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EFFECT OF ZINC AND N-P-K APPLICATION ON PHOSPHORUS AND ZINC UPTAKE BY MAIZE (*Zea mays* L.) ON AN ALFISOL

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ABSTRACT
A screen house experiment was conducted to determine the effect of zinc (Zn) and NPK fertilizers on the Zn and P content of maize ear-leaf, the P and Zn interactions with the application of Zn as ZnS04 and P as NPK 15-15-15 in maize plant and the Zn and P uptake at ear-leaf stage in the maize plant. Top soils from three identified profiles in a toposequence were sampled for general characterization and zinc contents. The 4 X 2 X 3 factorial potted experiment was laid out in an RCB design using maize as the test crop on 10 kg/pot of the top soils of each of the profiles. Phosphorus was applied with nitrogen (N) and potassium (K) as NPK 15-15-15 at the rate of 120 kg N/ha and Zn at 0, 15, 30 and 45 ppm/pot (i.e.0, 15, 30 and 45 kg Zn/ha). Maize ear-leaves were analyzed for P and Zn contents at tasseling. At maturity, the shoots and roots were harvested, weighed and recorded as dry matter yield. Results obtained showed that the soils were high in pH, total N, K and all other measured exchangeable cations, but low in P and Zn. The applied fertilizer (NPK), had significant ($P<0.05$) effects on the root and shoot dry matter yield of maize plants grown on the soils at the lowest part of the slope (Profile C) only. There was a linear positive correlation ($r = 0.072$) between NPK and Zn in the ear-leaves of plant grown on profile B (mid - slope).

KEY WORDS: Phosphorous, Zinc, dry matter yields.

INTRODUCTION

Maize (*Zea mays* L.) is a major cereal crop in the whole world and is also widely cultivated in Nigeria. It is a fast growing crop which produces large biomass. The demand for maize for primary nutrients is very high, especially in all the agro-ecological zones of Nigeria. Hitherto, emphasis has been on the application of nitrogen (N), phosphorous (P) and potassium (K) fertilizers to produce good maize yields in Nigeria (Agbede and Otonko, 2004). However, researchers in various locations in the Nigerian savanna have observed that the application of micronutrients, coupled with the current intensive use of land could lead to high maize crop response to micronutrients (Lombin, 1983a; Lombin, 1983b). The macronutrients and micronutrients essential for maize production are N, P and Zinc (Zn). The most widely deficient micronutrient for maize production is zinc and its lack in some savanna soils has been reported (Aduloju, 2004). It is important in the correct functioning of many enzyme systems, the synthesis of nucleic acids and auxins (plant hormones) metabolisms, protein analysis and normal crop development and growth (Mengel and Kirkby, 1982, Havlin *et al.*, 2006).

Phosphorus and zinc, though essential for plant growth, are antagonistic to each other in certain circumstances, such as when P is supplied in high levels and Zn uptake becomes slower or inadequate (Mengel and Kirkby, 1979). This may be as a result of slower rate of translocation of Zn from roots to tops, i.e. zinc accumulation in the roots and lower Zn uptake (Stukenholtz et al, 1966); a simple dilution effect on Zn concentration in the tops owing to a growth response of P; or a metabolic disorder in plant cells relating to an imbalance between Zn and P, as for example by an excessive concentration of P interfering with the metabolic function of Zn at specific sites in cells (Loneragan, 1975). This antagonism is known to cause yield reduction in many crops. The yield reduction is caused by either phosphorus or zinc deficiencies. Excessive phosphorus can cause zinc to become deficient in plant tissue. Similarly, excessive zinc can cause phosphorus deficiency, though this is not as common as the former phenomenon. Deficiency of zinc has been reported in Kwara State (Nigeria) soils (Aduloju, 1999, 2004; Ogunwale 2002). The common fertilizer use in the study area is the application of N-P-K of various grades without any micronutrient content. This study investigates the interaction between zinc and phosphorus in plant tissue and the dry matter yield of maize when zinc is applied together with NPK (15-15-15) fertilizer to potted maize plants.

MATERIALS AND METHODS

The study was conducted at the Faculty of Agriculture, University of Ilorin, Nigeria in the southern Guinea savanna agro-ecological zone. (8^0 29'N and 4^0 30' E). Top soils from three profiles on a previously identified toposequence (crest, middle and the lowest parts of the slope) were sampled and analyzed for physical and chemical analysis. Basic cations (Ca^{++}, Mg^{++}, Na^+, and K^+) were extracted with neutral, normal Ammonium Acetate solution and Ca^+ and Mg^{++} determined on the Atomic Absorption Spectrophotometer (AAS), while K^+ and Na^+

were determined using the flame photometer. Exchangeable acidity was extracted with 1N KCl solution and determined titrimetrically with standard NaOH solution (McLean, 1965), organic carbon by the chromate wet oxidation method (Nelson and Sommers, 1992), available P colorimetrically by the Bray-1 method, total Nitrogen by the micro Kjeldhal method, zinc by AAS and pH by an electronic pH meter.

A 4 X 2 X 3 factorial experiment using RCB design with 4 replicates was set up. The factors were 4 levels of Zn, 2 regimes of NPK fertilizer and soil from three profiles. The treatments were randomized completely within the three blocks. Ninety-six pots were used in the experiment, 32 pots from each of the profiles. Each of the 32 pots was filled with 10 kg of soil from the profiles. The maize variety used was ACR 933 Downy Mildew Resistant Yellow (DMRY) obtained from the Institute of Agricultural Research and Training, Ibadan, Nigeria. Four seeds per pot were planted and then thinned to 1 stand per pot 2 weeks after planting. The booster dose of fertilizer (NPK 15-15-15) at the rate of 60 kg N/ha was applied to the maize in all the 96 pots by side dressing two weeks after planting. Zinc at the different levels i.e. (0, 15, 30, and 45 ppm) in form of $ZnSO_4$ solution was applied to the maize in the pots. The second dose of NPK at the rate of 60 kg N/ha was applied at tasseling. At 50% tasseling, leaf samples were collected from each treatment and oven dried at 80^0C, then milled for analysis. The milled samples were digested with nitric and perchloric acid mixture, and Zn in the digest analyzed by using the AAS; P was determined by the vanadomolybdate yellow method using spectrophotometer 20 D (AOAC, 1970). The roots and shoots of the maize plants were oven dried for 3 days until constant weights were obtained. All collected data were subjected to Analysis of Variance (ANOVA) using Minitab output.

RESULTS & DISCUSSION

Physical and chemical properties of the soils studied

The results of the physical and chemical properties of the topsoils of the pedons studied are as shown on Table 1. The soils of the upper and middle slope pedons are loamy sand in texture while that of the lower slope is sandy. The soils of the sites are also high in nitrogen (3.5 -5.6%), potassium, K (0.90-1.25 cmol/kg soil), calcium, Ca (4.4-6.6%, cmol/kg soil), magnesium, Mg (2.4–3.6 cmol/kg soil). They are low in phosphorus (P) and zinc (Zn) (1.26-2.96 mg/kg) and (0.03-0.09 cmol/kg) respectively, judging by the nutrient rating for soil fertility classes in Nigeria (Agbede, 2009). Zinc and phosphorus content of the soils are below the critical levels for crop production which implies that application of the two nutrient elements are necessary in the soils studied to supplement the native contents. The % organic matter content of the soils (2.06-2.75%) was found to be above the critical level for the production of most arable crops (Agbede, 2009). Therefore, response to fertilizer application is expected, though it may vary, depending on the crop nutrient requirement and level of the applied nutrient. Phosphorus and zinc contents were generally low in the pedons studied (1.26, 1.49 and 2.96 mg/kg soil for the lowest, middle and top Pedons respectively). These soils are formed on basement complex rocks which are inherently low in P and Zn (Ogunwale *et al*, 2002); therefore the agronomic practices for good crop production on these soils must include organic manure, P and Zn application.

TABLE 1: Physical and chemical characteristics of the top soils of the pedons in the soils studied

Soil Properties	Upper slope (Pedon A) (0-20 cm)	Mid-slope (Pedon B) (0-20 cm)	Lower slope (Pedon) (0-25 cm)
Clay (%)	5.04	7.04	5.04
Silt (%)	6.00	8.00	400
Sand (%)	88.96	84.96	90.96
PH in1:1 H_20	7.63	7.60	7.47
Total N (%)	3.5	5.6	3.5
Organic Matter (%)	2.06	2.75	2.55
Mg (cmol/kg)	3.4	2.6	2.4
Ca (cmol/kg)	6.6	5,2	4.4
Na (cmol/kg)	1.22	1.30	1.22
K (cmol/kg)	0.90	0.48	1.25
Zn (cmol/kg)	0.03	0.01	0.06
Available P (mg/kg)	2.96	1.49	1.26
Exchangeable Acidity (cmol/kg)	1.0	0.8	1.8
Textural classes	Loamy sand	Loamy sand	Sand

Maize Root and Shoot Dry Matter Yield

The effect of Zn and NPK fertilizer application on root and shoot dry matter yield of maize did not differ significantly in the upper slope (Pedon A) and the mid-slope (Pedon B, Tables 2 and 3). This may due to the fact that the applied levels seemed too low to cause any appreciable increase in yield. Thus, a higher dose of P and Zn than the levels used in this study may be necessary to cause a positive response by maize grown on these soils. However, at the lower slope (Pedon C), NPK affected the root dry matter yield significantly. The three factors i.e. NPK, Zinc and their interactions had significant effects on the shoot dry matter yield at this part of the slope.

TABLE 2: Table of means of the maize root dry matter from maize grown on the soil from the three pedons studied

	Means		
	Pedon	Pedon	Pedon
Zinc applied (ppm)	A	B	C
0	6.488	6.175	8.200
15	4.238	5.688	5.675
30	7.538	6.038	5.212
45	3.763	6.050	4.950
SE mean	1.2884	0.9459	1.1191
NPK			
60 kg N/ha	4.688	5.632	4.838
120 kg N/ha	6.325	6.338	7.181
SE mean	0.91	0.67	0.79
Zinc x NPK (ppm) (kg N /ha)			
0 x 60	4.857	5.200	.525
0 x 120	5.436	7.150	9.875
15 x 60	4.625	6.875	5.350
15 x 120	3.850	4.500	6.000
30 x 60	5.900	5.057	4.500
30 x 120	9.175	7.000	5.925
45 x 60	3.375	5.400	2.975
45 x 120	4.150	6.700	6.925
SE mean	1.82	1.34	1.58

TABLE 3: Table of means of maize shoot dry matter yield from maize grown on soils from the three pedons. studied

	MEANS (g)		
	Pedon	Pedon	Pedon
Zinc applied (ppm)	A	B	C
0	39.56	48.51	39.63
15	34.99	48.08	35.10
30	36.69	46.18	31.18
45	27.44	41.86	26.99
SE mean	6.36	5.57	3.42
NPK			
60 kgN/ha	39.19	45.96	28.40
120 kgN/ha	30.15	46.35	38.03
SE mean	4.50	0.67	2.42
Zinc x NPK			
0 x 60	42.20	42.10	32.30
0 x 120	36.93	54.93	46.95
15 x 60	38.20	57.73	39.13
15 x 120	31.78	38.43	31.08
30 x 60	39.45	50.25	26.20
30 x 120	33.92	42.10	25.75
45 x 60	36.90	33.77	15.57
45 x 120	17.97	49.95	38.35
SE mean	8.994	11.535	4.833

Correlation analysis of the results of Phosphorus and Zinc in the maize ear-leaf showed that there was a positive linear correlation between Phosphorus and Zinc, though weak and not significant, on the soils of the top-slope ($r = 0.072$) and on plants grown on the upper and mid-slope. ($r = 0.781$). This implies that Phosphorus uptake by plants Phosphorus uptake by plants was not negatively affected by Zn and vice-versa. However, for plants grown on the mid-slope, a negative linear relationship was observed. This implies that an inverse relationship exists between Zinc and Phosphorus at this site. This also confirms the rare phenomenon of Zinc-induced Phosphorus deficiency reported in some literature. Phosphorus-induced Zinc deficiency is more common than Zinc-induced Phosphorus deficiency. This is because it is more common for growers to apply substantial amounts of Phosphorus fertilizers without Zinc application (Curvardic *et al.*, 2003). It is uncommon to see phosphorus–induced Zinc deficiency in soils that simply have a high soil test-P levels. In fact, these deficiencies occur just as readily in soils with low soil-test Phosphorus, i.e. the phenomenon is more related to the amount of fertilizer application for current season rather than the level already present in the soil (Bogdanovic *et al.*, 2003).

Significant interactions observed between NPK and Zn shows that P and Zn uptake by the test crop (maize) were affected by each other. This may be due to the fact that Nitrogen and Potassium enhanced the uptake of the two nutrient elements.

CONCLUSION & RECOMENDATIONS

The results of the study showed that zinc and phosphorus are deficient in the soils studied and a positive response is expected from maize when these nutrients (P and Zn) are applied to them. Maize content of P on plants grown on soil taken from the mid-slope reflected low P uptake than at the mid-slope.

Phosphorus deficiency could result from inherently low soil P because the soil parent material is inherently low in phosphorus. Also, the applied P levels are low for these soils. Inadequate fertilizer application can be avoided by carrying out soil testing before applying any fertilizer. The soil studied will require phosphorus fertilizer application when maize is grown on it from the result obtained in this study. The application of zinc, especially at the upper and lower parts of the toposequence studied, will boost maize production. Fertilizer formulations to be used on these soils should include Zinc to improve crop yields. Also, the use of organic manure to improve nutrient supply to plants on these soils should be explored. It has been reported that almost all plant nutrients are positively correlated with the soil organic matter in tropical soils (Adeoye and Agboola, 1985).

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