43.65a |
| **V1T2** | 26.03ab | 4.68a | 2.62a | 38.25b |
| **V1T3** | 26.35a | 4.60a | 2.63a | 38.62b |
| **V2T0** | 20.51d | 2.43d | 1.80c | 43.82a |
| **V2T1** | 22.85c | 3.16c | 1.97c | 43.90a |
| **V2T2** | 24.84bc | 3.34c | 2.31b | 37.85b |
| **V2T3** | 25.02b | 3.16c | 2.27b | 38.50b |
| **LSD (0.05)** | 2.31 | 0.330 | 0.26 | 3.839 |
| **CV (%)** | 7.82 | 6.22 | 8.23 | 6.35 |

In a column, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. V1, BARI Dherosh-2; V2, Chamak. T0, 0 kg P2O5 ha-1; T1, 70 kg P2O5 ha-1; T2, 90 kg P2O5 ha-1; T3, 110 kg P2O5 ha-1.

**3.6 Stem Base Diameter**

The effect of different varieties and phosphorus doses showed significant variation in the stem diameter of okra at 100 days after sowing, as summarised in Table 4. The V1T3 treatment exhibited the widest stem base diameter (2.63 cm), which was statistically similar to V1T2 but 50.3% wider than the stem base diameter observed with V1T0 treatment. Conversely, the V1T0 showed the lowest stem diameter (1.75 cm) at final harvest, which was statistically similar to V1T0 and V2T0 but varied statistically with other treatments.

**4.7 Days to first flowering**

The application of phosphorus significantly reduced the days to flowering in okra (Table 6). The minimum days required for the first flowering (38.25 days) of okra under the V1T2 treatment, which was statistically similar to V1T3, V2T2, and V2T3. The maximum day to first flowering (44.25 days) was under V1T0 treatment, which was statistically similar to the V2T0 and V2T1. These results demonstrate that both variety and the application of phosphorus can influence the day of flowering.

**4.8 Number of flowers per plant**

The effect of different varieties and phosphorus doses showed significant variation in the number of flowers of okra, as outlined in Table 5. The combination V1T2 exhibited the highest number of flowers (39.05), which was statistically similar to V1T3 and V2T2. The number of flowers observed under V1T2 treatment was 74.7% greater than V1T0. The V2T2 treatment had 63.9% higher number of flowers per plant compared to V2T0, but statistically similar to V2T3 treatment. Conversely, the V1T0 exhibited the lowest number of flowers (22.35). These findings highlight that the application of phosphorus can affect the flower production of okra, though the response may differ depending on the variety selection.

**4.9 Number of fruits per plant**

Application of different levels of phosphorus in selected Okra varieties exhibited significant variation in the number of fruits per plant (Table 5). The fruit number of BARI Dherosh-2 was maximum (36.65 plants) with T2 (90 kg P2O5 ha-1) treatment, which was statistically similar to the same variety under T3 (110 kg P2O5 ha-1) treatment. The plants under V2T0 treatment produced 86.9% and 97.6% greater fruits per plant than V1T0 and V2T0 treatments, respectively. The Chamak variety also produced the highest number of fruits per plant with T2 treatment; however, compared to BARI Dherosh-2, its average fruit number was 9.76% smaller at similar phosphorus levels. Both varieties produced the smallest number of fruits per plant under T0 (0 kg P2O5 ha-1, i.e., control condition). These findings underscore that both the variety and the application of phosphorus can influence internode length. In a previous study, Laxman et al. (2004) found that increasing phosphorus levels up to 90 kg/ha resulted in a higher number of fruits per plant. On the other hand, Sultana (2002) identified 80 kg/ha as the optimal phosphorus rate for okra.

**4.10 Fruit length**

Phosphorus application significantly influenced the average fruit length of okra recorded in Table 5. BARI Dherosh-2, and Chamak varieties showed 17.7 to 68.3% and 33.1 to 83.9% improvements with selected phosphorus treatments, respectively. The longest average fruit length (17.57cm) was produced by Chamak with T2(90 kg P2O5 ha-1) treatment which was statistically similar to the fruit length of the same variety under T3 (110 kg P2O5 ha-1) treatment. The BARI dherosh-2 variety also produced longest fruit length with T2 treatment; however, compared to Chamk, its average fruit length was 6.8% shorter at similar phosphorus levels. Both varieties produced the shortest fruit length under T0 (0 kg P2O5 ha-1, i.e., control condition). These results highlight that both the variety and the application of phosphorus can influence fruit length. Previous studies suggested that the application of phosphorus significantly increases internode length of okra (Uddin et al., 2014; Laxman et al, 2004; Afgad et al., 2016; Ingle et al., 2016). The findings are similar Naik and Srinivas (1992), who observed a significant increase in pod length in okra with the application of phosphorus.

**4.11 Fruit diameter**

The fruit diameter of okra varied significantly due to the different varieties and phosphorus levels, as shown in Table 5. The V1T2 treatment exhibited the widest fruit diameter (1.91 cm), which was statistically similar to V1T3 but 31.7% wider than the fruit diameter observed with the V1T0 treatment. The combination of V2T2 treatment exhibited the widest fruit diameter (1.87cm), which was 48.4% greater than V2T0 but statistically similar to V2T3 treatment. Conversely, the V2T0 showed the lowest fruit diameter (1.26 cm) on average, which was statistically similar to V1T0, V1T1 and V2T2 but varied statistically with other treatments.

**Table 5. Interaction effect of** phosphorus doses **and varieties on yield contributing characteristics of okra**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **No. of Flower plant-1** | **No. of Fruit plant-1** | **Average Fruit length (cm)** | **Average Fruit diameter (cm)** | **Fruit weight****(g fruit-1 )** | **Fruit yield** **(t ha-1)** |
| **V1T0** | 22.35c | 19.60e | 9.77c | 1.45bc | 8.75b | 5.67d |
| **V1T1** | 31.25b | 28.67d | 11.50bc | 1.47b | 9.40b | 8.97c |
| **V1T2** | 39.05a | 36.65a | 16.45a | 1.91a | 12.22a | 14.94a |
| **V1T3** | 38.82a | 35.97ab | 16.37a | 1.81a | 12.50a | 14.45a |
| **V2T0** | 23.07c | 18.52e | 9.55c | 1.26c | 8.72b | 5.38d |
| **V2T1** | 28.85b | 29.77cd | 12.72b | 1.45bc | 9.47b | 9.38c |
| **V2T2** | 37.82a | 32.77bc | 17.57a | 1.87a | 11.50a | 12.80b |
| **V2T3** | 37.65a | 32.60c | 17.42a | 1.85a | 11.47a | 12.42b |
| **LSD (0.05)** | 4.468 | 3.33 | 1.987 | **0.205** | **1.04** | **1.54** |
| **CV (%)** | 9.39 | 7.73 | 9.71 | **8.53** | **6.81** | **9.99** |

In a column, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. V1, BARI Dherosh-2; V2, Chamak. T0, 0 kg P2O5 ha-1; T1, 70 kg P2O5 ha-1; T2, 90 kg P2O5 ha-1; T3, 110 kg P2O5 ha-1.

**4.12 Fruit weight**

The interaction effect of varieties and different phosphorus levels demonstrated significant variation in the weight of fruits (Table 5). The combination of V1T2 treatment displayed the maximum fruit weight (12.50g), which was 42.8% and 43.3% greater than V1T0 and V2T0 treatments, respectively. The variation in fruit weight of V1T2, V1T3, V2T2 and V2T3 treatments was statistically similar. Lowest fruit weight (8.72g) was observed in V2T0, which was statistically similar to V1T0, but 31.8% and 31.5% lower than V2T2 and V2T3 treatments, respectively. These results emphasise that both the choice of variety and the application of phosphorus can influence the weight of individual fruits.

**4.13 Fruit yield**

Application of different levels of phosphorus in selected Okra varieties exhibited significant variation in the fruit yield (Table 5). The maximum yield was obtained from the V1T2 treatment (14.94 t/ha), which was 163.4% to 177.7% higher than the V1T0 and V2T0 treatments. It was statistically similar to the V1T3 treatment but significantly higher than all other treatments. The V2 also produced the highest fruit yield (12.80tha-1) with T2 treatment; however, compared to V1, its fruit yield was 16.7% smaller at similar phosphorus levels. Minimum fruit yield (5.38) observed in V2T0 treatment, which was statistically similar to V1T0.These results emphasise the synergistic effect of variety selection and phosphorus application on okra yield per hectare. Increasing levels of phosphorus up to 90 kg/ha increased yield/ha (Laxman et al., 2004; Ingle et al., 2016). Okra plants were more efficient in their use of P in terms of yield/ha.

4. Conclusion

Phosphorus application significantly enhanced the vegetative and reproductive performance of okra. The treatment with 90 kg P₂O₅ ha⁻¹ led to maximum growth and yield, particularly in the variety Bari Dherosh-2. While both tested varieties responded positively, Bari Dherosh-2 consistently outperformed Chamak across phosphorus levels. Therefore, the application of 90 kg P₂O₅ ha⁻¹ is recommended for optimal okra production during the kharif season in Bangladesh.

AUTHOR CONTRIBUTIONS

Rakibul Hasan and Md. Elias Hossain conceptualized and investigated the study, and they prepared the original draft of the manuscript with contributions from all co-authors. Asim Kumar Bhadra, Md. Moinul Haque performed supervision and acquisition of funding and resources. Rezowana Bonna and Lutfun Nahar designed the study and managed the resources. Md Elias Hossain performed the methodology. Binita Chowdhury and Faiza Islam analyzed data. All co-authors participated in result analysis and the writing-review and editing. All authors have read and agreed to the published version of the manuscript.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

Maity, A., Marathe, R. A., Sarkar, A., & Basak, B. B. (2022). Phosphorus and potassium supplementing bio-mineral fertilizer augments soil fertility and improves fruit yield and quality of pomegranate. *Scientia Horticulturae*, *303*, 111234.

Abgad, Nilesh P., Kuchanwar, Ommala D., Shirsat, Priti R., Ingle, Sagar N. and Zalte, Sainath G. (2015). Effect of phosphorus and potassium levels on yield and quality of spinach. Asian J. Soil Sci., 10(2) : 248-251.

Bhai, K.L. and Singh, A.K. 1998. Effect of different levels of phosphorus, GA3 and picking onseed production of okra (Abelmoschus esculentus L. Moench). Indian J. S ci., 38(3-4): 119-122.

Blake, C.A. (1965). Methods of Soil Analysis: Part I and II; American Society of Agronomy: Madison, WI, USA.

Blake, G.R. and Hartge, K.H. (1986) Bulk Density. In: Klute, A. (ed.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods, 2nd Edition, ASA-SSSA, Madison, 363-375.

Bremner, J. M. and C. S. Mulvaney. (1982). Total nitrogen. In: A. L. Page, R. H. Miller, D. R. Keeny (eds.). Methods of Soil Analysis. American Society of Agronomy and Soil Science Society of America, Madison, USA. Pp. 1119-1123.

Cordell, D., Drangert, J. O., & White, S. (2009). The story of phosphorus: Global food security and food for thought. Global Environmental Change, 19(2), 292-305.

Gee, G.W., and J.W. Bauder. 1986. Particle-size analysis. p. 383–411. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Ingle S. N., O.D. Kuchanwar, P.R.Shirsat, S.G. Zalte and Patangray, A.J. 2016. Effect of foliar application of zinc and iron on growth, yield and quality of Gladiolus. Plant Archives. Vol 16(1):387-389.

Ingle SN, Nagaraju MSS, Kumar N, Prasad J, Tiwary P, Srivastava R, Sahu N, Lal B, Das SP, Pradhan AK, Beura K, Karad GU. Soil quality assessment and mapping in basaltic terrain of Central India for sustainable soil and crop management using integrated PCA and GIS. Plant Science Today. 2024; 11(3): 800-812. https:// doi.org/10.14719/pst.4607

Kumar, A., Yadav, M., & Gupta, S. K. (2021). Nutrient management and its impact on growth and biomass production in okra. International Journal of Agricultural Sciences, 13(4), 118–123.

Kumar, S., et al. (1988). Nitrogen, phosphorus, and potassium fertilization effects on okra yield and quality. Indian Journal of Agricultural Science, 15(3), 178-192.

Kumari, R., Beura, K., Pradhan, A. K., Akhtar, S., Ingle, S. N., Das, S. P., … Baranwal, D. K. (2025). Seed nutripriming and foliar application of phosphorus for enhanced nutrition in brinjal. *Journal of Plant Nutrition*, *48*(10), 1632–1645. https://doi.org/10.1080/01904167.2025.2451931

Laxman, S., Dhaka, R.S. and M ukherjee, S. 2004. Flowering and fruiting of okra [(Abelmoschus esculentus L.) Moench] as influenced by application of nitrogen, phosphorus and gibberellic acid. J. Eco Physiol., 7(3/4): 181-18

M.J. U ddin, M. H. Akand, S. Is lam, H. M ehraj and AFM Jamal U ddin ( 2014). Phos phorus Levels on Growth and Yieldof Okra ( Abelmoschus esculent us). Banglades h Res . Pub. J. 10( 2): 120-124.

Naik, L.B. and K. Srinivas. 1992. Influence of nitrogen and phosphorus fertilization on seedcrop of okra. Indian Journal of Agronomy, 37(4): 769-771.

Patel, B., Anurag, Ekka, A.A., Ingle, S.N., Das, S.P., Lal, B., Mishra, V.N., Sonboir, H.L., Lakhera, M.L. (2024). Evaluation of Phosphorus and Sulphur Nutrition on Phosphorus Fractionation in Groundnut Cultivation on Inceptisols of Raigarh, Chhattisgarh, India. Legume Research. doi: 10.18805/ LR-5392.

**Pradhan, A. K., Beura, K. S., Das, R., Ingle, S. N., Mandal, B., Hazra, G. C., De, N., Polara, K. B., Kachroo, D., Sharma, A., & Patel, K. P. (2025).** Zinc in the soil–plant continuum: A long‐term perspective from selected Inceptisols in India. Soil Use and Management, 41(1), e70056. <https://doi.org/10.1111/sum.70056>

Raghothama, K. G. (1999). Phosphate acquisition. Annual Review of Plant Physiology and Plant Molecular Biology, 50(1), 665-693.

Rampal, L., & Gill, M. R. (1990). The Food Guide Pyramid: A Guide to Daily Food Choices. Journal of Nutrition Education, 22(5), 251-252.

Reed, R. (2006). Gumbo: A Savor the South Cookbook. The University of North Carolina Press.

Schachtman, D. P., Reid, R. J., & Ayling, S. M. (1998). Phosphorus Uptake by Plants: From Soil to Cell. Plant Physiology, 116(2), 447–453.

Singh, R. K., Verma, P., & Meena, M. K. (2022). Role of phosphorus in biomass accumulation and yield of okra. Vegetable Science, 49(1), 21–27.

Sultana, S. 2002. Effect of nitrogen, phosphorus, potassium, sulphur and boron on okra. M.S Thesis. Department of Soil Science, Banghabandhu Sheikh M uijibur Rahman Agril.Univ., Gazipur

Syers, J. K., Johnston, A. E., & Curtin, D. (2008). Efficiency of Soil and Fertilizer Phosphorus Use. FAO Fertilizer and Plant Nutrition Bulletin, 18, 7-26.

Singh, S. K., Singh, D., Deshwal, A., Rawat, A. K., Yadav, Y., Rai, P. K., & Yadav, S. (2025). Impact of Nitrogen, Phosphorus and Bio-fertilizer on Yield Dynamics & Quality of Okra (Abelmoschus esculentus L.Moench). Journal of Experimental Agriculture International, 47(5), 676–682. https://doi.org/10.9734/jeai/2025/v47i53455

Singh, A., David, A. A., Thomas, T., Toppo, N., Kumari, S., Singh, M., Dessai, B. R. S., & Bhinchar, S. (2024). Soil Test Crop Response on Soil Health Parameters and Yield Attributes of Okra (*Abelmoschus esculentus* L.) var. Kuber. Journal of Scientific Research and Reports, 30(7), 201–208. https://doi.org/10.9734/jsrr/2024/v30i72137

Oluleye, A. K., Ogunlade, M. O., & Adewoyin, O. B. (2023). Response of okra, Abelmoschus esculentus (L.) Moench, to biochar derived from cocoa pod husk and NPK fertiliser. *Tropical Agriculture*, *100*(1), 11-19.