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NUTRIENT AVAILABILITY TO SOYBEAN (*Glycine max* (L) MERR.) FROM OGUN PHOSPHATE ROCK AND ZINC APPLICATION IN SOME SOUTH-WESTERN NIGERIAN ALFISOLS.

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ABSTRACT

The response of soybean (*Glycine max* (L) Merr.) to phosphorus from beneficiated Ogun phosphate rock (OPR) and zinc application (as ZnO; 80 % Zn) was studied in both pot and field experiments. Pot experiment was conducted with six surface soils collected from 0-20 cm depth of different land uses within Ogun State, Nigeria while the most representative of the locations was used for the field trial. Soybean was raised to maturity in both pot and field trials. Phosphorus was applied as beneficiated product of Ogun phosphate rock at 0, 40, 60 and 80 kg P ha^{-1}. Zinc was applied at 0, 3, 6 and 9 kg Zn ha^{-1}, giving a total of 16 treatments per soil type. Zinc and phosphorus fertilizers were intimately mixed with the soil before planting. The pot trial was a factorial experiment with four replications while the field trial was a Randomized Complete Block Design with four replications. Soybean cultivar TGX 1485-1D was the test crop. Phosphorus application as OPR significantly increased the crop uptake of phosphorus and zinc in the pot trial and P uptake in the field. Phosphorus uptake, seed weight in some soils (pot trial) and yield (field trial) were significantly increased with the application of up to 9 kg Zn ha^{-1}. Phosphorus and zinc interaction was not significantly different among treatments for soybean yield and nutrient uptake in the field. Significant response of soybean yield to OPR up to 40 kg P ha^{-1} was observed. For soils low in P and Zn, application of 40 kg P ha^{-1} and 6 kg Zn ha^{-1} was recommended for optimum soybean yield.

Keywords: Nutrient Interactions, Legume, nutrient, Alfisols, Soybean.

INTRODUCTION

The importance of phosphorus as a yield improving factor in many Nigerian soils is well established (Adetunji 1994a and 1994b). It has been established that soybean (*Glycine max* (L) Merr.) requires high phosphorus content for growth, nodulation, dry matter yield and flowering (Akintokun *et al*., 2003), particularly in tropical countries like Nigeria.

However, tropical soils are generally low in available phosphorus (Adetunji 1994a). Hence, the need for large inputs of phosphorus fertilizer (Rao *et al.*,1998), to increase available phosphorus status of soils and improve soil properties.

There has been considerable interest in studying the efficiency of phosphate rocks for direct application as sources of phosphorus (Qureshi and Narayanasamy, 1999) because of its relatively low cost and ready availability. Phosphate rock (PR) has also been shown to have significant effects on phosphorus content and uptake by soybean (Akintokun *et al*., 2003). Commercial phosphate fertilizers are water-soluble and therefore dissolve rapidly. However, phosphate rock is not readily soluble in water and therefore dissolves slowly. Thus, the phosphorus is released slowly to the plants. The efficient utilization of phosphorus and other macronutrients by plants can be enhanced by the presence of appropriate quantities of other micronutrients. Particularly, when antagonisms between nutrients have been established. Zinc is an essential micronutrient element for soybean. Kiekens (1990), reported that soybean is particularly sensitive to zinc deficiency. Adetunji (1999), reported cases of zinc deficiency in many Nigerian soils, and this has been found to be a potential yield-limiting factor in these soils. However, an antagonistic interaction has been reported to exist between phosphorus and zinc (Nayak and Gupta, 1995). Other workers (Goh *et al*., 1997), observed inconsistent trends in the uptake and concentration of phosphorus and zinc in soybean. Rates of phosphorus fertilization or high levels of available phosphorus have been widely reported to induce zinc deficiency symptoms in crops. This is often referred to as "P induced-Zn deficiencies" (Mallarino and Webb, 1995).

Although data exist in Nigeria on phosphorus-zinc interaction in maize plants, information on the optimum level of zinc and phosphorus in combination that will enhance uptake and yield of soybean is still very scanty. Accordingly, this study was conducted with the objectives to determine (1) the response of soybean to Ogun phosphate rock (OPR) and zinc; (2) the relationship between phosphorus and zinc in the nutrition of soybean and (3) levels of phosphorus and zinc for optimum growth and yield of soybean.

MATERIALS AND METHODS

Soil sampling

Surface soil samples collected from the rooting zones of arable crops (0-20cm depth) were collected from 6 Alfisols in Ogun State Nigeria. Adetunji (1999), had initially described the soils. The locations, which included forest and savannah vegetations, were identified as: Soil A (Alabata 1) site under cassava cultivation; Soil B (Ifo) piggery waste dump site; Soil C (Wasimi) site under two months fallow; Soil D (Alabata 2) site under six months fallow; Soil E (Papalanto) site under sugar cane cultivation; Soil F (Alabata 3) site under four year fallow. Soil samples were air-dried and passed through a 2 mm-diameter soil sieve. A portion of each sample was retained for laboratory analysis while the remaining was used for pot experiment.

Soil analysis

Soil samples were analyzed using standard procedures (Page *et al*., 1982). Particle size analysis was done by the hydrometer method. Soil pH in water was determined potentiometrically using glass electrode in a 2:1 (soil: water). Organic matter was determined by the chromic acid oxidation procedure. Total nitrogen was determined by the Kjedahl procedure. Available phosphorus was extracted using Bray-1 (0.03N NH_4F + 0.025N HCl) extractant. Phosphorus in the extract was determined colorimetrically by molybdenum blue method. Exchangeable bases were extracted with 1 N neutral NH_4OAc solution. Na^+ and K^+ ions were determined using the flame photometer. Ca^{2+} and Mg^{2+} ions were determined by the atomic absorption spectrophotometer (AAS). Available Zn^{2+} extracted by 0.1N HCl and determined using the AAS. Exchangeable acidity of the soil was extracted with 1N KCl solution and determined by titrating with 0.025N NaOH solution. Cation exchange capacity was estimated by summation method. Available sulphur was determined turbidimetrically as $BaSO_4$ after extraction with KH_2PO_4

Pot experiment

Three kg each of surface soils from the six locations were dispensed into polythene pots. Six soybean seeds, (*Glycine max.)* cultivar TGX 1485-1D was planted into the pots and later thinned to three seedlings per pot after emergence. Zinc and phosphorus fertilizers were applied before planting. The treatments consisted of four levels of phosphorus (0, 40, 60 and 80 kg P ha^{-1}) applied as Ogun phosphate rock (31 % P_2O_5) and four levels of zinc (0, 3, 6, and 9 kg Zn ha^{-1}), applied as ZnO (80 % Zn). The composition of OPR was as presented by Fayiga and Obigbesan (1998). The experiment was a 6 x 4 x 4 factorial experiment using a completely randomized design with four replications. Plants were monitored to maturity. At 12 weeks after planting (WAP) (maturity), harvested samples were washed, dried at 70^{o}C for 48 hours, weighed and milled.

The entire above ground portion was milled together and 1g was weighed into 30 ml crucibles and ashed in a muffle furnace at 500 ^{o}C for 4 hours. The ash was dissolved in 1N HCl. Phosphorus in the solution was determined colorimetrically using a UNICAM UV/VISIBLE spectrophotometer at wavelength of 400 nm by the vanadomolybdate method, while zinc in the solution was determined by the atomic absorption spectrophotometer (Model 210 Buck Scientific VGP system).

Field trial

The field trial was located in the teaching and research farm of the University of Agriculture, Abeokuta (Long. 3^0 20' E and Lat. 7^0 10' N). Composite soil samples were collected and analyzed by standard procedures (Page *et al*. 1982), as reported above. The samples are the same as soil F in the pot experiment. The unit plot size for the field trial was 4m x 4m with spacing of 2m each between replicates. Soybean (*Glycine max*) was planted by drilling with nine rows in a plot at 50 cm spacing between rows and approximately 2 cm within rows. The field trial consisted of four phosphorus levels (0, 40, 60 and 80 kg P ha^{-1}) applied as Ogun Phosphate rock and four zinc levels (0, 3, 6 and 9 kg Zn ha^{-1}) applied as ZnO. Hoe and hand weeding at 3 weeks interval were carried out on all plots. Experimental Design was a Randomized Complete Block with four replicates. Data on nodulation at 9 weeks after planting, plant height (using a meter rule) at 9 and 12 weeks after planting, seed yield were also determined. Three plants were sampled randomly, within the net plot for these parameters. Samples were washed, dried at 70^{o}C in the oven for 48 hours, weighed and milled. One g of the milled sample was ashed in a muffle furnace. The ash was dissolved in 1N HCl. Phosphorus in the solution was determined colorimetrically by vanadomolybdate method with a UNICAM UV/VISIBLE spectrophotometer at 400 nm wavelength. Zinc was determined with the atomic absorption spectrophotometer (Model 210 Buck Scientific VGP system).

Data analysis

Correlation analysis and analysis of variance of data using LSD at 5% level of significance were carried out.

RESULTS

Experimental soils

The properties of the experimental soils show that the soils are mainly loamy sand, while the clay content varied from 10.4 % to 16.4 %. The organic matter content of the soil varied from low to medium. The P and Zn content of the soils were low.

Phosphorus uptake

Phosphorus uptake by soybean increased significantly with phosphorus application in soils B, D and F (Table 1). Up to 249 % increase was observed in soil D at 80 kg P ha^{-1}. Most of the soils recorded over 100 % increase in phosphorus uptake by soybean even with as low as 40 kg P ha^{-1} (Table 1). Zinc application was found to have significantly affected phosphorus uptake of soybean in soils C and D.

However, about 135% (soil C) and 89% (soil D) increase in phosphorus uptake was recorded at 9 kg Zn ha^{-1} application. There was no statistically significant interaction between phosphorus and zinc application for phosphorus uptake of soybean. Correlation studies also show that phosphorus uptake significantly increased growth and seed yield of soybean in some but not in all the soils.

Table 1: Effect of P and Zn application on phosphorus uptake of Soybean (mg pot^{-1})

Treatments		Site					
P kgha^{-1}	**Zn kg ha^{-1}**	**A**	**B**	**C**	**D**	**E**	**F**
0	0	6.65	18.04	5.74	3.34	24.29	46.34
	3	12.44	22.65	9.40	4.83	26.17	41.58
	6	9.38	25.90	8.76	9.57	46.03	33.80
	9	16.26	20.95	16.02	12.46	17.01	63.70
40	0	15.89	33.12	7.67	9.09	32.36	105.10
	3	26.82	34.46	17.56	27.50	46.82	139.90
	6	19.74	51.37	17.07	22.80	39.52	48.88
	9	33.09	60.90	18.69	18.50	30.87	89.12
60	0	31.63	28.07	10.37	13.98	52.16	71.42
	3	24.47	19.72	11.12	18.20	38.98	61.08
	6	26.39	56.18	12.71	18.11	42.93	61.90
	9	20.39	54.28	18.99	25.18	35.25	46.90
80	0	24.94	65.06	11.56	14.44	30.25	48.46
	3	20.48	55.86	16.12	30.87	51.45	55.14
	6	19.62	59.68	26.01	22.22	29.24	64.96
	9	23.66	54.88	15.20	36.87	21.39	51.42
	LSD 0.05 (p)	NS	15.64	NS	7.64	NS	11.05
	LSD 0.05 (Zn)	NS	NS	6.14	7.64	NS	NS
	LSD0.05 (PXZn)	NS	NS	NS	NS	NS	NS

A: Soil cultivated to cassava. B: Piggery waste-dump site.
C: Two month fallow soil D: Six month fallow soil.
E: Soil cultivated to sugarcane F: Four year fallow soil.

Zinc uptake.

Zinc uptake was significantly increased with phosphorus application to soybean in soils A, B, C and D. Application of zinc had no statistically significant effect on zinc uptake by soybean for this study (Table 2).

There was no significant phosphorus-zinc interaction observed for zinc uptake however, 40 kg P ha^{-1} appeared optimum for uptake of zinc in soybean in soils A (78%) and D (101%), while 80 kg P ha^{-1} appeared optimum for soils B (81%) and C (80%). Correlation studies showed a positive and significant relationship between zinc uptake and phosphorus uptake in soils B, C, and D. Also, between zinc uptake and dry-matter yield in all the soils.

Table 2: Effect of P and Zn application on zinc uptake (mg pot^{-1}) of soybean

Treatments P kgha^{-1}	Zn kgha^{-1}	Site A	B	C	D	E	F
0	0	126.50	174.45	54.74	34.91	114.28	253.45
	3	163.75	151.86	109.25	60.21	203.94	280.59
	6	192.00	196.59	85.26	65.75	216.05	306.19
	9	235.75	214.76	142.44	77.50	260.53	353.36
40	0	304.50	247.39	88.53	79.63	140.26	408.46
	3	406.00	282.16	143.47	71.38	208.95	359.58
	6	331.75	429.35	163.31	195.04	125.70	233.18
	9	237.00	301.98	150.21	133.30	160.26	244.06
60	0	213.50	178.16	112.51	101.38	212.56	341.74
	3	195.50	200.85	114.63	110.65	348.32	334.96
	6	258.25	308.41	111.15	97.23	188.57	248.72
	9	234.00	366.98	134.39	81.12	196.37	252.65
80	0	194.50	308.57	143.05	89.59	231.07	228.32
	3	195.00	549.36	168.19	120.12	258.57	441.85
	6	198.75	181.57	214.83	111.84	269.95	391.20
	9	199.00	299.23	180.40	154.85	218.58	306.94
	LSD 0.05 (P)	70.41	106.02	45.27	46.56	NS	NS
	LSD 0.05 (Zn)	NS	NS	NS	NS	NS	NS
	LSD0.05 (PXZn)	NS	NS	NS	NS	NS	NS

A: Soil cultivated to cassava. B: Piggery waste-dump site.
C: Two month fallow soil D: Six month fallow soil.
E: Soil cultivated to sugarcane F: Four year fallow soil.

Field trial

Soybean generally performed well on the field with significant response to separate applications of phosphorus and zinc fertilizer, depending on the growth parameters considered (Table 3). The data for number of leaves, pods, plant height and grain yield are shown in Table 3. For instance, at maturity, number of leaves, plant height and grain yield showed statistically significant response to zinc application, while number of pods at 9 and 12 WAP was significantly increased by phosphorus application. There was no significant P-Zn interaction observed on the field.

Table 3: Effect of Phosphorus and Zinc application on Soybean nodulation, number of leaves, height, pod number, yield and P and Zn uptake (Field trial)

P kg ha^{-1}	Zn kg ha^{-1}	NL (9WAP)	NP (9WAP)	PH (9WAP)	NP (12WAP)	YLD (kg ha^{-1})	P uptake (mg kg^{-1})	Zn uptake (mg kg^{-1})
0	0	40.46	39.20	20.54	42.80	1583	18.41	120.68
	3	22.34	15.40	15.33	40.80	1516	29.01	184.23
	6	33.67	29.10	18.08	44.60	1664	18.44	155.93
	9	27.75	21.70	17.00	35.30	1555	26.70	174.66
40	0	37.58	41.90	19.92	53.80	1852	45.51	150.72
	3	33.83	37.50	16.17	42.80	1469	41.35	152.39
	6	40.25	41.00	19.25	48.90	1461	50.87	157.72
	9	36.42	42.90	18.42	51.40	1453	67.32	130.32
60	0	38.33	31.00	21.50	39.70	1789	27.55	122.92
	3	35.17	26.90	17.37	50.10	1578	47.04	157.57
	6	29.92	31.90	17.42	39.60	1633	40.53	202.84
	9	32.09	31.00	18.75	16.20	1430	30.88	61.03
80	0	39.13	46.10	19.00	17.30	1664	23.48	29.30
	3	26.92	23.00	14.00	37.60	1602	29.85	169.24
	6	29.50	29.50	18.83	25.20	1430	21.98	76.21
	9	30.83	25.00	16.41	23.10	1508	17.42	52.54
	LSD 0.05 (P)	NS	10.67	NS	14.34	NS	16.65	NS
	LSD 0.05 (Zn)	5.10	NS	3.153	NS	166.56	NS	NS
	LSD0.05 (PXZn)	NS	NS	NS	NS	NS	NS	NS

NL, Number of leaves; NP, Number of Pods; PH, Plant height (cm); YLD; Yield in Kgha^{-1}; WAP, Weeks after Planting.

Phosphorus application appeared optimum for pod formation at 40 kg P ha^{-1} at both 9 WAP (55 %) and 12 WAP (20 %). Soybean plant height responded significantly to zinc application on the field. Response of soybean yield to zinc application is also not consistent. The Table also showed that phosphorus uptake was improved with phosphorus application. About 121 % increase was observed for phosphorus uptake at 40 kg P ha^{-1}, while 58 % was recorded at 60 kg P ha^{-1}. Phosphorus uptake by soybean was not increased by zinc application. Zinc uptake of soybean did not respond to both phosphorus and zinc application. There was also no phosphorus and zinc interaction observed.

DISCUSSION

The application of phosphorus had the most consistent effect on soybean growth, nodulation, yield and nutrient uptake mainly in soil D which had the least available phosphorus amongst all the soils, and to a less extent in soil B. Similar response was reported by Rehm *et al.* (1981). On the other hand, soil B with high available zinc still responded significantly to zinc application. Soybean grown on soil F on the other hand generally performed well, despite the zero response to phosphorus and zinc application. This is attributed to the long fallow period of this soil and the subsequent build-up of organic matter and improvement of the nutrient status of this soil. The response observed in pod number and leaves (data not shown), showed the importance of these two elements in soybean nutrition. Nayyak and Gupta (1995), reported reduction in leaf number of wheat with high phosphorus and zinc rates. Krishnakumari *et al.* (1999) and Dhillon and Sidhu (1992), recorded zero/low pod yield in mustard and groundnut without phosphorus application. The counteractions observed at high levels of both phosphorus and zinc application in this study could be due to uptake suppression of one over the other. This has earlier been reported by some workers (Nayak and Gupta,1995).

Zinc application significantly increased seed weight of soybean only in soil B. The increase observed in seed weight is similar to the observation of Gupta and Vyas (1994), who reported increase in seed weight with zinc fertilizer application at 3 kg and 6 kg Zn ha^{-1}. The response of soybean seed weight to phosphorus application at 60 kg P ha^{-1} and 40 kg P ha^{-1} observed in this study was similarly reported (Olufajo, 1990; Rao *et al*., 1998) with phosphorus rates varying from 26.4 kg P ha^{-1} to 90 kg P ha^{-1}, while Krishnakumari *et al.* (1999), recorded zero seed yield when no phosphorus was applied. The result from this study which shows response of soybean to applied phosphorus with respect to dry matter yield and root weight is similar to the result of previous workers. Ankomah and Osei-Kofi (1992), reported optimum dry matter yield of soybean at 60 kg P ha^{-1}. Qureshi and Narayanasamy (1999), also reported a response to soybean with the application of phosphate rocks.

Phosphorus application increased nodule number in most of the soils used, which confirmed the importance of this nutrient in soybean nodulation. This also confirmed the work of (Azeez, 2000).

Phosphorus uptake was significantly increased by the application of phosphorus in three of the soils used for this study. Zinc application also increased the uptake of phosphorus in only two soils. This is similar to the findings of (Nayak and Gupta, 1995) and Qureshi and Narayanasamy (1999). The solubility of OPR and soil pH might have affected the response of these soils to fertilizer application (Obigbesan and Akinrinde, 1999). A delayed response of the OPR is also possible since phosphate rocks are slow releasing. This implies that only the native P is available for plant uptake.

Zinc uptake

The application of zinc to soybean did not affect significantly, the uptake of zinc by soybean, because the applied Zn might not have dissolved sufficiently for soybean uptake, and precipitation of the oxide into hydroxide (Tiller and Hodgson, 1962). This is similar to the report of (Mallarino and Webb, 1995). This was at variance, however, with the findings of Nayak and Gupta (1995). Phosphorus application significantly affected zinc uptake in soybean. Some workers reported that soybean response to both phosphorus and zinc application is consistent with the inherent fertility status of the soil (Gupta and Vyas, 994). Singh and Nayyar (1997), reported that insufficient supply of zinc reduced growth, even with adequate supply of NPK, while Qureshi and Narayanasamy (1999), recorded zero yield without phosphorus application, despite the presence of other nutrients. Azeez (2000), reported that phosphorus uptake was highest in forest soils treated with 40 kg P ha^{-1}. However, optimum response was obtained in this study with 40 kg P ha^{-1} of beneficiated OPR.

In this study, application of 40 kg P ha^{-1} and 6 kg Zn ha^{-1} was optimum for nutrient uptake in the soils with moderate organic matter, while as much as 80 kg P ha^{-1} appeared optimum for soil C with low organic matter and total nitrogen. Ogun phosphate rock appeared to supply the required phosphorus needed by soybean in this study though not in all the soils. This was similarly reported by Akintokun *et al.* (2003) and Obigbesan and Akinrinde (1999), though at lower levels.

Field trial.

Phosphorus application improved the number of pods on the field. Lw yield and poor soybean response to application of zinc may be due to phosphorus and zinc interactions and nutrient fixing ability of the soil.

The response to phosphorus application is however, consistent with the findings of Dhillon and Sidhu (1992) and Qureshi and

Narayanasamy (1999). The result of the phosphorus uptake is as reported by Nayak and Gupta (1995) and Singh and Nayyar (1997). Despite the low zinc status of this soil, response to zinc was still inconsistent. This suggests that applied zinc might be insoluble or fixed, thereby making it unavailable for crop use. There was however, a favorable response to phosphorus application, especially the number of pods and phosphorus uptake. This is consistent with reports from various authors (Olufajo, 1990; Rao *et al*., 1998).

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