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RESPONSE OF MAIZE TO ZINC FERTILIZATION IN MINNA SOUTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

Zinc (Zn) is an essential mineral nutrient for plant and human growth, such that dietary Zn deficiency has become a worldwide nutritional problem. A field study was conducted during the 2014 and 2015 cropping seasons at the Teaching and Research Farm, Federal University of Technology, Minna to investigate the response of maize to Zn fertilization in Minna. The treatments were soil application of Zn at 0, 2.5, 5 kg ha^{-1} at 2 weeks after sowing (WAS), foliar application of Zn at 2.5 and 5 kg ha^{-1} at 3 and 6 WAS, arranged in a randomized complete block design with three replications. The results indicated that application of Zn significantly ($p<0.05$) increased maize growth at 12 WAS and yield in both years. Foliar spray of 5 kg Zn ha^{-1} at 3 WAS in 2014 and soil application of 5 kg Zn ha^{-1} in 2015, significantly ($p<0.05$) increased plant height compared to foliar spray and soil application at 2.5 kg Zn ha^{-1}, respectively. Stover and grain yields were significantly ($p<0.05$) increased by either soil or foliar application of 2.5 - 5 kg Zn ha^{-1} compared to the control treatment. Zinc concentration in maize grain was significantly ($p<0.05$) increased with foliar spray of 5 kg Zn ha^{-1} in comparison with other treatments in 2014, and foliar spray of 5 kg Zn ha^{-1} at 3 WAS compared to the control only in 2015. Foliar application of 5 kg Zn ha^{-1} was most effective in enhancing grain Zn concentration by 65.1 – 71.4 % and is hereby recommended to farmers in this agro-ecology of Nigeria.

Keywords: *Foliar application, Maize grain, Savanna, Soil application, Zinc concentration.*

1.0 INTRODUCTION

Maize (*Zea mays* L) is a major staple food crop widely grown in Nigeria. It is one of the most important, high value cereals consumed in many households in Nigeria, with a per capita consumption of 60 kg year^{-1} (Bauernfeind and Deritter, 1991). Maize kernels can be processed into different traditional food products such as pastes, gruels and porridges. It can be used for the production of indigenous and commercial food products that are enjoyed for their unique and distinctive flavours. It is eaten fresh or milled into flour and serves as a valuable ingredient for baby food, cookies, biscuits, ice cream, pancake mixes, livestock feed and a variety of traditional beverages.

and other various foods with various local or regional names in different parts of Nigeria (Ado *et al.*, 2004; Eleweanya *et al.*, 2005).

Zinc (Zn) is an important micronutrient in biological systems and is receiving growing attention worldwide because of increasing reports about its deficiencies in human populations and crop plants (Alloway, 2004; Cakmak, 2008). It is also essential for the functioning of many enzymes needed for nitrogen metabolism, energy transfer and protein synthesis (FAO/WHO, 2002). It is claimed to be the most commonly deficient trace element in plants (Cakmak, 2002). For example, it has been described as the most limiting nutrient for maize production in savanna soils (Chude *et al.*, 2003). Zinc deficiency does not only retard growth and yield of plants, it also has negative effects on human beings. It is currently listed as a major risk factor affecting human health and cause of death globally. According to WHO (2002), Zn deficiency ranks 11th among the 20 most important factors in the world, and 5th among the ten most important factors responsible for causes of illnesses and diseases in developing countries. Zinc deficiency is responsible for many severe health complications like impairments of physical growth, immune system and learning ability (Hotz and Brown, 2004; Gibson, 2006; Prasad, 2007).

The most sustainable solution for Zn deficiency in a developing country such as Nigeria is to increase the consumption of a diversified diet of meat, poultry, fish, fruits, legumes and vegetables among the people living in the rural areas. This is by nature of a long-term solution, but other short term solution measures that can decrease the level of Zn deficiency are food fortification and supplementation which are poorly accessed by people living in the rural areas. The application of Zn fertilizers to soil and / or by foliar methods, seem to be a viable approach to improve grain Zn concentrations (Shivay *et al.*, 2008). Maize response to soil application of Zn in some savanna soils have been reported by some workers Chude *et al.*, 2003; Uyovbsiere and Lombin, 1990). The objective of this study was to investigate the response of maize to Zn fertilization in Minna southern Guinea savanna of Nigeria.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The field experiments were conducted in 2014 and 2015 cropping seasons, at the Teaching and Research Farm, Federal University of Technology, Gidan Kwano Minna. Located between latitude 9° 30′ 49.8″ N and longitude 6° 26′ 17.5″ E, 207.8 m above the sea sea level in the southern Guinea savanna zone of Nigeria. Rainfall pattern of the area is monomodal, with rainy season starting in March and ending in October. Monthly rainfalls for the period of study are shown in Table 1. The soil was classified as Typic plinthu stalf (Lawal *et al.*, 2012). Prior to this study, the field has been under fallow for many years, after being sparing cultivated with maize and yam with no fertilizer application.

2.2 Treatments and Experimental Design

Treatments consisted of soil applied Zn at 0, 2.5, and 5 kg ha^{-1} at 2 WAS, and foliar applied Zn at 2.5 and 5 kg ha^{-1} at 3 and 6 WAS. The relatively low rate of Zn was applied, because previous studies have indicated relatively high extractable Zn contents of the soils of the area (Lawal *et al.*, 2014). The treatments were arranged in a randomized complete block design with three replications. Gross plot size was 6 m × 4 m, and net plot was 4 m x 3 m.

2.3 Agronomic Practices

The field was manually cleared and ridged at 75 cm apart. Maize variety. Oba super 2 (quality protein maize) was sown (2 plants per stand) at 25 cm intra row. All the plots had basal fertilizer application of 30 kg P ha^{-1} as single superphosphate, 30 kg K ha^{-1} as muriate of potash at 2 weeks after sowing (WAS) after thinning was done to one plant per stand. The recommended rate of N (90 kg N ha^{-1}) was applied in two split doses to all the plots. One – third was applied at 2 WAS, while the remaining two-third was applied at 5 WAS. The fertilizers were applied by side banding at 5 cm away from the seedlings and at 5 cm depth along the ridge. The source of Zn was $ZnSO_4.7H_2O$. The soil applied Zn was done by mixing the $ZnSO_4$ thoroughly with muriate of potash and applied together. Foliar application was by preparing a spray solution of 1.80 kg $ZnSO_4$ ha^{-1} in 400 litres of water, and sprayed onto the leaves using hand sprayer as described by Muhammad *et. al.* (2010). All the plots were hoe-weeded at 2 and 5 WAS and remoulding was done at 8 WAS.

Table 1: Monthly rainfall during the period of study

Month	Rainfall (mm)	
	2014	2015
January	0.0	0.0
February	0.0	0.0
March	20.0	56.5
April	50.0	0.0
May	85.00	109.3
June	131.5	138.7
July	95.0	175.5
August	204.3	223.5
September	260.7	209.9
October	139.2	30.8
November	0.0	0.0
December	0.0	0.0
Total Rainfall	**985.7**	**944.2**

Source: *Department of Geography, Federal University of Technology, Minna.*

2.5 Soil Sampling and Analysis

Surface soil, (0 – 15 cm) samples were collected from ten points along four diagonal transects. The samples were bulked together to form a composite sample which was used to characterize the field before land preparation. At maize physiological maturity, surface soil samples were collected between two plants stand and the furrow along two diagonal transects, bulked together to give a composite sample per plot for determination of soil extractable Zn. The soil samples collected were air–dried, crushed gently and passed through a 2 mm sieve prior to analysis. Particle size distribution was determined by Bouyoucos hydrometer method (Klute, 1986). Soil reaction was determined potentiometrically in 1: 2.5 soil to water suspension with the glass electrode pH meter. Organic carbon was determined by the Walkley and Black wet oxidation method (Nelson and Somers, 1982). Exchangeable bases were determined by extraction with neutral 1 N NH_4OAc. Potassium in the extract was determined with flame photometer, while calcium and magnesium was determined using atomic absorption spectrophotometer. Available phosphorous was extracted by the Bray P1 method and the P concentration in the extract was determined colorimetrically using spectrophotometer. Total N was determined by Kjeldahl digestion method (Bremner and Mulvaney, 1982). Zinc was extracted using the diethylenetriamine penta-acetic acid (DTPA) extractant (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M TEA) and Zn in solution was determined by atomic absorption spectrophotometer.

2.5 Data Collection

Plant height was recorded at 8 and 12 WAS by measuring from the soil level of maize plants to the tips of the tallest leaf using meter rule. Ten maize stands from middle row in each of the plots were selected and the mean determined. The maize in the net plot was cut above ground level at physiological maturity, dried and weighed using weighing balance to determine the stover yield. Maize grain yield was measured by harvesting maize ears in the net plot. The ears were air dried, shelled and weighed. The grain yield was adjusted to 12 % moisture content for each plot.

2.6 Grain Zinc Analysis

Grain Zn concentration was determined using standard methods as outlined by Agbenin (1995).

2.7 Statistical Analysis

Analysis of variance (ANOVA) was used to evaluate the treatment effects on data collected. Means separation was carried out using Duncan Multiple Range Test (DMRT) at 5 % level of probability. All computation was carried out by General Linear Model (GLM) procedure of SAS (SAS, 2002).

3.0 RESULTS AND DISCUSSION

3.1 Initial Soil Properties

Some selected physical and chemical properties of the soil prior to land preparation in 2014 are shown in Table 2. The textural class of the surface soil was sandy loam. It had slightly acidic soil reaction. The soil reaction implies that most plant nutrients may be readily available for the uptake of plants in the soil. Brady and Weil (2010) reported that most plant nutrients are available for plants uptake in the pH range of 5.5 – 7.0

The soil organic carbon, total N and available P were all low, while exchangeable Ca, Mg and K were medium (Chude *et al*., 2011).

The extractable Zn content of the soil was high (Esu, 1991) and above the critical range of 0.2 to 2.0 mg kg $^{-1}$ for DTPA extractable Zn established by Sims and Johnson (1991). The soil could therefore, be regarded as being adequate in extractable Zn.

Adequate extractable Zn has also been reported for some soils of the same southern Guinea savanna of Nigeria by Kparmwang *et al*. (2000). The value of Zn obtained (2.30 mg kg^{-1}) was similar to the critical level of 2.20 mg kg^{-1} established for some savanna soils in pot experiment by Yusuf *et al*. (2005). The relatively high extractable Zn of the soil may be attributed to the soil having been under fallow for many years resulting in Zn not mined from the soil. Low extractable Zn in soils usually results from reduction in length of fallow period, crop intensification, planting of high yielding varieties, use of high analysis fertilizers with very little or no micronutrients and increased Zn removal (Singh *et al*., 1999; Slaton *et al*., 2001).

Table 2. Some physical and chemical properties of the soil prior to planting in 2014

Parameters	Values
Sand (g kg^{-1})	881
Silt (g kg^{-1})	36
Clay (g kg^{-1})	83
Textural class	Loamy sand
pH in H_2O (1:2.5)	6.6
pH in $CaCl_2$ (1 : 2.5)	5.5
Organic Carbon (g kg^{-1})	5.08
Total Nitrogen (g kg^{-1})	0.06
Available P (mg kg^{-1})	9
Exchangeable Bases (cmol kg^{-1})	
Ca^{2+}	2.80
Mg^{2+}	0.66
K^{+}	0.18
DTPA Extractable Zn(mg kg^{-1})	2.30

3.2 Effect of Soil or Foliar Applied Zinc on Growth, Yield and Zinc Content of Maize Grain

Maize plants heights were significantly ($p<0.05$) affected by Zn fertilization at 4 and 12 WAS only in both seasons in Table 3. At 4 WAS in 2014, foliar applied 5 kg Zn ha^{-1} at 3 and 6 WAS resulted in taller plants when compared with the control and soil applied Zn at 2.5 kg ha^{-1}. However, at the last sampled period, 5 kg Zn ha^{-1} foliar applied at 3WAS recorded the tallest plants similar to foliar applied 2.5 kg Zn ha^{-1}. The increase in plant height with Zn fertilization was due to increasing Zn in the tissue. Thalooth *et al.* (2006) reported that spraying of Zn solution increased the growth, yield and yield components of plants. Zinc spraying has been effective for improving qualitative properties of maize grain (Mohseni *et al.,* 2006).

Soil or foliar applied Zn had no significant ($p>0.05$) effect on both stover and grain yields in 2014 (Table 4). However, in 2015, irrespective of method and time of application of Zn fertilizer, there was significant ($p<0.05$) response by stover and grain yields of maize. Treatments with Zn fertilization recorded significantly ($p<0.05$) higher grain yield than the control without Zn fertilization. Fertilization with Zn increased stover and grain yields by greater than 1ton ha^{-1} over the control. Under field conditions, maize yield was 1.3 times increased with application of Zn fertilization than yield without Zn fertilization (Manzeke *et al.*, 2014). Bukvic *et al.* (2003) also observed increase in yield of maize with application of Zn. In the same vein, Carsky and Reid (1990) reported that with the use of Zn fertilizers, maize grain yield can be increased by 20 %.

The Zn content of maize grain was significantly ($p<0.05$) affected by soil or foliar applied Zn in 2014 and 2015 seasons (Table 5). In 2014, the highest rate of foliar Zn application at the later growth stage of maize produced the highest Zn content in grain that was significantly ($p<0.05$) different from that of the other treatments. But in 2015, foliar application with 5 kg ha^{-1} at 3 WAS produced the highest grain Zn concentration which was significantly ($p<0.05$) different from that of control. The increase in the Zn content in grain with soil Zn fertilization is attributed to the presence of increased amount of Zn in the soil solution which facilitated its greater absorption. Similarly, the increase in grain Zn concentration by foliar Zn fertilization is ascribed to the quick absorption of Zn through the stomata. Increase in Zn content in grain due to Zn fertilization had been observed and reported by Mollah *et al.* (2009) and Fageria *et al.* (2011). Similar results had been reported by Naik and Das (2007). Sahay *et al.* (1993) and Maharana *et al.* (1993) also reported in rice grain, increased Zn concentration with both soil and foliar Zn fertilization.

Table 3: Effect of soil or foliar applied zinc on plant height of maize in 2014 and 2015 seasons.

Treatment	Year			
	2014		2015	
	8WAS	12WAS	8WAS	12WAS
/Control	158.17a	188.33ab	148.17a	208.67ab
2.5 kg Zn ha^{-1}SP	146.7a	166.83ab	156.00a	183.17b
2.5 kg Zn ha^{-1} FP	135.40a	180.07ab	158.80a	198.73ab
2.5 kg Zn ha^{-1} FL	138.53a	155.67b	155.00a	188.67ab
5 kg Zn ha^{-1} SP	138.48a	198.50ab	150.67a	215.17a
5 kg Zn ha^{-1} FP	153.79a	201.67a	147.33a	202.87ab
5 kg Zn ha^{-1} FL	142.67a	188.67ab	159.00a	193.07ab
SE±	13.15	14.68	5.33	9.72

Means with the same letter (s) in a column were not significantly different ($p>0.05$)

WAS- Week After Sowing.
SP - soil application at 2 WAS
FP - foliar application at 3 WAS
FL - foliar application at 6 WAS

Table 4: Effect of soil or foliar applied zinc on stover and grain yields of maize in 2014 and 2015 seasons.

Treatment	Stover yield (kg ha^{-1}) Year		Grain yield (kg ha^{-1}) Year	
	2014	2015	2014	2015
Control	5500a	4700b	4100a	4067b
2.5 kg Zn ha^{-1}SP	4700a	5730ab	4100a	6517a
2.5 kg Zn ha^{-1} FP	4920a	6500a	4000a	6223a
2.5 kg Zn ha^{-1} FL	4900a	6390a	4200a	5387a
5 kg Zn ha^{-1} SP	5480a	6040a	4913a	5510a
5 kg Zn ha^{-1} FP	4900a	6263a	4700a	5930a
5 kg Zn ha^{-1} FL	4500a	6343a	4080a	5953a
SE±	410	421	502	475

Means with the same letter (s) in a column were not significantly different ($p>0.05$)

SP - soil application at 2 WAS
FP - foliar application at 3 WAS
FL - foliar application at 6 WAS

In our study in 2015, there was an increase in grain Zn concentration by as much as 100 % with soil application of 5 kg Zn ha^{-1} at 2 WAS. This result was attributed to the build-up of soil Zn by the continuous Zn fertilization.

Table 5: Effect of soil or foliar applied zinc on grain zinc content in maize in 2014 and 2015 Seasons.

	Grain Zn concentration ($mg\ kg^{-1}$) Year	
Treatments	2014	2015
Control	36d	40b
2.5 kg Zn ha^{-1}SP	56cd	59ab
2.5 kg Zn ha^{-1} FP	73bc	76ab
2.5 kg Zn ha^{-1} FL	57cd	81ab
5 kg Zn ha^{-1} SP	47d	103ab
5 kg Zn ha^{-1} FP	89ab	140a
5 kg Zn ha^{-1} FL	103a	94ab
SE±	9.50	28.96

Means with the same letter (s) in a column were not significantly different ($p>0.05$)

SP - soil application at 2 WAS
FP - foliar application at 3 WAS
FL - foliar application at 6 WAS

4.0 CONCLUSION

It can be concluded from the results of this study that soil and foliar Zn application methods significantly increased maize plant height, stover and grain yields, and Zn concentration in grains. Foliar spray or soil application of Zn at 2.5 and 5 kg ha^{-1} increased grain yield by 24.5 – 37.6 %. Foliar spray of 5 kg Zn ha^{-1} enhanced grain Zn concentrations by 65.1 – 71.4 % compared to control.

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