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Effect of phosphorus on yield and economics of maize (*Zea mays*) under semi-arid conditions of Afghanistan

N M AHMADI[1], T K DAS[2], N NASRAT[3], S S RATHORE[4] and A K PAUL[5]

Afghanistan National Agricultural Science and Technology University, Kandahar, Afghanistan

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Maize (*Zea mays* L.) is the most versatile cereal crop with wider adaptability in varied agro-ecologies (Saad *et al*. 2015, Behera *et al*. 2018). It has higher yield potential than other cereals and absorbs large quantity of nutrients from soil (Behera and Das 2019). Maize production ranks third after wheat and rice in Afghanistan and its area, production and productivity are 0.16 mha, 0.32 mt and 2.0 t/ha, respectively (Anonymous 2013). Maize serves as a basic raw material and an ingredient to thousands of industrial products (Rai *et al*. 2013, Das *et al.* 2018, Susha *et al*. 2018). Phosphorus nutrition is vital for increasing grain yield and quality of maize (Yosefi *et al.* 2011). Soils with high fixation capacity have higher demand for P (Hussain and Haq 2000). P interaction increases the efficiency and effectiveness of N and makes crop resistant to disease as well as acts as a control to the negative impact of higher N applications (Sarajuoghi *et al.* 2012). Phosphorus helps in photosynthesis, energy transfer, cell division/ enlargement, root formation/growth and improves water use and hastens maturity. Only 15–20% of the applied phosphorus fertilizer becomes available to the crop, and still a smaller fraction to the succeeding crops (residual effect). Therefore, an experiment was conducted at the Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar, Afghanistan to evaluate growth, yield and economics of maize under the hot arid conditions of Kandahar province of Afghanistan during (2015). It is located at $31^0$30' - $31^0$61' N latitude and $65^0$42'- $65^0$71' E longitude and at an altitude of 986 m amsl. The site belongs to the desert and oasis agro-ecological zone. It received 190.6 mm rainfall during 2015. Monthly mean temperature during crop growing period was 26.8°C. Soil was sandy clay loam, well-drained, and deep red grey in colour with 0.8% soil organic carbon and *p*H 8.3. Seven P levels at 0 (control), 15, 30, 45, 60, 75 and 90 kg P_2O_5/ha were laid out in a randomized complete block designed with three replications. The gross and net plot areas were 5.6 m × 4.25 m and 5 m × 4 m, respectively. 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 City, Mexico), and the significance was tested by the variance ratio (i.e. F-value) at 5% level.

Maize yield attributes: The grain yield depends on the source-sink relationship and the rate at which translocation takes place from source to sink during the reproductive stage. In this study, P levels significantly influenced the number of cobs/plant, cobs/m^2, cob girth, cob diameter and thousand grains weight (Table 1). The 75 kg P_2O_5/ha resulted in highest values of these parameters, viz. number of cobs/plant (1.8), number of cob/m^2 (12.4), cob girth (14 cm), cob diameter (4.4 cm) and thousand grains weight (261.2 g). It increased cob per plant by 50%, cobs/m^2 by 69.9%, cob girth by10.2%, cob diameter by 7.3% and 1000 grains weight by 10.8% compared to control. Khan *et al*. (2005) reported similar increase in these yield components of maize due to P application. Greater length of cobs of maize under higher levels of P could be due to higher translocation of assimilates into cobs (Sahoo and Panda 2001). Amanullah and Zakirullah (2010) reported that maize cobs length showed positive response to increasing levels of P. In this study too, the longest cobs of 23.3 cm and highest 1000-grain weight of 261.2 g were obtained with highest level of 75 kg P_2O_5/ha and 150 kg N/ha over control. Higher grain weights with higher P levels, probably, accrued from higher P translocation into the seeds (Sahoo and Panda 2001, Khan *et al.* 2005, Amanullah and Zakirullah 2010).

Maize grain and stover yields, and harvest index: Highest maize grain yield was recorded in 75 kg P_2O_5/ha, while lowest grain yield was obtained from the control (Table 1 and Fig 1). Increasing P level above the 75 kg

[1]M Sc Scholar (nmw.ahmadi@gmail.com), [3]Lecturer (nasarat2015 @gmail.com), Afghanistan National Agricultural Science and Technology University (ANASTU); [2]Professor (tkdas64@gmail.com), [4]Principal Scientist (sanjayrathorears@ gmail.com), Division of Agronomy, ICAR-Indian Agricultural Research Institute; [5]Principal Scientist (amrit.paul@icar.gov.in), ICAR-Indian Agricultural Statistics Research Institute.

Table 1 Effect of different P levels on yield components, yield, biological yield and harvest index of maize

P_2O_5 (kg/ha)	Yield components of maize						Grain yield (t/ ha)	Biological yield (t/ha)	Harvest index (%)
	Cobs/plant	Cobs/m^2	Cob girth (cm)	Cob diameter (cm)	Grains number per cob	1000 grains weight (g)			
P_0	1.2	7.3	12.7	4.1	436.5	235.7	4.11	11.1	36.9
P_{15}	1.4	8.9	13.4	4.1	446.5	244.5	4.71	13.1	36.1
P_{30}	1.3	9.8	13.2	4.2	460.8	246.2	5.04	14.4	34.9
P_{45}	1. 7	10.2	13.7	4.2	458.0	247.2	5.56	16.4	33.9
P_{60}	1. 3	10.7	13.7	4.3	463.8	247.4	6.12	18.3	33.4
P_{75}	1.8	12.4	14.0	4.4	472.3	261.2	6.51	19.4	33.5
P_{90}	1.5	10.2	13.8	4.3	446.9	249.0	6.04	17.9	33.8
LSD (P = 0.05)	0.23	1.07	0.59	0.21	21.4	4.6	1.21	3.11	1.5

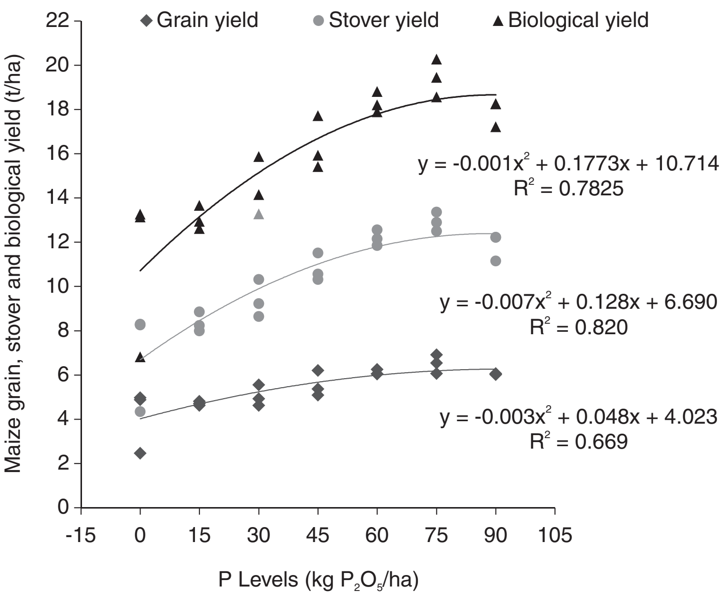

Fig 1 Effect of P levels on grain yield, stover yield and biological yield of maize (t/ha).

P_2O_5/ha led to decrease in grain yield. The 75 kg P_2O_5/ha application resulted 58.4% increase in grain yield over that in P_0 (control). The 75 kg P_2O_5 application again resulted in 75.4% increase in biological yield than the control. Higher supply of P increased root growth, which explored more soil nutrients and moisture. The yield components such as number of cobs/plant, grains/cob and grain weight/cob were also improved with this P application, leading to higher yield. Alias *et al.* (2003) observed that the increase in grain yield was due to increased number of grains/cob and 1000-grains weight in response to increasing levels of P. Phosphorus being responsible for good root growth directly affected the thousand grains weight (Hussain *et al.* 2006). The LAD during the reproductive stage and the fraction of total duration devoted to grain filling also influenced grain yield (Khan *et al.* 2005). The overall performance of P fertilization achieved was due to the fact that the smaller number of grains per cob was compensated by heavier grains observed in crops fertilized with P (Nour *et al.* 2005).

Highest harvest index (36.9%) was recorded with control (P_0), while lowest (33.4%) was with the 60 kg P_2O_5/ha, followed by 75 kg P_2O_5/ha (Table 1). This indicated lower biomass partitioning to grain production when P level was increased. Karki (2003) reported that there was no significant difference in harvest index, tissue P concentration and barren plant due to the applications of N, P, and their interactions. On the contrary, Alias *et al.* (2003) reported increase in harvest index in response to P application, but harvest index recorded at 75 and 150 kg P/ha were statistically similar.

Economic analysis: The application of P, especially at lower doses had least effect on grain and stover yields of maize, hence, higher returns could hardly be realized from the lower doses of P fertilization (Table 2). It was also obvious from this study that P application beyond 75 kg P_2O_5/ha resulted in reduction in grain yield by 7.2%, and led to an economic loss. A dose of 73.6 kg P_2O_5/ha on the basis of maize grain yield, and a dose of 86.7 kg P_2O_5/ha based on biological yield were found to be the economic optimum doses. This is in accordance with the findings of Nour *et al.* (2005). Economic analysis showed that, the 75 kg P_2O_5/ha resulted in highest gross returns, net returns and net B:C.

Table 2 Effect of different P levels economics on maize

P_2O_5 (kg/ha)	Cost of cultivation (AF/ha)	Gross returns (AF/ha)	Net returns (AF/ha)	Net B:C
P_0	52645	96073	43428	0.82
P_{15}	53950	111016	57066	1.06
P_{30}	55255	119503	64248	1.16
P_{45}	56560	132757	76197	1.35
P_{60}	57865	146713	88848	1.54
P_{75}	59170	156043	96873	1.64
P_{90}	60475	144610	84135	1.39
LSD (P = 0.05)		27895	27895	0.17

AF; Afghani.

SUMMARY

A field experiment was conducted at the Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar, Afghanistan during 2015 to find out the optimum level of P in maize. Seven phosphorus levels at 0 (control), 15, 30, 45, 60, 75 and 90 kg P_2O_5/ha were laid out in a randomized complete block design with three replications. Results showed that the application of 75 kg P_2O_5/ha resulted in maximum number of cobs/plant (1.8), number of cob/m (12.4), cob girth (14 cm), cob diameter (4.4 cm), thousand grain weight (261.2 g), grain yield (6.51 t/ha) and biological yield (19.43 t/ha) compared to those in control. A dose of 73.6 kg P_2O_5/ha based on grain yield, and a dose of 86.7 kg P_2O_5/ha based on biological yield of maize were economic optimum doses of P in maize. But, the 75 kg P_2O_5/ha resulted in highest values of most of the yield attributes, leading to highest grain, stover and biological yields and net returns. Therefore, a 75 kg P_2O_5/ha may be advocated to maize along with the recommended 150 kg N/ha, 20 kg K_2O/ha and 25 kg $ZnSO_4$/ha for obtaining higher yield and income in Kandahar, Afghanistan.

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