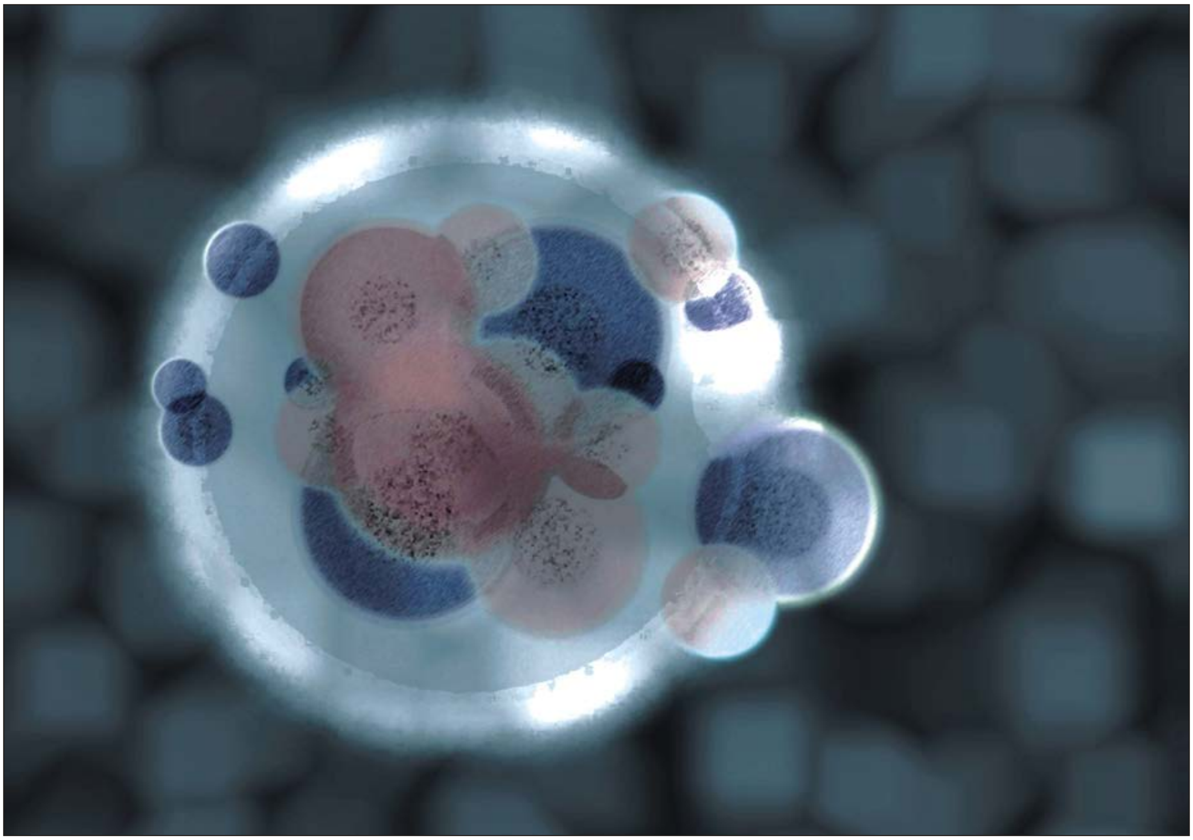

Journal of Biological Sciences

ISSN 1727-3048

Journal of Biological Sciences 6 (5): 854-860, 2006
ISSN 1727-3048

Influence of Various Sources of Nutrients on Growth Attributes, Nutrition and Biomass Production of Sweet Corn (*Zea mays* L. Saccharum)

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Abstract: In this study, the effectiveness of sole and combined fertiliser treatments of organic fertilisers, O.F (Dinos, 24 mg Zn kg^{-1}; Pacesetter, 190 mg Zn kg^{-1}) and different PRs, (Sokoto rock phosphate-SRP, Ogun RP and crystalliser) for sweet corn performance was evaluated in a slightly acid (pH 6.6) Alfisol and another medium acid (5.9) Alfisol in southwestern Nigeria. Sixteen fertilizer treatment combinations (applied to the test crop) were replicated three times in completely randomised design to give a total of 96 experimental units for the two soils. Treated soils were also incubated for 7 and 28 day(s) prior to determination of changes in pH, available P and extractable Zn. Analyses of short-term and residual effects of the fertilizer treatments indicated better crop performance in the slightly acid (1.40-2.63 g biomass pot^{-1}) than in the medium acid soil (0.57-0.88 g biomass pot^{-1}). Maximum yield and optimum P and Zn nutrition were obtained from combined application of PRs and O.F. Without OF, P and/or Zn applications reduced uptake of Zn by the crop. For sustainable production of the crop on the soils, PRs should be applied in combination with OF as P release from them is improved and Zn toxicity ameliorated.

Key words: Medium acid alfisol, organic fertilizer, phosphate rocks, phosphorus, phosphorus and zinc availability, slightly acid alfisol

INTRODUCTION

Substantial proportion of sub-Saharan African soils is deficient in phosphorus (P) and zinc (Zn). In most cases, total contents of these nutrients in soil may exceed crop requirement but availability may be the important limiting factor (Ojo, 2003). According to Marschner (1995) most tropical soils are deficient in the two nutrient elements and there is the possibility of high levels of one inducing the deficiency of the other, particularly in developing countries where the use of blanket fertiliser recommendation over the years has resulted in soil nutrient imbalance and Zn deficiency is a common phenomenon. Substantial proportion of soils in the savannah and derived savannah zones (where maize is the important cereal crop) are deficient in Zn. Osiname (2000) observed that high P application starts to suppress Zn uptake when P/Zn ratio is greater than 8. Zinc adsorption is known to increase as soil pH rises, implying that mobility of the element is restricted in neutral and alkaline soils and its level in soil solution is very low (Sillanpaa, 1990; Munkholm *et al.* 1993).

The most promising strategy of narrowing the gap between production and consumption of agricultural produce is to increase the cultivated area by ameliorating the unfavourable soil conditions concerning their properties (e.g., low fertility and high leaching rate). Application of mineral fertilisers raises costs of products and causes pollution with bio-magnified agrochemical residues (Selin and Hjelm, 1999; Selin, 2002).

The effect of organic manure, OM (commonly applied as a source of plant nutrients) on the growth and nutrient uptake of crops differs according to the nature of crop, type and condition of soil and source of manure used. Phosphate rocks and a commercial organic fertilizer were considered as P and Zn sources for reversing soil fertility depletion in sub Saharan Africa. Organic acids produced during OM decomposition may adsorb P released from rock phosphates (PR), which plants can absorb after mineralisation (Tian and Kolawole, 1999).

Das *et al.* (2002) obtained more percent increase in rice yield with the application of Zn-EDTA than from an equivalent quantity of $ZnSO_4.7H_2O$. They further observed that organic Zn fertiliser source (DINOS) is capable of increasing the use efficiency of applied Zn in maize production.

Toxicity of Zn results in a reduction in root growth and leaf expansion, followed by chlorosis and depresses the uptake of P and Fe (Buerkert *et al.* 1998; Bukvie, *et al.* 1999) while susceptibility of crop plants to

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Table 1: Properties of soils and fertilizer materials used

Soil and fertiliser properties	Values: Soil (Type/Location) A (Oxic Paleustalf/Ibadan)			B (Typic Paleudalf/Ikenne)	
Soil properties					
pH (1:1 soil/water ratio)	6.6			5.9	
Available-P (mg kg^{-1} soil)	10.8			6.34	
Total N (g kg^{-1} soil)	1.1			0.9	
Organic C (g kg^{-1} soil)	11.3			10.1	
Exchangeable Bases (cmol kg^{-1} soil)					
K	0.26			0.07	
Ca	3.62			3.76	
Mg	3.58			2.88	
Micronutrients (mg kg^{-1})					
Mn	68.04			76.00	
Fe	3.17			3.68	
Cu	1.56			1.60	
Zn	4.25			3.14	
Particle sizes (g kg^{-1})					
Sand	878			732	
Silt	68			114	
Clay	54			154	
Texture	Sand			Loamy sand	
	Phosphate rocks			Organic fertiliser	
	Ogun RP	Sokoto RP	Crystallizer	Pacesetter	Dinos
Fertiliser properties					
N (%)	-	-	-	2.3	-
P_2O_5 (%)	31.00	36.10	20.36	1.26	0.14
K_2O (%)	0.03	0.05	0.10	0.56	2.04
MgO (%)	1.35	0.95	0.50	0.22	0.83
CaO (%)	19.23	44.23	31.00	0.50	3.50
Zn (mg kg^{-1})	-	-	80.00	190.00	24.00
Al_2O_3 (mg kg^{-1})	6.91	1.79	-	-	-
Fe_2O_3 (mg kg^{-1})	7.28	2.19	-	0.36	2.75
Organic C (mg kg^{-1})	-	-	-	28.2	-

RP = Rock Phosphate

Zn deficiency depends on species and even cultivars. Maize is one of the plants generally regarded as test crops for Zn availability.

Therefore, the source of Zn may be the important criteria in minimising the intensity of Zn deficiency in maize, while chelating of Zn with OM may play an important role in increasing the use efficiency of applied Zn in maize. The objective of this work was to evaluate the effects of two forms of organic fertilizer (with or without rock phosphate fertilizer application) on the performance of sweet corn in two Nigerian alfisols. In achieving this, changes in soil pH, available P and extractable Zn would also be discussed as the specific research objective sought to select the fertilizer combination that could best enhance P and Zn availability in the soils.

MATERIALS AND METHODS

Experiment 1

Experimental soils and treatment combinations: Two greenhouse pot trials (each with 32 treatment combinations, repeated three times in a completely randomised design, CRD) were conducted at the University of Ibadan, Nigeria. The treatment combinations involved two soil types and 16 -P and -Zn fertilizer treatments. Soil A, slightly acid sand alfisol, *Oxic Paleustalf* (Agboola and Ogunkunle, 1993) was collected from the Rockefellar plot of the Teaching and Research Farm, University of Ibadan, Oyo-state, Nigeria and soil B, medium acid loamy sand alfisol, *Typic Paleudalf* (Soil Survey Staff, 1990) was from the Institute of Agricultural Research and Training sub-station at Ikenne, Ogun- state, Nigeria.

The soils were air-dried, passed through 2 mm sieve and their physico-chemical properties determined by Department of Agronomy, University of Ibadan methods described by Udo and Ogunwale (1991). Each of 96 plastic pots (48 for each soil) was filled with 2 kg soil. The 16 fertilizer treatments applied were Control, Crystalizer (Crys), Sokoto Rock Phosphate (SRP), Ogun Rock Phosphate (ORP), Pacesetter organic fertilizer grade B (PGB), Single Super Phosphate (SSP), Dinos organic fertilizer (DINOS), Zinc sulphate ($ZnSO_4$), PGB+Crys, PGB+SRP, PGB+ORP, PGB+SSP, $ZnSO_4$+Crys,

$ZnSO_4$+SRP, $ZnSO_4$+ORP and $ZnSO_4$+SSP. In supplying P or Zn from two fertilizers at the required/optimum level, 50% was applied from each source. Each of the fertilizer treatments was mixed with soil in addition to 200 mg N and 60 mg K per kg soil basal treatment, using urea and muriate of potash (KCl), respectively. Except for the Control, P was applied at the rate of 90 kg P ha^{-1} while Zn was at the rate of 20 kg Zn ha^{-1}. The properties of the fertilizer materials used (rock phosphates, pacesetter organic fertilizer and Dinos) are also given in Table 1.

First cropping: The first cropping was aimed at evaluating the main or direct effects of each of the fertilizer treatments. Five seeds of sweet corn (*Zea mays* L. Saccharum) (var. AK 95 DMR VS) were planted and thinned to two seedlings after one week of growth while watering was maintained at 60% field capacity; F.C. Mean plant heights were measured for four weeks, starting from the first week after emergence.

At harvest, fresh and dry weights of plant tops were recorded. Drying involved placing the fresh forage inside an oven for 24 h at a temperature of 75°C. The dried plant materials were digested and analysed for their contents of P and Zn. The respective P and Zn uptake values were computed through the multiplication of tissue nutrient content by the dry weight data.

Second cropping: The treated soils were cropped for the second time with a view to evaluating the residual effects of the fertiliser treatments. The soils were air-dried, sieved to ensure freedom from crop residue, mixed with only 100 mg N kg^{-1} and re-sown with two seedlings of the test crop. The data resulting from the trial were evaluated as done for the first cropping, but terminated after only 3 weeks when significant differences in growth were already obvious.

Experiment II: An incubation study was conducted in the laboratory to evaluate the changes in soil available-P and extractable-Zn (during 7 and 28 days) as influenced by the fertilizer treatments. Two hundred and fifty gram soil samples were weighed into each of 48 plastic pots and thoroughly mixed with the fertilizers according to treatment. Phosphorus was applied at the rate of 90 mg kg^{-1} soil, using the different P-sources while Zn was applied at the rate of 20 mg kg^{-1} soil. The content of each pot was watered to 60% F.C. After the 7th and 28th days of incubation, soil samples were taken from each treatment pot, dried and extracted with Bray-P-1 solution and 0.1N HCl to determine the available-P and extractable-Zn, respectively. Soil pH of each of the samples was also measured.

In all cases, analysis of variance (ANOVA) was performed based on the completely randomised design, CRD (Steel and Torrie, 1981), using the Statistical Analysis System (1985) computer software. Treatment effects and the magnitude of interactions were determined and the F-LSD (Carmer and Swanson, 1971) was used to detect differences between treatment means at 5% significant level.

RESULTS AND DISCUSSION

Fertility status of experimental soils: The characteristics of the experimental soils are provided in Table 1. Soil A had available-P and Total N values of 10.8 mg kg^{-1} and 1.10 g kg^{-1}, respectively. These analytical values are quite low for maize production (Akinrinde *et al.*, 2003, 2005). Considering the 2.5-5.0 mg kg^{-1} critical Zn-level for the production of the crop on Alfisols (Uyovbiesere and Lombin, 1991), soil A could be said to be marginal in it's content of the micronutrients. Soil B was loamy sand having lower fertility status (e.g., available-P, 6.34 mg kg^{-1} and Total N, 0.9 g kg^{-1}) than soil A.

Influence of fertilizer treatment and incubation on phosphorus and zinc availability: After 7 days of incubation, SSP treated soil samples had the highest mean available-P values of 1.04 and 1.11 mg P_2O_5 kg^{-1} soil, respectively (Table 2). The OF+SSP treatment followed with mean values of 0.78 and 0.73 mg P_2O_5 kg^{-1} soil, respectively. Unlike after 7 days incubation, however, $ZnSO_4$+SSP treatment also resulted in relatively high (0.8 mg P_2O_5 kg^{-1}) available P values after 28 days. Soil samples treated with Dinos, $ZnSO_4$+ORP, PGB+Crys had almost similar available - P values as the untreated ones.

Sole $ZnSO_4$ application and the combined treatments of $ZnSO_4$ with crystalliser, SRP, ORP and SSP led to higher exchangeable Zn values of 1.64, 1.27, 1.57, 1.91 and 2.42 mg Zn kg^{-1}, respectively after 7 days. After 28 days, however, the exchangeable Zn reduced drastically in $ZnSO_4$, $ZnSO_4$+crystalliser and $ZnSO_4$+SRP treated soil samples to 0.24, 0.20 and 0.23 mg Zn kg^{-1}, respectively.

Influence of fertilizer treatment and soil type on maize performance: Table 3 shows significant differences in maize height and biomass yield as caused by the fertiliser treatments and soil type. The range of heights of plants in the two soil types were quite close but those grown in the slightly acid soil were much taller (30.2-36.2 cm) than those produced in the medium acid soil (17.32-21.4 cm). Similarly, biomass production in the slightly acid soil (1.40-2.63 g pot^{-1}) was more than twice the production (0.57-0.88 g pot^{-1}) in the medium acid soil. It is also evident from the summarized data that nutrient supply

Table 2: Influence of fertiliser treatment and incubation period on available phosphorus and extractable zinc across the experimental soils

	Incubation period (days)			
	7	28	7	28
Fertiliser treatment	Available-P (mg kg^{-1})		Extractable-Zn (mg kg^{-1})	
Control	0.26	0.43	0.94	1.12
Phosphorus (P) sources				
Crystallizer (CRYS)	0.25	0.64	0.99	0.91
Sokoto rock phosphate (SRP)	0.26	0.54	0.80	0.81
Ogun rock phosphate (ORP)	0.27	0.45	0.89	0.81
Pacesetter Grade B (PGB)	0.26	0.57	1.04	0.91
Single Super phosphate (SSP)	1.04	1.11	0.93	1.59
+SE	0.02	0.02	0.03	0.03
Zinc (Zn) Sources				
Dinos	0.19	0.33	0.93	0.58
Zinc Sulphate ($ZnSO_4$)	0.40	0.47	1.64	0.24
+SE	0.02	0.02	0.03	0.03
P+Zn Treatment				
PGB+CRYS	0.37	0.27	0.79	0.13
PGB+SRP	0.30	0.42	0.91	1.24
PGB+ORP	0.44	0.46	0.97	0.98
PGB+SSP	0.78	0.73	0.83	0.14
$ZnSO_4$+CRYS	0.43	0.46	1.27	0.20
$ZnSO_4$ SRP	0.44	0.44	1.57	0.23
$ZnSO_4$+ORP	0.27	0.50	1.91	1.77
$ZnSO_4$+SSP	0.44	0.80	2.42	2.92
+SE	0.02	0.02	0.03	0.03

SE = Standard Error

Table 3: Effect of fertiliser treatment and soil type on sweet cron plant height and biomass production

	Plant height (cm)		Biomass yield (g pot^{-1})	
Fertiliser treatment	Soil location A, (Oxic Paleustalf)	Soil location B, (Typic Paleudalf)	Soil location A, (Oxic Paleustalf)	Soil location B, (Typic Paleudalf)
Control	30.52	17.92	1.43	0.58
Phosphorus (P) sources				
Crystallizer (CRYS)	30.77	20.00	1.67	0.72
Sokoto Rock Phosphate (SRP)	31.87	18.45	1.73	0.80
Ogun Rock Phosphate (ORP)	31.78	18.35	1.68	0.77
Pacesetter Grade B (PGB)	36.17	20.65	2.63	0.82
Single Super Phosphate (SSP)	32.57	20.45	1.77	0.88
+SE	0.15	0.02	0.15	0.02
Zinc (Zn) Sources				
Dinos	30.20	17.58	1.52	0.57
8. Zinc Sulphate ($ZnSO_4$)	32.42	17.32	1.80	0.57
+SE	0.15	0.02	0.15	0.02
P+Zn Treatment				
PGB+CRYS	35.05	19.85	1.80	0.68
PGB+SRP	33.12	19.65	1.90	0.68
PGB+ORP	35.05	18.97	2.22	0.73
PGB+ SSP	35.55	21.43	2.23	0.80
$ZnSO_4$+CRYS	32.55	18.82	1.78	0.63
$ZnSO_4$ SRP	32.65	18.28	1.93	0.60
$ZnSO_4$+ORP	31.25	17.82	1.48	0.62
$ZnSO_4$+SSP	33.68	19.42	2.07	0.70
+SE	0.15	0.02	0.15	0.02

SE = Standard Error

through organic and organo mineral fertilisers led to better plant growth and biomass production in the two soil types.

The differences in performance (exemplified by heights and biomass yields) of plants treated with the various sole and combined fertilisers were significant both in the first and in the second cropping (Table 4). Application of Zn through organic Dinos or inorganic $ZnSO_4$ significantly reduced plant vigour/height and biomass yield. When the inorganic form was applied along with P fertiliser, however, growth and yield performance of the crop were better. Thus, in the second cropping when the residual effects of the fertilizer materials were tested, yield performance was about 0.5 g pot^{-1} in the medium acid soils that were initially treated with either Dinos or $ZnSO_4$ compared with about

Table 4: Comparative analysis of the effectiveness of fertiliser treatments in the two location soils on sweet corn plant height and biomass production in the first and second cropping

	Plant height (cm)				Biomass yield (g pot^{-1})			
	1st cropping		2nd cropping		1st cropping		2nd cropping	
Fertiliser treatment	location A, OP	location B, TP	location A, OP	location B, TP	location A, OP	location B, TP	location A, OP	location B, TP
Control	38.3	18.7	22.7	17.2	1.87	0.60	1.00	0.57
Phosphorus (P) Sources								
Crystallizer (CRYS)	35.9	19.2	25.6	20.8	2.03	0.57	1.30	0.87
Sokoto rock phosphate (SRP)	38.2	17.5	25.5	19.4	2.03	0.67	1.43	0.93
Ogun rock phosphate (ORP)	38.9	16.7	24.7	20.0	1.97	0.57	1.40	0.97
Pacesetter Grade B (PGB)	48.0	18.5	24.3	22.8	3.90	0.67	1.37	0.97
Single Super phosphate (SSP)	42.0	21.8	23.1	19.1	2.23	1.03	1.30	0.73
+SE	2.8	2.8	0.4	0.4	1.78	1.78	0.25	0.25
Zinc (Zn) Sources								
Dinos	37.7	17.9	22.7	17.3	1.93	0.50	1.10	0.63
Zinc Sulphate ($ZnSO_4$)	42.8	16.6	22.0	18.0	2.37	0.53	1.23	0.60
+SE	2.8	2.8	0.4	0.4	1.78	0.78	0.25	0.25
P+Zn Treatment								
PGB+CRYS	41.7	18.0	28.3	21.7	2.40	0.63	1.20	0.73
PGB+SRP	42.2	18.2	24.0	21.1	2.53	0.63	1.27	0.73
PGB+ORP	44.2	18.6	25.9	19.4	3.00	0.63	1.43	0.83
PGB+SSP	43.9	20.8	27.2	22.0	3.33	0.87	1.13	0.73
$ZnSO_4$+CRYS	40.7	17.1	24.4	20.5	2.33	0.50	1.23	0.77
$ZnSO_4$ SRP	41.8	18.0	23.5	18.6	2.57	0.53	1.30	0.67
$ZnSO_4$+ORP	38.6	16.3	23.8	19.3	1.90	0.50	1.07	0.73
$ZnSO_4$+SSP	43.9	19.3	23.5	19.5	3.00	0.70	1.13	0.70
+SE	2.8	2.8	0.4	0.4	1.78	1.78	0.25	0.25

OP = Oxic Paleustalf; TP = Typic Paleudalf; SE = Standard Error

Table 5: Effects of fertiliser treatment combinations on sweet corn plant uptake of phosphorus and zinc

	P		Zn	
Fertiliser treatment	Content (%)	Uptake (mg pot^{-1})	Content (mg kg^{-1})	Uptake (mg pot^{-1})
Control	0.20	11.20	49.50	0.28
Phosphorus (P) sources				
Crystallizer (CRYS)	0.25	15.25	50.00	0.31
Sokoto rock phosphate (SRP)	0.19	11.59	44.00	0.27
Ogun rock phosphate (ORP)	0.24	14.16	53.50	0.32
Pacesetter Grade B (PGB)	0.17	19.89	51.50	0.60
Single Super phosphate (SSP)	0.24	16.08	56.50	0.38
+SE	0.01	2.26	2.50	0.05
Zinc (Zn) Sources				
Dinos	0.21	12.18	53.00	0.31
Zinc Sulphate (ZnSO4)	0.24	17.04	61.50	0.44
+SE	0.01	2.26	2.50	0.05
P+Zn Treatment				
PGB+CRYS	0.15	10.80	92.50	0.67
PGB+SRP	0.21	15.96	86.00	0.65
PGB+ORP	0.17	13.77	73.50	0.55
PGB+ SSP	0.20	20.00	62.00	0.62
$ZnSO_4$+CRYS	0.17	11.90	67.50	0.47
$ZnSO_4$ SRP	0.22	14.74	55.50	0.37
$ZnSO_4$+ORP	0.24	13.68	52.00	0.30
$ZnSO_4$+SSP	0.18	16.20	51.00	0.46
+SE	0.01	2.26	2.50	0.05

SE = Standard Error

0.8 g pot^{-1} obtained from the same soil type but originally treated with P+Zn fertiliser sources. Of course, without Zn application, P from organic fertiliser, PR or SSP increased both the height and biomass production by the maize plants; suggesting an antagonistic relationship between P and Zn. It is noteworthy that the organic fertiliser (Pacesetter grade B) alone or in combination with inorganic P or Zn fertiliser sources enabled the plants to perform well as SSP treated ones.

Influence of fertilizer treatment and soil type on maize uptake of phosphorus and zinc: The content of P and Z in maize tissue as well as their uptake by the crop under the influence of the various fertilizer treatments and the

Table 6: Correlation coefficients relating:(a) Content and uptake of phosphorus and zinc with maize performance parameters; (b) Tissue content with uptake of phosphorus and zinc and (c) Soil pH, available phosphoms and zinc relations

(a) Content and uptake of phosphorus and zinc with maize performance parameters

	Plant height	Dry matter production
% P	-0.4	-0.13
%Zn	0.32	0.26
P uptake	0.44	0.55*
Zn uptake	0.58**	0.50*

(b) Tissue content Vs Uptake of phosphorus and zinc

	%P	%Zn	P uptake	Zn uptake
% P	1	-0.05	0.13	-0.18
%Zn		1	-0.01	0.92**
P uptake			1	0.17
Zn uptake				1

(c) Soil pH, available phosphoms and zinc relations

	pH	Available P	Extractable Zn
pH	1	-0.24	-0.34
Available P		1	-0.04
Extractable Zn			1

n = 16; * and ** indicate significance of correlation coefficients at 5% and 1% confidence limits, respectively

inherent or native fertility of the crops are given in Table 5. Among the plants treated solely with organic fertiliser, PRs or SSP,% P in maize tissue was highest (about 0.25% with crystalliser, ORP or SSP and lowest (0.17%) with the use of organic fertilizer whereas the latter enabled the largest total uptake (about 20 mg pot^{-1}) of the nutrient, compared with only about 11.0 mg pot^{-1} by the untreated and SRP treated plants. Application of organic Zn fertiliser (Dinos), PGB Crys and $ZnSO_4$+C also led to quite low P uptake by the crop.

As regards Zn nutrition of the crop, P application via SRP gave the least tissue content (about 40.0 mg kg^{-1}) of the micronutrient compared with PGB+Crys that had above 80.0 mg kg^{-1}. Combined application of organic fertiliser and PR (SRP or ORP) increased maize tissue Zn content values (> 80.0 mg kg^{-1}) above that obtained with SSP alone (50 mg kg^{-1}) or in combination with the organic fertilizer, (60 mg kg^{-1}). The uptake of the nutrient by the crop followed a similar trend. In the absence of organic fertiliser treatment, P and/or Zn fertilizer application reduced Zn uptake, suggesting the capability of the organic fertilizer to ameliorate Zn toxicity condition and/or Zn uptake antagonism by P.

Maize performance in relation to phosphorus and zinc availability: The contents of both P and Zn in plant tissue were poorly associated with the performance parameters (plant height and dry matter produced at harvest) (Table 6p). However, dry matter production significantly ($p < 0.05$) correlated positively with P-uptake ($r = 0.55$) and Zn uptake ($r = 0.50$), indicating that biomass production increased as the uptake of each of the nutrient elements increased. As regards plant height, positive relationship was obtained only with Zn uptake ($r = 0.58$). Among the content and uptake values of P and Zn, only% Zn and Zn uptake were closely related, r-value being 0.92. The insignificance of most of the correlations in Table 6b seemed to be due to the fact that the organic nutrient fractions involved in the fertilizer treatments must first be converted (by mineralization) to inorganic fractions prior to absorption by plants in accordance with the explanation of Das *et al.* (2001). This also explains the insignificance of the correlations between pH, available P and extractable Zn of incubated soil samples (Table 6c). However, the trend for inverse relationship between the parameters (soil pH vs available P; pH vs extractable Zn; and Available P vs Extractable Zn) is evident.

Improvement in the effectiveness of phosphate rocks when applied with organic fertilizer can be attributed to enhanced solubilization of the rock-P. The organic Zn fertilizers could also have ameliorated soil conditions (e.g., pH, excess amounts of nutrients like Zn, etc.) that may be toxic and limiting to crop growth. The technique of chelation (metallic nutrient-organic compound combination) for agricultural purposes would also serve to sanitise the metropolis environments from contamination and pollution threats by livestock manures and city organic wastes.

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