



Response of maize (*Zea mays* L.) to the soil application of phosphorus fertilizer

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Summary

To investigate the effect of different phosphorus levels on the yield and yield components of maize crop, the experiment was carried out in the Badakhshan province of Afghanistan and was laid out in a randomized complete block design with three replications having a plot size of 2 m x 3 m (6m²) with row-to-row distance of 0.75 m and plant to plant distance of 0.25 m. The levels of phosphorus were 0 (control), 40, 80, 120, 160, 200, 240 kg P₂O₅ ha⁻¹. Results indicated that the different levels of phosphorus significantly affected maize plant height, leaf area index, No. of cobs/plant, Cob length (cm), No. of Grains/cob, No. of Rows/cob, 100 grain weight (gr), seed yield and Stover yield. Application of Phosphorus at the rate of 160 kg ha⁻¹ resulted in maximum plant height (181.02 cm), leaf area index (2.30), No. of cobs/plant (2.20), Cob length (18.63cm), No. of Grains/cob (347.33), No. of Rows/cob (17.67), 100-grain weight (20.33gr), seed yield 4882 kg/ha and Stover yield 6943 kg/ha as compared to the minimum values in control plots. It is concluded that Phosphorus should applied at the rate of 160 kg P₂O₅ ha⁻¹ for the best grain yield in the agro-ecological conditions in Badakhshan province.

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Introduction

Maize (*Zea mays* L.) crop is one of the most important crops in the world, maize serves as basic raw material for the production of starch, oil and protein, alcoholic beverages and food sweeteners. Maize is an important grain crop of the world and it ranks third, after wheat and rice (Mosisa et al. 2001).¹² Maize is a versatile crop having wider adaptability under varied agro-climatic conditions and can be successfully cultivated in diverse seasons and ecologies for numerous purposes. Globally, it is known as the "Queen" of cereals because it has the highest genetic yield potential among the cereals (Dass et al. 2012).⁴ Maize is being cultivated in an area of 185 million ha throughout the globe with a production of 1,018 million tones with average productivity of 5.5 t/ha, Maize is also the third most important cereal crop in Afghanistan after wheat and rice. In Afghanistan, the total annual production of maize is 0.312 million tons from an area of 0.142 million ha and an average grain yield of 2.20 tons/ha (Anonymous, 2014; Bana et al. 2022; Haldhar et al. 2023).^{3,17,18} In Afghanistan, fodder and grain yields of maize are very low as compared to other maize-growing countries such as Israel, the USA and China, even though the soil and climatic conditions

of Afghanistan are suitable for maize production.

Generally, Phosphorus is the second most crop-limiting nutrient in most soils. It is second only to nitrogen in fertilizer use. Plant growth behaviour is influenced by the application of phosphorus (Hajabbasi & Schumacher 1994; Nazir et al. 2022).^{5,13} it is needed for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division, and fat and albumen formation. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and reproduction, It is readily translocating within the plants, moving from older to younger tissues as the plant forms cells and develops roots, stems and leaves (Alias et al. 2003).¹ Adequate Phosphorus results in rapid growth and earlier maturity and improves the quality of vegetative growth. Phosphorus deficiency is responsible for crooked and missing rows as kernel twists and produces small ears nubbins in maize. Its deficiency is widespread in 90% of the Pakistani soils and the application of phosphate fertilizers is considered essential for crop production and its deficiency will slow overall plant growth. Alias et al. (2003)¹ reported a significant effect of Phosphorus application on grain yield; whereas Hemmat et al. (2023)⁷ observed significant effect of Phosphorus application on dry matter yield and individual plant characteristics like plant height, number of leaves and leaf area. The farmers in Afghanistan do not have much awareness about the method and application of macronutrient and micronutrient fertilizers for improving crop quality and productivity.

The addition of inorganic fertilizers, primary phosphorus to satisfy the nutrient demand of the crop is

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crucial. In addition, determining the optimum rates of phosphorus for higher yield is economically profitable, socially acceptable and environmentally sustainable (Khaleeq et al. 2023a).¹¹ The production of maize is highly related to the phosphorus fertilizer applied to it (Alias et al. 2003; Samim et al. 2023).^{1,15} However, an excessive or deficiency of phosphorus fertilizer application should be avoided. For instance, inadequate phosphorus slows the process of carbohydrate utilization the leaves of maize develop a purple color, delays the maturity of maize and decreases disease resistance. The excessive use of phosphorus affects the environment and the health status of the people. Adequate Phosphorus results in rapid growth and earlier maturity and improves the quality of vegetative growth. Phosphorus deficiency is responsible for crooked and missing rows as kernels twist and produce small ears in maize (Alias et al. 2002).¹ Because of this reason efficient phosphorus fertilizer applied on maize yield and yield components must be determined. Thus, the purpose of the present. The investigation was to assess and identify the effect of different levels of phosphorus fertilizer on yield and Yield components of maize.

Materials and Methods

Experimental Design and Treatments

In this experiment, seven levels of phosphorus (0, 40, 80, 120, 160, 200 and 240 kg/ha) were used in 7 treatments and laid out in a Randomized Complete Block Design (RCBD) with three replications in 2021. The experiment site is in the Badakhshan province of Afghanistan, The Soil was sandy loam, and the total number of plots was 21. Each treatment was randomly assigned to each plot. The plot size was an area of 2 m x 3 m (6 m²) and the total area of the experimental site was 207m² (18m*11.5m). The distance between blocks and plots was 0.75 m and 0.5m, respectively. Seeds of maize were sown on rows by 25cm spaced between seeds, 75cm between rows and each row contained 8 plants. The plot had four rows and the middle rows were used for all data collection including final yield performance determination.

Data Recorded

By taking five random representative samples from the middle rows, plant height, leaf area index, No. of cobs/plant, Cob length (cm), No. of Grains/cob, No. of Rows/cob, 100-grain weight (gr), seed yield kg/ha and Stover yield was recorded.

Data Analysis

Analysis of variance was performed for all measured data to test the significant difference of maize in different rates of phosphorus. So, data recorded from different parameters was subjected to the analysis of variance (ANOVA) and the treatment was compared using a CD test.

Results and Discussion

The growth parameters, viz. plant height and leaf area index were significantly affected by different levels of phosphorus (Table 1). The application of phosphorus fertilization at a rate of 160 kg P₂O₅ ha⁻¹ resulted in

significantly higher plant height (181.02cm) and higher leaf area index (2.30) as compared to control and other treatments, it could be attributed to the increased photosynthetic capacity of the plant by phosphorus nutrition, which improves cell elongation and cell division and increased vegetative growth. The better phosphorus nutrition to crop plants also has a beneficial effect on plant metabolism, which affects the physiological process of the crop and thereby increases the growth parameters. The other aspects with the effect of high phosphorus levels on growth parameters were probably due to better Development of root system and nutrient absorption. Higher levels of Phosphorus increase the ability of plants to absorb more essential nutrients from soil resulting in more photosynthesis. Therefore, the regimes of Phosphorus at the rate of 0 kg ha⁻¹ resulted in the shortest stature plant height and less leaf area index, The Promotion effect of high Phosphorus level on plant height and leaf area index was probably due to better development of root system and nutrient absorption (Hussain et al. 2004 & Nazir et al. 2022).^{8,13} Plant height of maize increased with an increase in Phosphorus application. A significant effect of Phosphorus Application was observed on plant height (Alias et al. 2002; Khaleeq et al. 2023b).^{1,10} However, the results are contrary to the findings of (Anonymous, 2000)³ who reported that plant height of maize plants increased with increasing phosphorus levels. Analysis of variance indicated that plant height was significantly different at 5% among all treatments. Alias et al. (2002)¹ and Sadiq et al. (2023).¹⁴ also reported a significant increase in the plant height of kharif maize with 100% recommended fertilizer dose (RFD) compared to 75% RFD. Leaf area index, a vital photosynthetic character, was found significantly affected by fertility levels. An increase in the level of fertility from; N: P: K (60: 40: 20) to F2 (75: 50: 30) significantly improved leaf area index at different crop growth stages. The investigation revealed that yield contributing characters, namely, No. of cobs/ plant, Cob length, No. of Grains/cob, No. of Rows/cob, 100-grain weight (gr), seed yield kg/ ha and Stover yield increased significantly up to 160 kg P₂O₅/ha level beyond which difference was non-significant (Table 2). The highest yield attributes and yield was No. of cobs/plant (2.20), Cob length (18.63cm), No. of Grains/ cob (347.33), No. of Rows/ cob (17.67), 100-grain weight (20.33gr), seed yield 4882 kg/ ha and Stover yield 6943 kg/ ha in treatment 160 kg P₂O₅/ha as compared to control and other treatments. The increase in grain yield might be due to the increase in 100-grain weight, no of grains and cobs (Table 2). Similar findings were reported by (Hussien 2009; Yosefi et al. 2011).^{9,16} Besides, the increase in 100-grain weight might be due to enhancement in source efficiency as well as sink capacity. These results are in accordance with the findings of Amanullah et al. (2010).² The positive effect of Phosphorus application on the grain yield of maize and its components has also been reported by (Haq et al. 2014).⁶

Table 1. Effect of phosphorus levels on Plant height at harvest (cm), Leaf area index, No. of cobs/plant, Cob length (cm) and No. of Grains/cob

Treatments	Plant height at harvest (cm)	Leaf area index	No. of cobs/plant	Cob length (cm)	No. of Grains/cob
0 kg P ₂ O ₅ /ha	169.02	1.10	1.06	11.76	324.33
40 kg P ₂ O ₅ /ha	170.01	1.40	1.30	12.67	325.33
80 kg P ₂ O ₅ /ha	173.21	1.63	1.60	13.76	329.33
120 kg P ₂ O ₅ /ha	175.41	1.76	1.63	14.53	335.00
160 kg P ₂ O ₅ /ha	181.02	2.30	2.20	18.63	347.33
200 kg P ₂ O ₅ /ha	179.24	2.16	1.80	16.33	340.66
240 kg P ₂ O ₅ /ha	178.43	2.16	1.70	16.47	335.00
SEm±	0.617	0.107	0.126	0.227	3.717
CD (P=0.05)	169.02	1.10	0.393	0.707	11.580

Tale 2. Effect of phosphorus levels on No. of Rows/cob, 100-grain weight (gr), seed yield kg/ha and Stover yield kg/ha

Treatments	No. of rows/ cob	100-grain weight (g)	seed yield Kg/ ha	Stover yield Kg/ ha
0 kg P ₂ O ₅ /ha	13.33	16.66	4080	6192
40 kg P ₂ O ₅ /ha	14.00	17.00	4151	6323
80 kg P ₂ O ₅ /ha	14.67	18.00	4362	6511
120 kg P ₂ O ₅ /ha	15.00	18.33	4461	6632
160 kg P ₂ O ₅ /ha	17.67	20.33	4882	6943
200 kg P ₂ O ₅ /ha	16.67	17.67	4664	6794
240 kg P ₂ O ₅ /ha	16.67	18.33	4691	6922
SEm±	0.385	0.337	36.008	54.666
CD (P=0.05)	1.199	1.051	112.18	170.30

Conclusion

Maize is an exhaustive crop, among the cereal crops, having a higher potential to absorb large quantities of nutrients from the soil in various growth stages. Among the essential nutrients, phosphorus is one of the most important nutrients for higher yield in larger quantities and controls mainly the reproductive growth of maize. Results of the present study showed that phosphorus fertilizers up to 160 kg/ ha can increase maize yield. Therefore, for Afghanistan conditions, the above findings may be taken to the level of recommendation in maize cultivation regions. For future research, the interaction of phosphorus with other nutrients may be taken up for studies in a cropping system mode. Further, diverse nutrient sources, including organic manures, composts and bio-fertilizers may be tested in conjunction with mineral fertilizers.

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Declaration of Interests

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are within the manuscript.

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