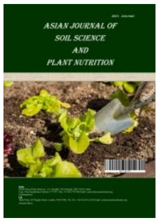

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Effects of Different Levels of Phosphorous and Zinc Fertilizers on the Yield and Nutrient Uptake of Maize (*Zea mays* L.) on Luvisols in Northern Guinea Savannah Region of Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author MA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AB managed the analyses of the study as well as the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The study aimed to determine the effects of different levels of phosphorous and zinc fertilizers on the yield and nutrient uptake of maize (*Zea mays* L.) The experiments were conducted in a factorial experiment under Randomized Complete Block Design (RCBD) to determine the effect of P and Zn applications on TZL white composite improved variety of maize. Four levels of phosphorus (0, 10, 20 and 30 kg P ha^{-1}) and three levels of zinc (0, 5 and 10kg Zn ha^{-1}) were applied on experimental plots of 4.5m x 5m replicated thrice. The results shows no significant differences in both the years however, highest mean values of 2327.5 kg $ha-^{1}$ and 2191.5 kg $ha-^{1}$ was recorded at 20 kg P ha^{-1} and 10 kg Zn ha^{-1} Application of P and Zn at different rates increases their uptake in the stover with highest values of 22.57 mg $^{-1}$ kg and 7.8 mg $^{-1}$ kg in 2018 at 30 kg Pha^{-1} and 18.40 mg $^{-1}$ kg and 5.21 mg $^{-1}$ kg at 20 kg Pha^{-1} in 2019. While 26.54 mg $^{-1}$ kg and 21.85 mg $^{-1}$ kg in 2018 at 10 kg $Znha^{-1}$ and 6.76 mg $^{-1}$ kg and

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5.27 mg $^{-1}$ kg in 2019 with 0 kg Znha^{-1} respectively. It is therefore recommended the best results of the application of 30kg P ha-^{1} and 10 kg Zn ha $^{-1}$ should be adopted for optimum yield of maize.

Keywords: Fertilizers; maize; nutrients uptake; phosphorous; yield; zinc.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important grain crop with great economic value for both livestock and human consumption [1] Maize is a high-nutrient demanding cereal crop with rapid growth rate and it produces large biomass. [2]. Plant growth and development needs the availability of essential nutrients in the balance form that lead to the formation of good yield [3]. The importance of phosphorus has been emphasized by many workers [4]. After nitrogen and phosphorus, Zinc has been reported as the third most important limiting nutrient elements in crop production [5]. It promotes the early growth and formation of roots, which also improves the crop resistance against certain diseases [6;7]. Zinc (Zn) is one of the most functional micronutrients in biological system [8]. Zn is a constituent of different enzyme involved in metabolism of carbohydrate, auxin, protein, pollens' formation and maintenance of the biological membranes integrity and infection resistance against certain pathogens [9;10]. Zn promotes the synthesis of carbonic enzyme, which is responsible for the biosynthesis of chlorophyll and is present in all photosynthetic tissues [11]. Physiological pathways involved in the processing of photosynthetic assimilates are also Zn dependant [12;13]. Generally, due to limited availability of these nutrients, maize crop grown in alkaline-calcareous soils suffers from deficiencies phosphorus (P) and zinc (Zn) [14]. Therefore, Quality and quantity of the crop produce can be improved through balanced nutrition. Micronutrients are indispensable for plants, required in trace amounts [15]. The plant's physiological activities and growth is mainly harmonized by these nutrients [16]. In maize, higher P and lower Zn concentrations as a result of P toxicity and Zn deficiency reduces the shoot growth, nutrient uptake and ultimately, the yield. Thus, there is ardent need to determine the effects of different levels of phosphorous and zinc fertilizers on the yield and nutrient uptake of maize with an objective for deciding suitable recommendation of fertilizer use to the small scale farmers for sustainable and profitable food production. With this back drop the present study is aimed to determine the effects of different levels of Phosphorous and zinc fertilizers on the yield and nutrients uptake of maize on Luvisols in northern Guinea Savannah of Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at Teaching and Research Farm of School of Agriculture and Agricultural Technology, Modibbo Adama University, Yola situated at 9°16'N 12°35E and is 152 m above sea level, with an average rainfall of 910.8 mm which occurred between May to October. The soil of the study area was sandy loam and it is classified as Typic Palecustaff (USDA) or Chromic Luvisols (FAO/UNESCO) [17]. The study area falls within the Northern guinea savannah zone having maximum temperature in the state can reach 40°C with the mean monthly temperature ranging from 26.7°C in the northeastern part. [18;19].

2.2 Experimental Design and Layout

Experiments were conducted at the University Research Farm during 2018 and 2019 rainy seasons with plot size of 4.5m x 5m. Randomized Complete Block Design (RCBD) was used in the experiment to test various levels of P and Zn applications on Txa ZL composite white improved variety of maize. Four levels of phosphorus (0, 10, 20 and 30 kg P/ha) and three levels of zinc (0, 5 and 10 kg/ha) were laid in twelve treatment combinations replicated thrice.

2.3 Agronomic Practices

The land was ploughed using tractor and harrowed to break the soil clods. The maize seeds TZL composite variety were sown in July 8th, 2018 for the first year and July 10th 2019 for the second year at the rate of 3 seeds per hole at a spacing of 75 cm× 25 cm. Phosphorus and zinc fertilizers were applied to each experimental plot according to treatment rates in a single dose. Weeding was done manually and harvesting was carried out on the 8^{lll} of October for first year of experiment in 2018 and 10th October for second year of experiment in 2019 respectively at 90 days of maturity. Each experimental plot was harvested separately and yield parameter 'were recorded.

The total cob yield dry matter yield and grain yield was recorded

$$\text{Shelling \%} = \frac{\text{Grain weight after shelling}}{\text{Cob weight}} \times 100$$

3. RESULTS

3.1 Effects of P and Zn Application on Cob Weight, Grain Weight and Shelling Percentage

The result of Phosphorus and Zinc levels on cob weight and grain weight presented on Table 1 shows no significant differences in both 2018 and 2019 cropping years however, highest mean values of 2327.5 and 2191.5kgha-^{J} was recorded at P_2 and Zn_2 with the least mean values at $PoZn_0$. Also, it was observed that there was significant interaction effect on shelling % in 2018 and 2019 respectively.

3.2 Effects of P and Zn Application on Straw Weight and Total Dry Matter

The result presented on Table 2 shows that the main effect of the treatments (P and Zn) did not show any significant difference in straw weight and total dry matter in both 2018 and 2019. However, a highest value of 2126.50kgha-1 of straw weight was observed at P_3Zn_2 levels respectively. Similarly, lowest values of 1690.00 and 1773.00kgha^{-1} were recorded at P_0Zn_0. Also 3862.50 and 3593.50kgha"' values was observed to be the highest for total dry matter at P_0Zn_0while 3168.50 and 3228.50kgha $^{-1}$ was observed as the lowest values for total dry matter at P_0 Zn_0 levels correspondingly.

3.3 Effects of P and Zn Application on Total P and Zinc in Stover

Table 3 shows the effects of P and Zn application on total P and Zinc contents in Stover. The result clearly indicate that P_3 and Zn_0 significantly influenced Stover P content in 2018, However, there was no significant effect in 2019 but highest values of 18.40 and 26.54 was recorded at P_2Zn_2 and lower values at P_0Zn_0 respectively. The main effect of the treatments (P and Zn levels) on zinc content in Stover was significantly affected in both 2018 and 2019 cropping years. There was significant interaction effect among the treatments on total P in 2018 and zinc content in both years.

4. DISCUSSION

4.1 Cob-Weight, Grain Weight and Shelling Percentage

Comparative analysis of the results (Table 1) shows that, the untreated plots weigh less cob weight and grain weight per treatment. These low values may be due to low P/Zn content in the soil of the study area of and may be attributed to the reduction in the activities of photosynthesis, delayed silking, tasseling and maturity. Thus, most crops including maize plants are

Table 1. Effect of P and Zn application on cob weight, grain weight shelling percentage

Treatment	Cob weight (kgha^{-1})			Grain weight (kgha^{1})			Shellin (%)		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
P_0	1941,00	1796.00	1868.50	1210.00	1038.00	1124.00	59.41	64.37	61.89
P_1	2065.00	2127.00	2096.00	1286.00	1431.00	1358.50	61.34	67.89	64.61
P_2	2031.00	2574.00	2327. 0	1300.00	1717.00	1508.50	61.59	68.10	64.84
P_3	1805.00	2034.00	1919.50	1086.00	1333.00	1209.50	59.60	65.69	62.64
SE_+	184.80	227.70	206.25	198.20	227.30	212.75	3.66	4.21	3.94
Zinc									
Zn_0	1807.00	2022.00	1914.0	1086.00	1140.00	1113.00	57.58	61.75	59.66
Zn_1	2000.00	2103.00	2051.0	1280.00	1512.00	1391.00	63.02	71.42	67.22
Zn_2	2111.00	2272.00	2191.0	1296.00	1486.00	1396.00	64.87	68.36	66.61
SE_+	194.50	214,90	204.0	147.30	160.90	154.10	2.37	3.54	2.95
Interaction									
(Zn & P) LSD(0.05)		NS	NS	NS	NS	NS	0.1*	0.1*	0.1*

** Significantly different P=(0.05), NS = non-significant*

Table 2. Effect of P and Zn application on straw weight and total dry matter ($kgha^{-1}$) of maize

Treatment	Straw weight			TD (Straw Weight)		
	2018	2019	Mean	2018	2019	Mean
Phosphorus						
P_0	1630.00	1750.00	1690.00	3094.00	3243.00	3168.50
P_1	1580.00	1866.00	1723.00	3203.00	3444.00	3323.50
P_2	2012.00	1987.00	1990.50	3770.00	3955.00	3862.50
P_3	2198.00	2055.00	2126.50	3096.00	3443.00	3269.50
SE_+	370.30	454.60	412.45	276.90	313.70	295.30
Zinc						
Zn_0	1767.07	1780.00	1773.54	3128.00	3329.00	3228.50
Zn_1	1778.00	1830.00	1804.00	3298.00	3495.00	3396.50
Zn_2	2120.00	2133.00	2126.50	3447.00	3740.00	3593.50
SE_+	273.10	296.70	284.90	204.50	203.60	204.05
Interaction						
(Zn & P) LSD(0.05)		NS	NS	NS	NS	NS

** Significantly different P=(0.05), NS = non-significant*

Table 3. Main effect of P and Zn application on Phosphorous and Zinc content in stover ($mgkg^1$)

Treatment	2005	2006	Mean	2005	2006	Mean
Phosphorus						
P_0	19.49	16.86	18. 18	2.90	4.26	3.58
P_1	17.36	13.27	15.32	4.34	5.01	4.68
P_2	21.41	18.40	19.91	4.20	5.21	4.71
P_3	22.57	17.71	20.14	7.84	4.66	6.25
SE_+	0.66	1.95	1.30	1.33	1.39	1.36
Zinc						
Zn_0	11.13	19.77	15.45	6.76	5.27	6.02
Zn_1	22.95	18.06	20.51	3.78	4.78	4.28
Zn_2	26.54	21.85	26.54	3.93	4.29	4.11
SE_+	0.93	0.70	0.81	1.16	1.18	1.17
Interaction						
(Zn & P) LSD(0.05)	1.32*	NS	1.32*	1.92*	2.43*	2.18*

** Significant difference P=(0.05), NS = Non Significant*

susceptible to P and Zn deficiency. Shahen et al., [2015] Ref. [20] reported that Phosphorus and Zn source significantly affected the grain yield and plots treated with Zn at 15 kg ha^{-1} produced higher grain yield (5099), while lower (4293) was observed at no Zn addition. Also the cob weight and grain weight increases with increased in the rate of P/Zn application. Arian et al., 1989 Ref. [21] also reported an increased in plant height, number of cobs and grain yield with increase in P application. Khan et al.,1999 Ref. [22] and Sahoo and Panda, 2001 [23] reported that grain yield of maize increased increased with the increase of P application. In essence, the higher values obtained at the P level treated plots compared to Zn level treated plots may be due to the role P played in influencing growing parts of the plants, flowering, translocation and fruiting as well as improving the quality of the crop product coupled with the low Zn content of the soil which delayed silking, tasseling and maturity. Similarly, Abuyemva and Mercerquarshie, 2004 Ref. [24] found increase in the grain yield at higher level of Zn. In addition, Zn, plots with 10 kg Zn ha^{-1} produced the heavier grains (243.2) as compared with the lighter grains (228.3) noted in the control plots as reported by [20]. Khan et al., 2013 Ref. [25] and. Marwatt et al. [26] also reported that application of Zn and macro-nutrients increased the yield related parameters of maize. This is because Zinc enhances root development leading to improve N uptake and rapid vegetative growth and improve grains up to 35 kg $ZnSO4$ ha^{-1} [14].

4.2 Straw Weight and Total Dry Matter (TDM)

It is evidenced from Table 2 that the maximum production of straw yield and total dry mater was recorded from P3 and Zn_2 treatment respectively. A significant reduction in the production of dry matter of maize and P/Zn deficiency symptoms were recorded in the $PoZn_0$ treatments. The straw weight and total dry matter is higher in all the treatments with higher P concentration than Zn treatment. Rupa et al., 2003 Ref. [27] reported that the dry matter production increased significantly with increasing phosphorus levels. The possible reason for increase in dry matter production could be due to the absorption of applied phosphorous by the maize plant. The result of the present study showed that the differences in straw weight and the total dry matter obtained per treatment can be consequences of differences in their initial content in the soil, rate of application, uptake and translocation abilities of phosphorus and zinc as well as their ratio in the straw and the dry matter respectively. Though, the interactive effect of P/Zn application was non-significant, the straw weight and TDM was higher at P level of treatment than Zn level of treatment. This may be detrimental either due to formation of complexes of higher P levels with other nutrients i.e. antagonistic effect with Zn,. [28;29;30] or limitation of N and K nutrients in soil [31]. This assertion agreed with earlier findings of [32) that the data on the performance of phosphorus levels revealed a significant positive relation of grain and straw yield with the increased phosphorus application.

4.3 Nutrient Uptake of Phosphorus and Zinc Content in Stover

Phosphorus levels had significant effect at 5% level of significance on grain, stover and biological yield of maize (Table 3). The Zinc deficiency may be attributed to the immobilization of zinc owing to the increase in the concentration of P in the stover. Also, since the concentration of P in the Stover is raised manifold by adding P into the soil, it can be stated that, the immobilization of Zinc could be expected somewhere in the short (stover, leaves) of the plant. However, nothing is known about the biochemical causes of zinc immobilization because of the high phosphorus content in the plant. So, it could be concluded that the tendency of P to depress Zn nutrition is physiological in nature and not due to activation in the soil. Application of P and Zn at different rates increases their uptake in the Stover (Table 3). So, the appearance of deficiency symptom of P in maize plant at a high level of Zn application clearly indicated their antagonistic effect and vice versa. The result of this study shows an increase of the total over ground biomass as a result of phosphorus fertilization. Also, the application of increasing P rates did not decrease the content of available zinc in the soil but increases in the plant stover. Thus, it is good to note that application of excessive P to soil may induce Zn deficiency in plants. However, the uptake of Zinc by maize plant (stalk and leaves) was significantly higher in the fertilized plots than unfertilized plots. So, the interactive effect of P/Zn exchange occur somewhere in the plant not in the soil. Generally, since nutrient uptake is a function of their content in grain and straw and yield of crop, the increase in these parameters due to phosphorus application leads to an increase in the uptake of this nutrient. Similar results have also been reported by earlier researchers [33;34;35].Thus, Phosphorus is one of the most important major nutrients required for the growth and development of crop plants [36,37].

5. CONCLUSIONS

It is obvious that phosphorus and zinc are very important and essential for profitable maize production due to their vital role on growth and yield. Thus, this present study determined the effects of different levels of phosphorous and zinc fertilizers on the yield and nutrient uptake of maize (*zea mays* l.) on luvisols in northern guinea savannah region of nigeria in two growing seasons (2018 and 2019) respectively. The result indicated that an application of P and Zn at different rates increases the maize grains yield, cob weight, straw weight and uptake in the stover. Therefore, this study therefore ascertained that the application of phosphorus and zinc fertilizers at the rates of 30 kg P ha^{-1} and 10 kg Zn ha^{-1} is recommended for effective growth and optimum yield of maize in the northern Guinea Savannah region of Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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