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Effects of Phosphorus and Zinc on Maize and Cowpea grown on Alfisols in Sourthern Nigeria.

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Abstract

Trials were conducted at three locations on Alfisols in southwestern Nigeria to study the optimum phosphorus – zinc balance in the soil for field grown maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* s.sp. *unguiculata* L. Walp).

The incidence of P induced Zn deficiency in maize was observed to be more probable in the sandy soils of the savanna zone than in the sandy loam soils of the forest zone. Correcting P deficiency without correcting Zn deficiency resulted in lower maize yields. In soils with Bray-1 P test of ≥ 7.0 ppm and 0.1N HCL extractable Zn of ≤ 1.0 ppm, further addition of P. was observed to induce Zn deficiency in maize.

Cowpea was less sensitive to either the deficiencies of P and Zn or to the incidence of P induced Zn deficiency.

Introductión

Phosphorus induced zinc deficiency is a common occurrence in crops such as maize (Rudgers *et al.*, 1970; Terman *et al.*, 1966), beans, *Phaseolus vulgaris*, (Boawn and Brown, 1968), and soyabean (Paulsen and Rotimi, 1968). Christenson and Moore (1970) observed that the so-called P induced Zn deficiency could be the result of correcting only the P deficiency when both elements are deficient thereby allowing the deficiency of Zn to be manifested. Adriano and Murphy (1970) observed that banded P resulted in higher plant P concentration and also induced more severe Zn deficiency than broadcast P. Irrigated corn grown on Zn deficient sandy loam soil suffered from increasingly severe Zn deficiency when 40 kg P/ha was banded. High P concentration in plant tissue was observed to inhibit the translocation of Zn from roots to tops. The severity of P induced Zn deficiency is known to be influenced by P and Zn availability in the soil (Ellis *et al.*, 1964; Sharma *et al.*, 1968; and Ganiron *et al.*, 1969), temperature (Paulsen and Rotimi, 1968) and crop species and variety (Brown and Liffin, 1962).

The deficiencies of both P and Zn in maize are common occurrences in many soil in southern Nigeria (Osiname *et al.*, 1973; Osiname 1979; Kang and Osiname, 1979). The correction of P deficiency alone, especially in the savanna zone, often induces severe Zn deficiencies and subsequent poor yields of maize. The purpose of this study therefore was to investigate the critical levels of available P and Zn that will eliminate P induced Zn deficiencies in Maize and Cowpea in selected soils of southwestern Nigeria.

Materials and Methods

Trials were set up in the early cropping season of 1976 (March to August) on Alfiosols at Ikenne (Latitude 6^{O} 55') in the rainforest region, Ilora (Latitude 7^{O} 49') in the derived savanna region and Shaki (Latitude 8^{O} 41') in the southern Guinea savanna region. Some characteristics of soils from the three sites are shown in Table 1. The site at Shaki was on a terrace slope on-which fluvial action has deposited fine colluvial material from the pediment slope.

The experimental design was a 4 x 4 factorial with four replicates. The treatments consisted of four rates of P:- 0, 50, 100 and 200 kg/ha as single superphosphate and four rates of Zn:- 0, 2, 4 and 8 kg/ha as sequestren zinc chelate. All the plots were given a basal fertilizer dressing of 50kg N/ha as sulphate of ammonia and 30 kg K/ha as muriate of potash. The treatments and the basal fertilizer dressings were broadcast and worked into the soil with a hoe a day prior to planting the test crop which was maize (cv. Western Yellow I). Five weeks after planting, another 50kg N/ha as sulphate of ammonia was side dressed.

Ear leaf samples were taken from each plot at silking. They were oven-dried at 80 C for 48 hours, ground in a stainless steel Wiley mill, and analysed for P and Zn. The cobs from a net plot size of $16.2m^{-2}$ were havested and weighed at maturity. The grain yields were expressed in kilograms per hectare at 12% moisture content.

Available P in the soil was determined by the Bray 1 method (Bray and Kurtz, 1945), total N, by the micro-Kjeldhal method, while available K in 0.13N HN03 in soil extract was determined on the flame photometer (Sobulo, 1973). Available Zn in 0.1N HCL in soil extract was determined on the atomic absorption spectrophotometer.

Earleaf samples were wet-digested in a mixture $HCL0_4$ - $HN0_3$ - H_2S0_4. Their phosphorus content was determined by the molydenum yellow method (Jackson, 1958) and their Zn. on the atomic absorption spectrophotometer.

TABLE 1: SOME CHARACTERISTICS OF SOILS FROM THE THREE EXPERIMENTAL SITES

Location	Soil Description	Mechanical Analysis Sand %	Silt %	Clay %	pH H_2O	Org. C %	Total N %	Available P, ppm	K, me/100g	Zn ppm
Ikenne	Alagba Series (Typic Haplorthox)	87.2	6.1	6.7	6.0	0.64	0.08	8.5	0.09	1.78
Ilora	Oyo Series Oxic Ustropept	89.2	6.1	4.7	5.6	0.60	0.04	14.7	0.14	1.00
Shaki	Apomu Series Oxic Ustropept	70.0	20.6	9.4	5.9	0.47	0.05	6.2	0.16	

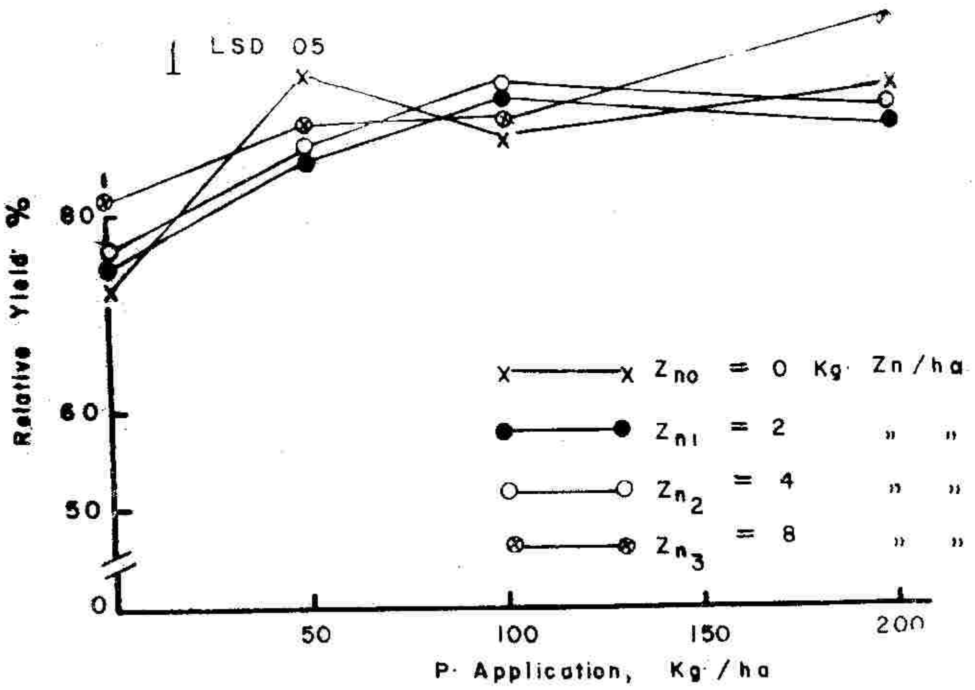

Fig. 1. Effect of P and Zn application on the relative yield of maize grown on Alagba soil at Ikenne.-

In 1977 at the Shaki site (where responses to both P and Zn were obtained in the previous year), the stubbles from the previous crop were cleared from the plots. The soil was re-sampled and analysed for available P and Zn as in the previous year. Thereafter, another crop of maize (cv. Western Yellow I) was grown. Basal fertilizer application, sampling and harvest procedures were similar to those of 1976.

During the late season (Agust to December) of 1978, the Shaki site was cropped with cowpea, (*Vigna unguiculata* s.sp. *unguiculata* L. Walp cv. Ife Brown), to test the effects of residual P and Zn. The plots were sampled and analysed for available P and Zn, and subsequently fertilized with 20kg N/ha as sulphate of ammonia prior to sowing. At full bloom, the first matured leaf blades were sampled and analysed for P and Zn. Harvesting was done at maturity from a net plot of $19.8m^2$, and the yields, expressed in kilogramme grains per hectare at 12% moisture content.

Results

Maize Yield

The combined effects of P and Zn application on the dry grain yield of maize at the three sites of the trials are shown in Figs. 1, 2 and 3. At Ikenne, the yield response to P application was significant at (P .01) up to 100 kg P/ha rate of application (Fig. 1). There was no yield response to Zn application. Even though zinc deficiency at Ilora was so severe on plots that were treated with 200 kg P/ha without any Zn application, and reduced stands by about 20%, the yield responses to both P and Zn were not statistically significant. The absence of significant responses to both P and Zn application may be due to the drought that hit the crop at the filling stage of growth. The application of 200 kg P/ha consistently depressed maize grain yields at all levels of Zn application (Fig. 2). At Shaki, there were highly significant (P .01) responses to both P and Zn application (Fig. 3). When no Zn was applied, the severity of the Zn deficiency symptoms became greater with increasing rates of P application. At the rate of 200kg P/ha, Zn deficiency also reduced stands by about 20%. The largest yield response to P was at the first 50 kg/ha. Thereafter, increasing rates of P application either produced a sharp depression in grain yields when no Zn was applied, or did not significantly increase grain yields when Zn supply was adequate.

The data obtained from the second crop of maize grown in 1977 at Shaki are shown in Fig. 4. Both applied P and Zn showed pronounced residual effects. The grain yields of the maize crop increased significantly

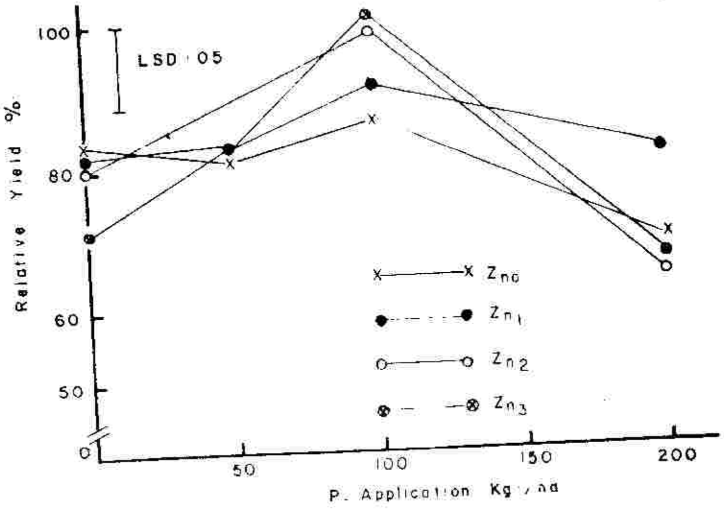

Fig. 2. Effect of P and Zn application on the relative yield of maize grown on Oyo soil at Ilora.

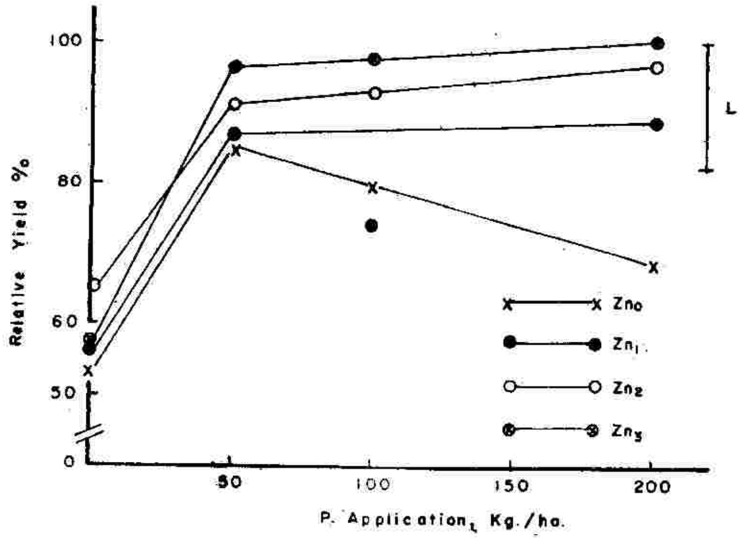

Fig. 3. Effect of P and Zn application on the relative yield of maize grown and Apomu soil at Shaki.

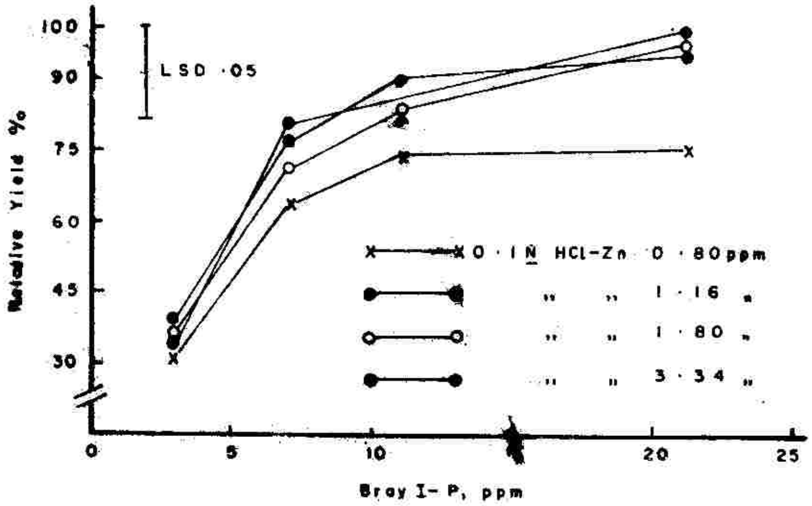

Fig. 4. Effect of residual P and Zn on the relative yield of maize grown on Apomu soil at Shaki.

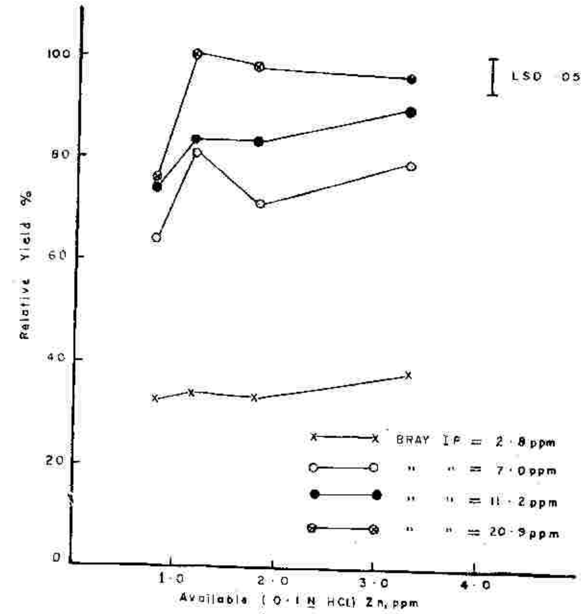

Fig. 5. Effect of soil available P on maize response to Zn in Apomu soil at Shaki

TABLE 2: EFFECTS OF VARYING LEVELS OF SOIL AVAILABLE P AND Zn ON THE GRAIN YIELD OF COWPEA AT SHAKI (1978).

	Soil available Zn (ppm)				
	0.58	*0.73*	*1.12*	*1.55*	*Mean*
Available P (ppm)		*Grain yield (kg/ha)*			
1.4	863	901	767	990	**880**
2.8	873	774	859	939	**861**
6.8	862	925	1017	842	912
18.9	1021	1251	1271	1076	**1155**
Mean	905	963	979	**962**	—

TABLE 3: EFFECTS OF P AND ZN APPLICATION ON THE P CONTENT OF MAIZE EAR LEAVES, 1976.

	Zn rate, Kg/ha				
	0	*2*	*4*	*8*	*Mean*
P rate kg/ha		*% Tissue P*			
		Alagba Soil (Ikenne)			
0	0.22	0.24	0.22	0.24	0.23d
50	0.30	0.30	0.31	0,3	0.30c
100	0.34	0.32	0.32	0.34	0.33b
200	0.39	0.37	0.38	0.37	0.38a
Mean (S.E. ± 0.009)	0.31a	0.31a	0.32a	0.31a	
		Oyo Soil (Ilora)			
0	0.21	0.24	0.21	0.21	0.21d
50	0.24	0.23	0.22	0.20	0.22c
100	0.27	0.23	0.26	0.26	0.25b
200	0.40	0.32	0.32	0.30	0.34a
Mean (S.E. ± 0.009)	0.28a	o.26ab	o.25b	0.24b	
		Apomu Soil (Shaki)			
0	0.18	0.17	0.18	0.19	0.18d
50	0.24	0.23	0.24	0.23	0.24c
100	0.32	0.25	0.25	0.29	0.27b
200	0.42	0.36	0.36	0.33	0.37a
Mean (S.E. ± 0.007)	0.29a	0.25b	0.26b	0.26b	

Means followed by the same letter are not significantly different at • – 5% (DMNRT).

with increasing levels of available P in the soil. The magnitude of the yield increases was greater when the available Zn in the soil was 1.16 ppm and higher than when it was 0.8 ppm. The pattern of maize response to increasing levels of available Zn under different regimes of available P in the soil is shown in Fig. 5. When P was deficient, the response to Zn was slight. When available P in the soil was adequate, no significant yield increases were produced by increasing available Zn in the soil beyond 1.16 ppm.

Cowpea Yield

Grain yields of cowpea grown at Shaki in the third year of cropping, are presented in Table 2. The yield responses to both residual P or Zn were not statistically significant even though the yields ranged from 863 to 1271 Kg/ha of grains. Plots with high P (Bray 1-P test = 19 ppm), showed luxuriant vegetative growth and delayed flowering.

Maize Tissue Analysis

The concentration of P in maize earleaf as affected by both P and Zn treatments are presented in Table 3. At Ikenne, P concentration in the earleaf increased with P rates. The increases were significant (P .01). The P concentration in the tissue was not affected by increasing rates of Zn application when P application was constant.

At both Ilora and Shaki, the concentration of P in the earleaf increased with the rates of P application. It is noteworthy, however, that at the higher rates of P application (100 and 200 kg/ha), P concentration in the ear leaf decreased with increasing rates of Zn application (Table 3). The P x Zn interactions were however not significant.

The data on the Zn content of the earleaf are presented in Table 4. At all the three sites, Zn concentration was depressed by increasing rates of P application. The depression did not however result in P induced deficiency symptoms at Ikenne where there was a higher level of available Zn in the soil (Table 1).

Cowpea Tissue Analysis

The results of the tissue analysis for the cowpea crop are presented in Table 5. The tissue P content increased as the Bray-I P soil test increased. The P content of the cowpea tissue was not significantly affected by the amount of available Zn in the soil. As was the case with maize, increasing levels of available P in the soil led to some depression in Zn concentration of the cowpea leaf tissue, while increasing levels of available Zn in the soil increased the leaf tissue Zn concentration. No Zn deficiency

TABLE 4: EFFECTS OF P AND ZN APPLICATION ON THE ZN CONTENT OF MAIZE EARLEAVES, 1976.

	Zn rate, kg/ha				
	0	*2*	*4*	*8*	*Mean*
P rate (kg/ha)		*Tissue Zn (ppm)*			
		Alagba Soil (Ikenne)			
0	33.6	33.4	32.8	34.1	33.3a
50	26.0	25.3	29.1	28.5	27.2b
100	22.3	22.0	21.3	21.8	21.8c
200	16.8	19.0	18.8	18.5	18.3d
Mean (S.E. + 0.84)	24.7a	24.9a	25.5a	25.7a	
		Oyo Soil (Ilora)			
0	14.6	17.6	19.6	22.3	18.5a
50	13.3	14.9	17.3	17.8	15.8b
100	13.2	12.8	14.6	17.8	14.6c
200	11.0	11.1	11.4	11.7	11.3d
Mean (S.E. ± 0.71)	13.0c	14.1bc	15.7ab	17.4a	
		Apomu Soil (Shaki)			
0	18.3	22.9	20.6	23.6	21.4a
50	11.8	13.9	17.5	19.3	15.6b
100	11.1	12.9	16.3	19.8	15.0b
200	9.3	11.3	13.8	18.0	13.1c
Mean (S.E. ± 0.53)	12.7d	15.3c	17.1b	20.2a	

·Means followed by the same letter are not significantly different at 5% (DMNRT).

TABLE 5: EFFECTS OF SOIL AVAILABLE P AND ZN ON THE CONCENTRATIONS OF P AND ZN IN THE LEAF BLADE TISSUE OF COWPEA AT SHAKI (1978).

	Soil Available Zn (ppm)				
	0.58	*0.73*	*1.12*	*1.55*	*Men*
Soil Available P		*% P in tissue*			
1.4	0.15	0.15	0.17	0.16	0.16d
2.8	0.19	0.18	0.20	0.19	0.19c
6.8	0.22	0.24	0.23	0.23	0.23b
18.9	0.23	0.24	0.28	0.25	0.25a
Mean (S.E. ± 0.006)	0.20a	0.20a	0.22a	0.21a	
		ppm Zn in tissue			
1.4	30.5	43.2	44.1	49.1	41.7a
2.8	39.8	40.6	41.9	47.3	42.4a
6.8	34.1	40.6	37.5	48.3	40.1ab
18.9	21.7	35.9	41.3	43.4	38.0b
Mean (S.E. ± 1.11)	34.0d	40.1c	41.2b	47.0a	

Means followed by the same letters are not significantly different at 5% (DNMRT).

symptoms were observed on the cowpea crop even when available Zn in the soil was as low as 0.5ppm.

Discussion

In the Alagba Soil at Ikenne where available Zn was adequate, P application did not cause any depression in the grain yield of maize even though it significantly decreased the Zn concentration of the ear leaf (Table 4). This is due mainly to the fact that the depression in Zn concentration of th eer leaf did not go below 12 ppm previously observed as critical level for maize in Western Nigeria (Osiname et al., 1973). The depression in the grain yields at Ilora seems real when it is noted that the application of 200 kg P/ha depressed Zn concentration of the earleaf below the observed critical level of 12 ppm for maize in Western Nigeria.

The interrelationship between available P and Zn in the soil and the grain yield of maize appears to be more delicate at Shaki than at the other two sites. Without Zn application, a rate of 50 kg P/ha significantly (P $\angle$.01) depressed Zn concentration in the earleaf below the critical level for maize. Under adequate Zn supply, the response to P application in the soil levelled up rapidly after 50 kg P/ha.

Figure 4 shows that maize response to increasing amounts of soil available P at various levels of available Zn in the soil, are similar in pattern but different in magnitude. The largest boost in the response to P occurred when soil available Zn rose from 0.80 ppm to 1.16 ppm. Figures 4 and 5 confirm that critical level for available Zn in the soil for maize is about 1.0 ppm in Western Nigeria. From Fig. 4 it also appears that if the available P in the soil goes beyond 7.0 ppm in the light textured soils of the savanna region, a soil test should be carried out to determine the status of available Zn in the soil, and establish the probable need for Zn supplementation.

The cowpea crop did not show any deficiency symptoms of P or Zn. Cowpea therefore appears to be less sensitive to P and Zn deficiencies than the maize crop. The grain yield from cowpea was 69% of the maximum yield when Bray-1 was 1.3 ppm compared to 34% for maize even when Bray-1 was 3.0 ppm. Cowpea also appears to be more efficient in utilizing available Zn in the soil than maize as seen from the lower depression in Zn concentration of tissue with increasing soil P levels.

Conclusion

Phosphorus induced Zn deficiency in maize is more probable in the light textured soils of the savanna zone which are low in Zn content.

than in the heavier textured soils of the forest region of southwestern Nigeria. Correcting P deficiency without correcting Zn deficiency, may therefore lead to very poor stand and subsequent low grain yields of maize. It is recommended that the available (0.1N HCl) Zn in the soil should be 1.0 ppm or higher whenever available (Bray-1) P is greater than 7.0 ppm in the light textured soils of the savanna region. Cowpea does not appear to be as sensitive to either the deficiencies of P and Zn or to the phenomenon of P induced Zn deficiency as maize.

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References

Adriano, D.C. and Murphy, L.S. 1970. Effects of ammonium polyphosphates on yield and chemical composition of irrigated corn. *Agron. J.*, 62: 561-567.

Boawn, L.C. and Brown, J.C. 1968. Further evidence of P-Zn imbalance in plants. *Soil Sci.*, 88: 219-227.

Boawn, L.C., Rasmussen, P.E. and Brown, J.W. 1969. Relationship between tissue Zn levels and maturity period of field beans. *Agron. J.*, 61: 49-51.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of P in soil. *Soil Sci.*, 59: 39-45.

Brown, J.C. and Tiffin, L.O. 1962. Zinc deficiency and iron chlorosis dependent on the plant species and nutrient – element balance in Tulare Clay. *Agron. J.*, 54: 356-358.

Christensen, N.W. and Moore, D.P. 1970. Effects of increasing phosphorus concentration on the zinc nutrition of corn grown in nutrient solution culture. *Agronomy Abstracts*. Ann. Meeting American Society of Agronomy.

Ellis, R., Jr, Davis, J.F. and Thurlow, D.L. 1964. Zinc availability in calcareous Michigan soils influenced by phosphorus level and temperature. *Soil Sci. Soc. Amer. Proc.* 28: 83-86.

Ganiron, R.B., Adriano, D.C., Paulsen, G.M. and Murphy, L.S. 1969. Effect of Phosphorus carriers and zinc sources on phosphorus-zinc interaction in corn. *Soil Sci. Soc. Amer. Proc.*, 33: 306-309.

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice-Hall, Inc., Englewood Cliffs, J.N. USA.

Kang, B.T. and Osiname, O.A. 1979. Phosphorus response of maize (*Zea mays* L.) grown on Alfisols in the foest zone of Southern Nigeria. *Agron. J.*, 71: 873-877.

Osiname, O.A., Kang, B.T., Schulte, E.E. and Corey, R.B. 1973. Zinc response of maize (*Zea mays* L.) grown on sandy Inceptisols in Western Nigeria. *Agron. J.*, 65: 875-877.

Osiname, O.A. 1979. Maize response to phosphorus fertilization in different ecological zones of Western Nigeria. *Nigeria. Nigeran J. Agric. Sci.*, 1: 9-13.

Paulsen, G.M. and Rotimi, O.A. 1968. Phosphorus – zince interaction in two soyabean varieties differing in sensitivity to phosphorus nutrition. *Soil Sci. Soc. Amer. Proc.*, 32: 73-76.

Rudgers, L.A., Demetrio, J.L., Paulsen, G.M. and Ellis Jr., R. 1970. Interaction among atrazine, temperature and phosphorus – induced zinc deficiency in corn (*Zea mays* L.). *Soil Sci. Soc. Amer. Proc.*, 34: 240-244.

Sharma, K.C., Krantz, B.A., Brown, A.L. and Quick, J. 1968. Interaction of P and Zn with soil temperature in rice. *Agron. J.*, 58: 652-655.

Terman, G.L., Allen, S.E. and Bradord, N.N. 1966. Response of corn to zince as affected by nitrogen and phosphorus fertilizers. *Soil Sci Soc. Amer. Proc.*, 30: 119-122.