



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

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Authors' contributions

This work was carried out in collaboration among all authors. Authors Md. RH and Md. EH conceptualized, investigated the study, and they prepared the original draft of the manuscript. Authors AKB and Md. MH performed supervision and acquisition of funding and resources. Authors RB, LN designed the study and managed the resources. Author Md. EH performed the methodology. Authors BC and FI analyzed data. All RH, Md. EH, AKB, BC, Md. MH, RB, LN and FI participated in result analysis and the wrote, reviewed and edited of the manuscript. All authors have read and agreed to the published version of the manuscript.

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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 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 and leaves 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 et 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. MATERIALS 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.

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, diameter of stem, number of branches per plant, length of internode, diameter of fruit, fresh weight of plant, dry weight of plant, yield/plot, and yield/hectare.

Plant height and leaves number per plant 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.

2.6 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 (Fig. 1). Phosphorus application increased plant height by 11.1 to 35.9% over the control. At each time point, T_2 treatment yielded the tallest plants, which were statistically similar to T_3 treatment. T_1 treatment showed intermediate heights, while the shortest plants were observed under T_0 (control). The interaction effect of P doses and varieties on plant height also indicated similar trends. The combination V_1T_3 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 V_2T_0 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).

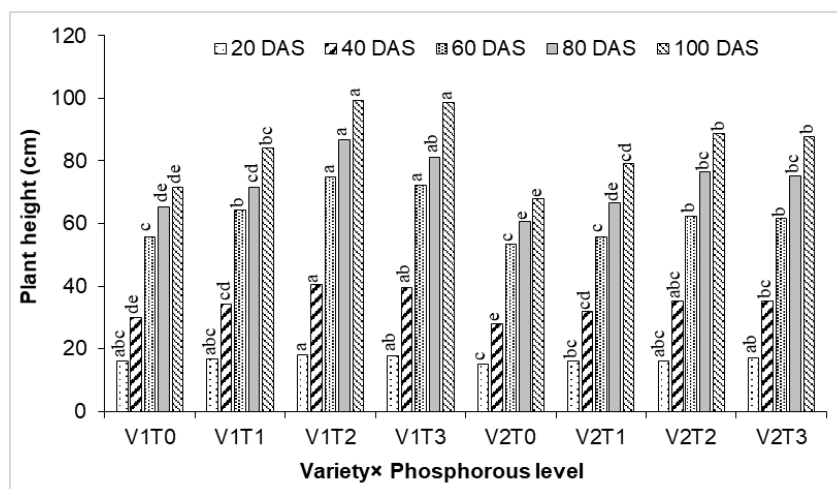


Fig. 1. Bar graph showing interaction effects of phosphorus doses and varieties on plant height of okra at different days after sowing (DAS). In a bar, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. V_1 , BARI Dherosh-2; V_2 , Chamak. T_0 , 0 kg P_2O_5 ha⁻¹, T_1 , 70 kg P_2O_5 ha⁻¹; T_2 , 90 kg P_2O_5 ha⁻¹; T_3 , 110 kg P_2O_5 ha⁻¹. DAS, days after sowing

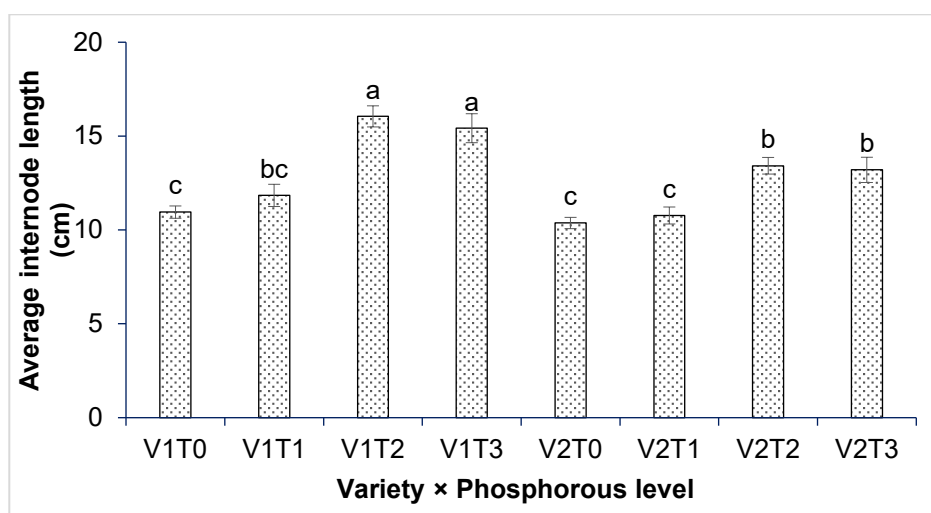


Fig. 2. Bar graph showing interaction effects of phosphorus doses and varieties on average internode length of okra at final harvest (100 DAS). In a bar, groups with similar letter(s) are statistically alike, while those with different letter(s) show significant differences at a 0.05 probability level. 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

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

Particulars	Value	Methods
Sand (%)	16	Hydrometer meter method (Gee and Bauder, 1986)
Silt (%)	56	
Clay (%)	28	
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	K ₂ Cr ₂ O ₇ oxidation-titration method (Blake, 1965)
Extractable P (g kg ⁻¹)	0.043	Olsen method
Total N, %	0.064	Modified Kjeldahl Method (Bremner and Mulvaney,1982)

3.2 Internode Length

Phosphorus application significantly improved the average internode length of okra recorded at final harvest (100 DAS) (Fig. 2). BARI Dherosh-2 and Chamak varieties showed 8.13 to 40.08% and 13.5 to 29.41% improvements in internode length 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).

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 V_1T_0 and V_2T_0 treatments, respectively. Okra leaf production per plant at different DAS under V_2T_2 treatment was significantly higher than V_2T_0 treatment and statistically identical with V_2T_3 treatment, but 11.6 to 13 % less compared to V_1T_2 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, V_1 (BARI Dherosh-2) produced more leaves than V_2 (Chamak), highlighting its superior photosynthetic potential.

3.4 Leaf dry Matter Content

Dry matter 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 T_2 (90 kg P_2O_5 ha⁻¹) treatment, which was 26.1% and 28.5% greater than V_1T_0 and V_2T_0 treatments, respectively. The variation in leaf biomass content of V_1T_2 , V_1T_3 , V_2T_2 , and V_2T_3 treatments was statistically identical. Lowest leaf biomass content (20.51 g plant⁻¹) observed in V_2T_0 treatment, which was statistically similar to V_1T_0 but 21.15% and 22% lower than V_2T_2 and V_2T_3 treatments, respectively.

Singh et al. (2022) reported that plants receiving 90–100 kg P_2O_5 /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 P_2O_5 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 P_2O_5 ha⁻¹ (V_1T_2) recorded the highest number of branches per plant (4.68), which was a 44% increase over the control (V_1T_0). The V_2T_2 treatment had 37.4% height number of branches per plant compared to V_2T_0 but statistically similar with V_2T_1 and V_2T_3 treatments. Conversely, the combination V_2T_0 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.

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 V_1T_3 treatment exhibited the widest stem base diameter (2.63 cm), which was statistically similar to V_1T_2 but 50.3% wider than the stem base diameter observed with V_1T_0 treatment. Conversely, the V_1T_0 showed the lowest stem diameter (1.75 cm) at final harvest, which was statistically similar to V_1T_0 and V_2T_0 but varied statistically with other treatments.

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
T_0	6.21b	16.83b	31.07a	39.30c	42.00b
T_1	6.01b	17.47b	33.63bc	40.78bc	44.56b
T_2	6.88a	21.36a	37.06a	45.58a	49.47a
T_3	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. T_0 , 0 kg P_2O_5 ha⁻¹; T_1 , 70 kg P_2O_5 ha⁻¹; T_2 , 90 kg P_2O_5 ha⁻¹; T_3 , 110 kg P_2O_5 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
V ₁ T ₀	6.17cd	16.77c	35.70bc	40.75cde	42.82bc
V ₁ T ₁	5.80d	17.75bc	37.62ab	42.67bcd	46.00b
V ₁ T ₂	7.27a	22.62a	39.90a	46.72a	52.50a
V ₁ T ₃	7.17ab	22.42a	39.72a	45.15ab	52.00a
V ₂ T ₀	6.25cd	16.90c	27.67d	38.10e	40.92c
V ₂ T ₁	6.22cd	17.20c	29.65d	38.90de	43.37bc
V ₂ T ₂	6.50bcd	20.10ab	35.22bc	44.45abc	46.45b
V ₂ T ₃	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.

Table 4. Interaction effect of phosphorus doses and varieties on Dry leaf biomass, branches number, stem base diameter, and days to first flowering of okra at final harvest

Treatments	Dry leaf biomass (g plant ⁻¹)	Branches number (plant ⁻¹)	Stem base diameter (cm)	Days to first flowering
V ₁ T ₀	20.89d	3.25c	1.75c	44.25a
V ₁ T ₁	23.29c	4.26b	1.81c	43.65a
V ₁ T ₂	26.03ab	4.68a	2.62a	38.25b
V ₁ T ₃	26.35a	4.60a	2.63a	38.62b
V ₂ T ₀	20.51d	2.43d	1.80c	43.82a
V ₂ T ₁	22.85c	3.16c	1.97c	43.90a
V ₂ T ₂	24.84bc	3.34c	2.31b	37.85b
V ₂ T ₃	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.

3.7 Days to First Flowering

The application of phosphorus significantly reduced the days to flowering in okra (Table 4). 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.

3.8 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.

3.9 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 T_2 (90 kg P_2O_5 ha⁻¹) treatment, which was statistically similar to the same variety under T_3 (110 kg P_2O_5 ha⁻¹) treatment. The plants under V_2T_0 treatment produced 86.9% and 97.6% greater fruits per plant than V_1T_0 and V_2T_0 treatments, respectively. The Chamak variety also produced the highest number of fruits per plant with T_2 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 T_0 (0 kg P_2O_5 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 (Kumar et al., 1988, Singh et al., 2022).

3.10 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 T_2 (90 kg P_2O_5 ha⁻¹) treatment which was statistically similar to the fruit length of the same

variety under T_3 (110 kg P_2O_5 ha⁻¹) treatment. The BARI dherosh-2 variety also produced longest fruit length with T_2 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 T_0 (0 kg P_2O_5 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 (Abgad et al., 2015, 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.

3.11 Fruit Diameter

The fruit diameter of okra varied significantly due to the different varieties and phosphorus levels, as shown in Table 5. The V_1T_2 treatment exhibited the widest fruit diameter (1.91 cm), which was statistically similar to V_1T_3 but 31.7% wider than the fruit diameter observed with the V_1T_0 treatment. The combination of V_2T_2 treatment exhibited the widest fruit diameter (1.87cm), which was 48.4% greater than V_2T_0 but statistically similar to V_2T_3 treatment. Conversely, the V_2T_0 showed the lowest fruit diameter (1.26 cm) on average, which was statistically similar to V_1T_0 , V_1T_1 and V_2T_2 but varied statistically with other treatments.

Table 5. Interaction effect of phosphorus doses and varieties on yield and 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)
V_1T_0	22.35c	19.60e	9.77c	1.45bc	8.75b	5.67d
V_1T_1	31.25b	28.67d	11.50bc	1.47b	9.40b	8.97c
V_1T_2	39.05a	36.65a	16.45a	1.91a	12.22a	14.94a
V_1T_3	38.82a	35.97ab	16.37a	1.81a	12.50a	14.45a
V_2T_0	23.07c	18.52e	9.55c	1.26c	8.72b	5.38d
V_2T_1	28.85b	29.77cd	12.72b	1.45bc	9.47b	9.38c
V_2T_2	37.82a	32.77bc	17.57a	1.87a	11.50a	12.80b
V_2T_3	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. V_1 , BARI Dherosh-2; V_2 , Chamak. T_0 , 0 kg P_2O_5 ha⁻¹; T_1 , 70 kg P_2O_5 ha⁻¹; T_2 , 90 kg P_2O_5 ha⁻¹; T_3 , 110 kg P_2O_5 ha⁻¹

3.12 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.

3.13 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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.

COMPETING INTERESTS

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.

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