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Research Communication

Effect of phosphorus on growth and yield of maize (*Zea mays*) under arid conditions of Kandahar, Afghanistan

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ABSTRACT

An experiment was conducted during summer 2015 at the research farm of the Afghanistan National Agricultural Science and Technology University, Kandahar, to assess the effect of variable levels of phosphorus on growth and productivity of maize (*Zea mays* L.) under semi-arid conditions of Kandahar, Afghanistan. The experiment was laid out in a randomized complete, block design with 3 replications, having a plot size of 4.25 m × 5.60 m with row-to-row distance of 0.60 m and plant-to-plant distance of 0.25 m. The levels of phosphorus were 0 (control), 15, 30, 45, 60, 75 and 90 kg P_2O_5/ha. Different levels of phosphorus significantly influenced all growth parameters of maize, viz. plant height, leaf area index, number of green leaves per plant, dry-matter accumulation, leaf area duration, crop growth rate and net assimilation rate; and yield. The application of 75 kg P_2O_5/ha resulted in the maximum plant height (200.6 cm), higher leaf area index (6.41), greater dry matter accumulation (222 g/plant), net assimilation rate (10.9 g/m^2/d) and grain yield (6.51 t/ha) compared to the control. Thus, P may be applied at the rate of 75 kg P_2O_5/ha for getting higher grain yield and income in the agro-ecological conditions of Kandahar, Afghanistan.

Key words: Growth, Leaf area index, Maize, Phosphorus, P-fertilization, Yield

Maize is the most versatile cereal crop with wider adaptability in varied agro-ecologies. It has highest genetic yield potential among the foodgrain crops. Maize ranks third after wheat and rice in production from the 12% total cultivated area in Afghanistan. The area, production and productivity of maize in Afghanistan were 0.16 mha, 0.32 mt and 2.0 t/ha, respectively (MAIL, Afghanistan, 2013). Maize is a quality feed for animals. Maize is grown in eastern and southern regions of Afghanistan where irrigation is not sufficient for rice cultivation. Maize serves as a basic raw material and an ingredient to thousands of industrial products such as starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceuticals, cosmetics, films, textiles, gum, package and paper industries (Rai *et al*., 2013). In order to ensure sustainable and profitable agriculture that has a minimal impact on the environment, the application of P-based fertilizers is routinely used to overcome soil deficiencies and to maintain the productivity of agricultural systems. Phosphorus nutrition is a major consideration for increasing grain yield and quality of maize. Phosphorus should be applied in such a way that would maximize its utilization for seed production. Soils with high fixation capacity have higher demand for P (Hussain and Haq, 2000). Phosphorus deficiency is invariably a common limiting factor for crop growth and yield in unfertilized soils, especially in soils high in calcium carbonate, which reduces P solubility. Phosphorus fertilizers are primarily applied in 'water-soluble' forms, such as superphosphate (Richardson *et al.*, 2009). Maize is an exhaustive crop having higher potential than other cereals and absorbs large quantity of nutrients from the soil during different growth stages. Phosphorus is needed for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division, fat and albumen formation. Phosphorus is involved in energy transfer, cell enlargement, root formation and growth, improves fruit and vegetable quality, vital to seed formation, improves water use and helps hasten maturity (Roberts, 2010). Therefore a study was conducted to assess the optimum level of phosphorus to the maize crop under semi-arid Kandhar region of Afghanistan during 2015.

A field experiment was carried out at Kandahar province (31°30' - 31°61' N and 65°42'- 65°71' E with an altitude

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of 986 m above mean sea level), Afghanistan during spring season 2015. The site belongs to dry southern agro-ecological zone (dry and hot summer). The experimental area received 190.6 mm of rainfall during 2015. The mean annual temperature was 18.5°C and mean monthly temperature 26.8°C, which is of moderate range. The average daily temperature was 16.7°C. The soil of experimental field was sandy clay loam, well-drained, and deep red grey in colour. It belongs to the desert and Oasis Agro-ecological Zone. Soil organic carbon content was 0.8% and *p*H was 8.3. In order to investigate the effect of different P levels on the yield and yield components of maize, P levels were undertaken at 0 (control), 15, 30, 45, 60, 75 and 90 kg P_2O_5/ha. The experiment was laid out in a randomized complete-block design (RCBD) with 3 replications and 7 treatments. The plot size was 5.6 m × 4.25 m and the space/gap between adjacent plots and blocks were kept at 1 m and 1.5 m respectively. The net plot was 5 m × 4 m. Maize seeds were sown at 0.60 m (row-row) × 0.25 m (plant-plant) spacing. Data on maize crop were subject to the analysis of variance (ANOVA) by using MSTAT C software (CIMMYT, Mexico), and the significance was tested by the variance ratio (i.e. F-value) at 5% level (Gomez and Gomez, 1984). The least significant difference (LSD) were worked out for comparing treatment means of each studied variables of maize.

The P levels significantly influenced maize plant height (Table 1). Maximum plant height (200.6 cm) were observed at P_{75}, while the lowest plant height (170.2 cm) was recorded under control (P_0). Maize plant height continued to increase up to maturity. Phosphorus improves root growth, which has a great role on the overall plant growth. Therefore, the regime of no P application (P_0) resulted in the shortest maize plants. Promotion effect of high P level on plant height was probably owing to better development of root system and nutrient absorption (Katalin *et al*., 2011). The leaf area index was enhanced up to 90 DAS (Fig. 1). During this period, the effect of P levels remained significant, which indicated that the effect of P level was exerted up to 90 kg P_2O_5/ha. Phosphorus @ 75 kg P_2O_5/ha resulted in 6.9, 28.1 and 36.7% increase in leaf area index compared to P_0, respectively, at 30, 60 and 90 DAS (Table 1). Shaban *et al*. (2012) reported that P has got a role in leaf initiation and elongation, and leaf growth of maize. Plant senescence rate was reduced by 15 to 33% during most of the grain filling period. Leaf-area index and leaf area/plant were increased progressively with increasing level of P from 0 to 150 kg/ha (Alias *et al*., 2003; Yazdani *et al*., 2009). In general, the leaf area duration (LAD) of maize was influenced due to different P levels (Fig. 1). The P level of 75 kg P_2O_5/ha resulted in 18.7 and 33% increase in LAD in 30–60 and 60–90 DAS, respectively, compared to that in the control. Phosphorus deficiency limits grain yield by decreasing LAD (Marschner, 1995).

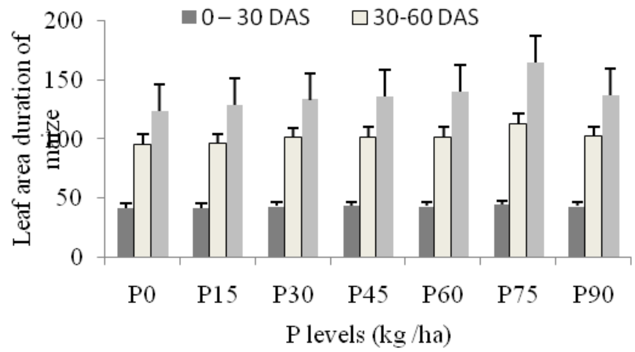

Fig. 1. Effect of Phosphorus levels on leaf area duration of maize

In the present study, the dry-matter accumulation (DMA) increased significantly (Table 1) due to P application. The stalk yield increased with increasing level of P application gradually up to 75 kg P_2O_5/ha, but the DMA decreased at 90 kg P_2O_5/ha. The increase of DMA in P_{75} compared to the control was 14.3, 95.3, 60.9 and 41.8% during 30, 60, 90 and 120 DAS respectively. The results are in conformity with those of Pholsen and Suksri (2007). The result indicated that crop growth rate was low in early stages and then gradually increased and reached the maximum during the flowering stage when the foliage cover was complete (Table 1). Phosphorus @ 75 kg P_2O_5/ha led to increase at 30–60 DAS and 60–90 DAS by 181.8 and 41%, but the CGR decreased at 90–120 DAS by 13% compared to the control. Efficacy of P uptake is enhanced by the availability of soil moisture (Nazeri *et al*., 2009). In general, the net assimilation rate of maize plants was influenced due to P levels (Table 1). The NAR was the highest at 30–60 DAS and declined at 60–90 DAS across the P levels. Net assimilation rate was the highest (10.9 $g/m^2/d$) due to P_{75} and the lowest (4.2 $g/m^2/d$) in P_0 (control) at 30–60 DAS. The net assimilation rate was highest at 30–60 DAS and declined at 60–90 DAS across the P levels. Ebrahim *et al*. (2011) stated that, net assimilation rate of crops was affected by P chemical fertilizer and phosphate microbial biofertilizer.

The P levels significantly influenced maize grain yield (Table 1). The highest grain yield (6.51 t/ha) was recorded in 75 kg P_2O_5/ha, while the lowest grain yield (4.11 t/ha) was obtained in the control. Increasing P level above 75 kg P_2O_5/ha decreased the grain yield of maize. Phosphorus @ 75 kg P_2O_5/ha resulted in 58.4% increase in grain yield over that in P_0 (control). A good and optimum supply of P is associated with increased root growth due to which the plants explore more soil nutrients and moisture. That is why the grain yield of maize was the lowest in control

Table 1. Effect of P levels on plant height, leaf area index, dry-matter accumulation (DMA) of maize, crop growth rate and net assimilation rate of maize and grain yield

P_2O_5 (kg/ha)	Plant height (cm) at 120 DAS	Leaf area index			Dry matter accumulation (g/plant) of maize (DAS)		Crop growth rate of maize [g/m (land area)/d] DAS		Net assimilation rate [g/m (leaf area)/d] of maize		Grain yield (t/ ha)
		30	60	90	30	120	30-60	60-90			
P_0	170.0	0.94	4.14	4.4	21.1	156.5	4.4	17.0	4.2	3.8	4.11
P_{15}	184.0	0.60	4.64	4.7	22.4	183.7	6.0	20.6	5.0	4.5	4.71
P_{30}	186.7	0.79	4.81	4.8	22.1	179.5	10.4	18.2	8.0	3.7	5.04
P_{45}	189.7	0.63	5.06	5.3	21.8	198.4	10.7	21.3	8.2	4.6	5.56
P_{60}	193.0	0.74	5.46	5.49	22	196.7	9.4	23.7	7.5	4.6	6.12
P_{75}	200.6	0.87	5.71	6.41	24.1	222.0	12.4	24.0	10.9	5.3	6.51
P_{90}	190.4	0.90	5.7	5.8	21.1	186.7	11.7	21.3	8.3	4.2	6.04
SEm±	5.1	0.18	0.22	0.23	1.6	9.7	1.71	0.98	1.75	0.65	0.62
CD (P=0.05)	12.4	0.41	0.44	0.5	NS	20.7	3.9	2.02	3.5	NS	1.21

DAS, Days after sowing.

plots because lack of P reduced the root growth of plants, which negatively affected other physiological functions of maize plants in the control plots. It is also obvious from this study that P application beyond 75 kg P_2O_5/ha (P_{75}) resulted in reduction in grain yield by 7.2%, and led to an economic loss. Most of the important yield components of maize plants that improved grain yield were obtained with this rate of P application. Alias *et al*. (2003) and Hussain *et al*. (2006) observed that increase in grain yield per hectare was owing to increased number of grains per cob and 1,000-grains weight in response to increasing levels of P.

Application of phosphorus @ 75 kg P_2O_5/ha resulted in higher grain yield (6.51 t/ha). The response of maize crop was optimistic and remunerative across the phosphorus levels up to 75 kg P_2O_5/ha; however, beyond this level the grain yield decreased by 7.2% at 90 kg P_2O_5/ha. Phosphorus @ 75 kg P_2O_5/ha resulted in better growth, yield components and yield of maize compared to all other P levels; therefore, 75 kg P_2O_5/ha proved the best treatment in our study. Hence, it can be concluded that maize is responsive to higher dose of P and a dose of 75 kg P_2O_5/ha is best from yield and economic perspective.

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