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Phosphorus use Efficiency and Maize (*Zea mays L*) Production under Different Placement Methods

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***Abstract* – The objective of this study was to evaluate the initial growth of maize plants and phosphorus use efficiency due to phosphate fertilization rates with different phosphorus placement methods. The experiment was conducted in a farmer's farm land. Eight treatments were accomplished under a 3*4 factorial arrangement, with four doses of phosphorus fertilizer rates and two types of placement methods. The data obtained were submitted to analysis of variance by the Genstat 18th edition probability; the qualitative data were submitted to analysis according to the source by the Fisher's unprotected test. The higher grain yield (78.40 qtha^{-1}) were noted from surface banding of phosphorus fertilizer to the sides of the seeds at application of 69 kg P_2O_5 ha^{-1} when compared with the deep banding and control. However, higher phosphorus use efficiency 1.8585 and 1.2431) were recorded at surface banding and deep banding at application of 23 kg P_2O_5 ha^{-1} respectively. The initial growth of the maize plants was higher when they were fertilized with 69kg P_2O_5 ha^{-1} at surface banding application method than deep banding application method.**

***Keywords* – Maize (*Zea mays L.*), Nutrient Use Efficiency, Total Phosphorus Uptake.**

I. Introduction

Phosphorus is an essential, unique part of nutrient in every living cell, both plant and animal. Plants up take a large amounts of phosphorus from the soil solution as phosphate ions, mostly, H2PO4− and HPO4=, but the concentration in the soil solution is very small, typically 10-5 M, consequently there must be a supply of readily-available phosphorus in the soil to maintain this concentration as phosphorus is taken up by the roots. Much of the phosphorus in the crop is removed in the harvested produce and phosphate fertilizers must replace that phosphorus. Phosphate rock (PR), the ore from which phosphorus fertilizers are made is a limited, nonrenewable resource. About 80% of the PR ore mined annually is used to make phosphorus fertilizer. Its long-term supply is fundamental to world food production. Because PR supplies are consequently significant to food security, the size and longevity of global resources are of great interest and subject to considerable debate. At current production levels of 160-170 million t/year, exploitable reserves of PR may last 300-400 years or longer [1]. Mineable reserves of phosphorus rock (PR) ore are dynamic. Upcoming availability depends on prices, supply demand functions, exploration, technology development, and other issues [2]. The present farming systems are unsustainable without external inputs of nutrients, will continue to be low in productivity, and have long-term destructive potential to the environment. In such systems, plant nutrient balances are negative [3]. Phosphorus is one of the highest limiting nutrients in agricultural cropping systems [4-6]. Also, phosphorus use efficiency (PUE) for cereal production in the world is too low, varying between 15and 30% [7].

While there is no immediate concern of running out phosphorus rock (PR), the increasing demand for phosphorus fertilizers, the need to maintain and improve the phosphorus status of many agricultural soils, especially in developing countries, and the adverse impacts of the transfer of soil phosphorus to surface waters and the resulting detrimental effects of eutrophication, the need to use phosphorus efficiently is vitally important and commonly acknowledged. There is a general perception that phosphorus fertilizer use is very inefficient because field studies show phosphorus recovery in the year of application by the crop rarely exceeds 25% and more often is only 10-15% of the phosphorus applied. The phosphorus not taken up by the crop that the residual phosphorus has been believed to be irreversibly fixed in the soil in unavailable forms, but those views are changing as agronomic field experiments have shown that is not the case [8]. Maize is the basis for food security in many developing countries in Africa, Asia and Latin America. According to the FAO AMIS 2021/22 forecast, global Maize production has reached 1,191million metric tons, growing at an average annual rate of 3% from 1,156 million metric tons in 2020/21. Ethiopia is one of sub Saharan African country which Maize is an important crop for food. During the 2020/21 main cropping season, Maize production covered 2.5 million hectares of land with total production of nearly 105 million Quintals. [9]; equivalent to 10.5 million tons. From the 81 percent of total Cereals in Ethiopian grain production, with Maize accounting for 35 percent of cereals production followed by Wheat, Tef and Sorghum with 19, 18 and 15 percent respectively in 2020/21 [9]. The maize production increment came from the 11 percent increment of area under maize cultivation. Average productivity has slightly declined from 42 Qt/Hectare to 41Qt/Hectare. One of the determining variables in achieving high yields is the supply of nutrients, among which phosphorus stands out. Phosphorus is essential in the plant for photosynthesis, respiration and energy transfer. Phosphorus use efficiency in maize fields is critically important, since this nutrient constitutes one of the most limiting factors to production [10].

II. Materials and Methods

The experiment was conducted on farm land at Bedele district. The district is located between 8°14'30"N to 8°37'53"N and 36°13'17"E to 36°35'05"E is about 483km road distance south-west of Finfine. The soils of southwestern Ethiopia are in general classified as Nitosols according to FAO/UNESCO or Alfisols according to USDA soil classification systems [11]. Soil samples were collected from the experimental fields at the depth of 0-30 cm before planting were analyzed for some selected soil physic-chemical properties (Table 1).The soil is clayey in texture with clay content of (55.67%) and strongly acidic with a pH value of 5.48. The soil contained 2.73% organic carbon, 0.16% total nitrogen and 1.51 ppm available phosphorus. Besides, the cation exchange capacity (CEC) of the soil was 17.41cmol/kg in which the dominant cation being potassium followed by Magnesium and calcium were the dominant exchangeable cation (Table 1) Available Phosphorus in soil was determined by the Bray II [12] extraction method and Available Phosphorus was determined from these extracted with Spectrophotometer method.

Table 1. Physical and chemical properties of experimental soils before planting.

Soil Properties	$Sample_1$	$Sample_2$	$Sample_3$	Mean
Particle size (%)				
Sand	20	20	18	19.33
Silt	27	25	23	25.00
Clay	53	55	59	55.67
Textural class	Clay	Clay	Clay	Clay
Total N (%)	0.16	0.17	0.16	0.16
Av.P (ppm)	1.34	1.71	1.48	1.51

Soil Properties	$Sample_1$	$Sample_2$	$Sample_3$	Mean
OC (%)	2.85	2.78	2.57	2.73
pH(H_2O)	5.43	5.39	5.62	5.48
CEC ($cmol_c$/kg)	19.03	16.03	17.17	17.41
Exchangeable K ($cmol_c$/kg)	2.37	2.84	2.30	2.50
Exchangeable Ca($cmol_c$/kg)	1.13	1.12	1.11	1.12
Exchangeable Mg($cmol_c$/kg)	1.84	1.84	1.81	1.83

2.1. *Experimental Procedure and Treatments*

The treatments used for this experiment were two methods of placement and four levels of P fertilizer. The factorial experiment was laid out in randomized complete block design with four levels of phosphorus fertilizers (0, 23,46, and 69 kg P_2O_5 ha^{-1}) in a factorial combination with two placement methods of surface banding P_2O_5 to the side of the seeds and Deep Banding P_2O_5 to below of the seeds up to 15cm. There were combined eight treatments contained of four levels of phosphorus fertilizer rate and two method of placement replicated three in a randomized complete block design. The following treatment combinations were undertaken, 0 kg P_2O_5 with surface banding, 0 kg P_2O_5 with deep banding, 23 kg P_2O_5 ha^{-1} with surface banding to the side of the side, 23 kg P_2O_5 ha^{-1} with deep banding, 46 kg P_2O_5 ha^{-1} with surface banding, 46 kg P_2O_5 ha^{-1} with deep banding, 69 kg P_2O_5 ha^{-1} with surface banding, and 69kg P_2O_5 ha^{-1} with deep banding. Three central rows maize were harvested and sun dried for four days, threshed manually, grains were separated and weighed on an electric sensitive balance to compute the grain yield and then converted into kg ha^{-1}. One gram oven dried stalk and grain sample was digested in 10 mL of di-acid mixture (concentrated HNO_3 and 72% $HC1O_4$, with 9:4 ratio) cooled the digest, transferred to 100 mL volumetric flask and made volume. 5mL of the digested aliquot was taken in 50 mL volumetric flask, 5 mL of ammonium vanadate (0.25%) and ammonium molybdate (5%) was added, made volume and allowed to stand for 15-30 min. Reading was recorded on spectrophotometer. Then from the standard curve, phosphorus concentration (%) in grain and stalk was calculated. Total P uptake by stalk and grains was calculated using the following formulae:

$$\text{P uptake (kgha}^{-1}\text{)} = \frac{\text{P contents (\%) in plant part (dry matter)*yield (kgha}^{-1}\text{)}}{100}$$

According to the formulae of given by [13] phosphorus use efficiency (PUE) was recorded as follows:

$$\text{PUE(\%)} = \frac{\text{[Total P uptake(kg ha}^{-1}\text{)in fertilizer plot]-[Total P uptake (kg ha}^{-1}\text{)in control plot]}}{\text{P dose applied (kg ha}^{-1}\text{)}}$$

III. Results and Discussion

Different phosphorus rates and phosphorus application methods significantly ($p<0.01$) influenced the grain yield of Maize (Table 2). Generally, the reality of interaction effect between the factors on the measured variables indicated that the main effects of phosphorus fertilizer rates and its application methods factors influence each other on grain yield of maize. This results shows the higher grain yield of maize was recording at surface banding on 69Kg $P_2O_5ha^{-1}$ than the deep banding. This results agreed with [6] who reported that, the surface band phosphorus application method gave higher yield of maize than other placement methods.

Table 2. Effects of Phosphorus fertilizer rate and its methods on Grain yield, and stalk P contents, P uptake and PUE of Maize.

P_2O_5 Level ($kgha^{-1}$)	Placement method of phosphorus fertilizer							
	Grain Yield ($Qtha^{-1}$)		Stalk P Contents (%)		Total P Uptake (Kg Ha^{-1})		P Use Efficiency (%)	
	Surface Banding	Deep Banding	Surface Banding	Deep Banding	Surface Banding	Deep Banding	Surface Banding	Deep Banding
0	26.00^{e}	17.63^{f}	1.41	1.34	36.71^{b}	23.35^{a}	0.000^{a}	0.000^{a}
23	56.77^{b}	38.07^{d}	1.40	1.36	79.45^{d}	51.94^{c}	1.8585^{b}	1.2431^{b}
46	58.03^{b}	42.87^{c}	1.50	1.50	87.00^{d}	64.24^{c}	1.0933^{b}	0.8891^{b}
69	78.40^{a}	55.23^{b}	1.44	1.57	112.92^{e}	86.76^{d}	1.1045^{b}	0.9190^{b}
LSD (5%)	3.96		ns		12.6601		0.3984	
CV (%)	6.08		9.02		11.3		24.4	

3.1. *Phosphorus uptake by Maize Stalk*

In the dry matter accumulation by the maize plants, there was no difference between the phosphorus fertilizer rates and application methods (Table 2). Among treatments the maximum phosphorus uptake (1.57%) by stalk was received in treatment treated by 69 kg P_2O_5 ha^{-1} at deep banding below the seeds and the lowest recorded in control. Although, [14] studying the influence of phosphorus in nutrient solution on dry matter in eight maize genotypes, also found that higher phosphorus concentration promoted higher dry matter accumulation. Similarly, [15-16] obtained the same results; as the doses of phosphate fertilizers increase caused proportional increase in dry matter production by maize plants.

3.2. *Phosphorus use Efficiency*

No significant differences were observed for phosphorus use efficiency (PUE) of maize among the tested phosphorus fertilizer rates except control plot which was significant difference from the fertilized plots. As phosphorus fertilizer rate increase the phosphorus use efficiency of maize was decrease (Table 2). This result agreed with [17], even with increasing phosphorus availability and regardless of the source, the maize reduced linearly the efficiency rate. Likewise, [15] who observed that a reduction in phosphorus use efficiency with rate increases in maize crops. Though, increased nutrient availability and the source used are not the only issues that can change the degree of use efficiency. Additional important aspect would be the cultivar inherent characteristics. According to [18-19] maize cultivars show variation in the phosphorus use efficiency rate in tests conducted both in nutrient solution and in the field.

IV. Conclusion

The initial growth of the maize plants was higher when they were fertilized with 69kg P_2O_5 ha^{-1} at surface banding application method than deep banding application method. However, phosphorus use efficiency did not increase with phosphorus fertilizer rates and no significance shows between the two methods and phosphorus fertilizer rates except the control plot which shows zero phosphorus use efficiency.

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