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Phosphorus-zinc interaction for soybean production in soil developed on charnockite in ekiti state

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ABSTRACT

The soils derived from charnockite in Ekiti State Nigeria were found to be low in zinc and phosphorus. This study was therefore conducted during the rainy seasons of 2006 and 2007 to evaluate growth and yield response of soybean TGX-1440LE from the direct effect and interaction of phosphorus and zinc. Treatments consisted of factorial combination of two levels of P(0,and 30kgPha^{-1}), three levels of Zn(0,2,and 4kg Zns0_4ha^{-1}) in a randomized complete block design in a soil developed in charnockite in Ekiti State The growth data were collected at 2 weekly intervals while yield components were taken at harvest. Stem girth, number of nodules and nodule weight significantly ($P < 0.05$) increased with 2kg Zn ha^{-1} application, which gave 111.2% yield advantage over the control treatment (0kgZn ha^{-1}). Fertilizer rate above 2kgZn ha^{-1} significantly ($p<0.05$) decreased P uptake. The 30kgP ha^{-1} rate produced better growth, which was not significantly different from 0 kgP ha^{-1} while increase in P and Zn uptake was significant. The P x Zn interaction was significant for grain yield and Zn uptake. The treatment combination that gave the highest yield was 30kgP ha^{-1} and 2kgZn ha^{-1}.

Introduction

Soybean is a legume being integrated into the cropping systems of smallholder farmers in Ekiti State as a plant protein source for employment in the diet and as a cash crop with huge industrial potential. There is presently a dearth of information on effects of phosphorus and zinc fertilizer on soybeans. This is more severe for the soils developed over Charnockite which comprise a large portion of the arable land in Ekiti and the agricultural lands with great prospects for soybean cultivation.(Shittu,2008)

Differential response of soybean to high levels of applied Phosphorus (P) was first reported by Howell (1954) and confirmed by subsequent studies (Fort and Ellis 1997, Vaughan, 2007). Differences in P sensitivity were associated with differences in P uptake. Some authors claimed that applied P affects the absorption of Zn by roots by some way other than precipitation of an insoluble Zinc phosphate (Chiezey, 1999, Ogoke et al, 2004). It has also been reported that P decreases the concentration of Zn mostly in leaves and least in roots, suggesting that the effect of P on Zn originates in roots which retards translocation of Zn to the upper plant parts, probably due to the formation of compound that is either less mobile or has a lower solubility product (Chiezey, 1999). It is also reported that antagonism between P and Zn involves physiological reaction (Hague et al, 2008; Hopkins and Elisworth, 2003).

Study reported was carried out to determine the effects of P and Zn fertilizer rates on the growth and yield components of soybean and on the nutrient uptake of the plant grown in a soil derived from Charnockite at Ikere.

Materials and Methods

The study was carried out along Ise Road, Ikere Ekiti, Ekiti State lat 70 29"; long 5013' during the rainy seasons of 2006 and 2007. Soybean (TGX 1440-LE) a determine variety that matures in 110days was grown at a factorial combination of two levels of P(0, 30kg Pha^{-1}) sourced from single superphosphate strong Zn and three levels of Zn (0, 2, 4kg $ZnSO_4$ha^{-1}) and sourced from $ZnSO_4$ design treatment was replicated three times and assumed to held

Soil samples were taken up to a depth of 30cm before fertilizer application and analysed for physical and chemical properties using standard laboratory produces (IITA, 1970). Available P was determined by the Bray-1-method while exchangeable cations including Mn were extracted with 1 N ammonium acetate at pH 7 and determined by flame photometry. Exchangeable acidity was extracted with 1N KCl and determined by titration with 0.1N NaOH pH was determine in a 1:1 soil:water ratio and organic C by wet oxidation method.

Planting was done one on flat seed bed at 10cm spacing in rows and 75cm apart to achieve a planting density 133,333 plants/ha. The fertilizers were side-banded at planting, 7.5cm away from the seed row.

Weeds were controlled by spraying the plots with a pre-emergence herbicide Galex (metalochlor + metabronium in the ratio 1:1) at 2.25kg a.i/ha. Subsequently, one weeding was done manually at 6 weeks after planting. Growth parameters were taken at 2 weeks intervals.

However, leaf area was obtained from intact leaf according to Lazarov (1965) by multiplying the product of leaf length and breadth by a factor of 0.65. Nutrient uptake was obtained using the equation.

$$Nu - \frac{\text{Nutrient Concentration x Dry Weight}}{100}$$

Yield and yield components were determined at maturity from harvested from four inner rows. The harvested pods were

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hand-threshold and grain yields recorded. The number and yield of pods per plant and 100-seed weight were determined from sub-sample taken from the harvested plot.

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) and means that showed significant difference were separated using least significant difference (LSD).

Results and Discussion

Soil Properties

The soil is a sandy loam with low organic matter and total N content exchangeable Ca was moderately high. The high base saturation (90.4%), presence of thick ochric epipedon and argillic horizon are criteria for the classification of the soil as Alfisol at order level and sub order Udalf (soil survey staff 2003). However, due to the udic moisture regime, it is further classified as Grossarenic Plinthic Kandiudalf. The soil is deficient in available Zn (Table 1)

Effect of P and Zn fertilizers and rates on growth parameters

Application of P had no significant effect on height at 4 and 8 week after planting in the first year while 30kgPha^{-1} produced tallest plants of 25.02cm at 4WAP in the second year. At 8WAP during the second year, 30kgPha^{-1} application had slight increase in plant height which was not significantly different from control which also had little effect on plant height while 64.29cm was obtained with 4kgZnha^{-1} at 8WAP in 2006 in 2007 mean plant height of 62.21cm was obtained with 2kgZnha^{-1} at 8WAP.

The mean stem girth of soybean was not significantly ($P \leq 0.05$) affected in both 2006 and 2007 at 4WAP and 8WAP by P application. Also, Zn fertilizer had no significant effect on mean stem girth in 2006 cropping season whereas 2kgZnha^{-1} gave highest stem girth of 1.71cm an 2.69cm at 4WAP and 8 WAP in 2007.

The number of branches was highest at 30kg Pha^{-1} at 4 WAP in 2007 and gave highest number of branches at 8WAP. Application of Zn had no significant effect on number of branches at 4WAP in 2006 but sophistication number of branches was obtained with 2kgZnha^{-1} at 8WAP. In 2007, application of 2kgZnha^{-1} significantly ($P \leq 0.05$) increased the number of branches at 4WAP and 8WAP respectively.

P application had significant($p<0.05$) effect on the number of nodules at 4WAP in 2007 while 30kgPha^{-1} increased nodule number by 12.82%. At 6WAP in 2007 highest nodules was obtained from 2kgZnha^{-1} (Table 2).

The fresh weight of nodules from plants receiving 30kgPha^{-1} were higher than 0kg Pha^{-1} at 4WAP and 6WAP in 2006 and 2007. Nodule weight from 2kg Znha^{-1} was significantly($p<0.05$)higher than 0kgZnha^{-1} and4kgZnha^{-1} in 2006 and 2007.

P-Zn interactions on growth parameters of soybean

There were no significant P-Zn interaction on growth parameters taken in 2006 cropping season. The interactions were however, significant($p<0.05$) on plant height, stem girth, leaf area and number of branches at 4WAP and 8WAP in 2007. The best combination for the optimum performance of soybean was 30kg Pha^{-1} and 2kg Znha^{-1}.(Table 3)

Nutrient uptake of soybean as affected by P and Zn fertilizer rates

Leaf P was significantly($p<0.05$) increased by fertilizer rates in 2006 and 2007. P uptake at 30kg Pha^{-1} was significantly $P<0.05$) higher than the 0kgPha^{-1} rate. Application of Zn fertilizer at Znha^{-1} increased P uptake up to 2kgZnha^{-1} but P uptake significantly decreased above this rate in 2006 and 2007 cropping season.

P fertilizer had significant effect on Zn uptake in 2006 and 2007. The application of P at 30kg ha^{-1} in 2006 and 2007 significantly increased Zn uptake. Application of 4kg Znha^{-1} significantly increased Zn uptake in both years especially the 0kg Znha^{-1} rate. (Table 4)

The P-Zn interaction was also significant on dry matter yield of soybean in 2007. The treatment combination 0kg Pha^{-1} and 2kg Znha^{-1} gave the highest dry leaf weight, root dry weight, number of nodules and nodules weight at 4WAP and 8WAP (Table 5).

Effects of P-Zn Interactions on aspects of yield in soybean

The interactions of P-Zn application on P pod yield per plant, grain yield per plant and grain yield per hectare during the two years are shown in Table 6. The P-Zn interaction was significant on pod and grain yield in 2006 and 2007 while the best combination were 0kg Pha-1 and 2kg Znha^{-1}. P-Zn interactions had significant ($P < 0.05$) effects on the grain yield and the best combination were 30kg Pha^{-1} and 2kg Znha^{-1} in both years of study.

Discussion

The high sand content of the soil is largely a reflection of the parent material from which the soils were formed. The predominance of sand in the surface is attributed to preferential removal of clay and silt by erosion (Ojanuga, 1971) and the influence of the parent material (Greenland, 1971). The available P content is critically low compared to 15mgkg^{-1} considered as the critical level for soybean production (Staton and Darry, 2007). The soil is clearly deficient in available Zn about 50% of the critical level established for some soils in South Western Nigeria. (Osiname et al, 1973; Adeoye and Agboola 1985). The organic matter content is moderate. The high pH observed might be due to a prevalent feature of the traditional slash and burn farming practices. The low CEC may be due to intensely weathered nature of the soil.

Phosphorus is an essential nutrient for soybean. The response of applied P was not spectacular, despite the low level of available P in the soil. Growth parameters such as plant height, stem girth, number of branches, nodules weight and nodules number were not significantly influenced by P application. Ogoke et al (2004) working in the guinea savanna reported that at sites where responses were observed due to low initial soil test P, 30kg Pha^{-1} application was not different from 60kg Pha^{-1} on pod number, pod weight and grain weight suggesting that applying P at rates above 30kg Pha^{-1} may not be desirable for soybean even when soil test P is low.

Addition of Zn and P increased the translocation of P and Zn to the leaves. The antagonism between Zn and P has already been reported in other crops like maize and wheat (Zhimini et al, 1999). Zinc application increase its uptake reduced the P content of the leaves at a moderate level of P nutrition but had no effect on Zn contents at a high level of P nutrition. The root content was less affected than the leaf content which indicated that P slowed down the translocation of Zn to the top of the plant.

There were significant differences in pod yield and grain yield per plant between control and treatment which required. The combination of 30kg Pha^{-1} and 2kg Znha^{-1} gave the tallest plants at 65.52cm while application of Zn alone at 2kg Znha^{-1} increased plant height compared with other P and Zn fertilizer combinations.

Table 1: Physical and chemical properties of soil developed from charnockite at Ikere, Ekiti State

Soil properties	
Sand %	83.24
Silt %	10.00
Clay %	7.30
Textural classification	Sandy
Organic carbon %	2.91
Total N(%)	0.24
Available P	5.40
Organic matter %	5.04
Exch. Bases Cmol/kg	
Ca	2.60
Mg	0.20
K	0.25
Na	0.21
CEC	3.38
Ex. Acidity Cmol/kg	0.12
Micronutrients	
Zn(mg/kg)	0.53
Fe(mg/kg)	7.10
Mn(mg/kg)	12.12
Cu(mg/kg)	0.27
Base saturation (%)	90.41

Table 2 Effects of P, Zn fertilizers rates on plant height, number of branches, stem girth, number of nodules and nodules weight

Fertilizer	Rate(kg/ha)	Plant Height		Nos of branches		Stem Girth		Nodule weight		Number of nodules	
	2006	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP	4WAP	6WAP	4WAP	6WAP
SSP	0	25.89^{a}	63.88^{a}	6.39a	11.6a	1.56a	3.10a	0.80a	1.16a	16.94a	29.39a
	30	25.63^{a}	62.59^{a}	7.10a	11.21a	1.59a	2.98a	0.85a	1.48a	17.61a	32.67a
$ZnSO_4$	0	25.13^{a}	61.10^{a}	6.73a	10.53b	1.57a	3.13a	0.62a	1.54a	15.50a	32.67a
	2	25.84^{a}	64.23^{a}	7.27a	11.88a	1.60a	3.09a	1.31a	1.38a	20.67a	35.33a
	4	26.30^{a}	64.39^{a}	7.03a	11.80a	1.54a	2.90a	0.56a	1.05a	15.67a	25.08a
	2007										
SSP	0	22.99^{b}	56.93^{a}	2.89b	7.99a	1.56a	2.40a	1.20a	1.74a	19.11b	35.11a
	30	25.02^{a}	59.92^{a}	3.38a	8.57a	1.61a	2.47a	1.44a	1.81a	21.56a	37.78a
$ZnSO_4$	0	23.07^{b}	57.58^{a}	3.41a	8.42b	1.56b	2.33a	1.08a	1.57b	16.25b	32.83b
	2	25.51^{a}	62.21a	3.35a	9.98a	1.71a	2.69a	1.90a	2.40a	28.50a	45.96a
	4	23.49^{b}	58.20a	2.69b	6.44c	1.48b	2.29b	0.98b	1.36b	16.25b	30.58b

Means with the same letter in each column for each fertilizer types are not significantly different by DMRT.p<0.05
WAP=weeks after planting

Table 3a Phosphorus and Zinc Fertilizers Interaction on Growth Parameters in 2006 and 2007 Cropping Season

Fertilizer Rate (kg/ha)		Plant Height (cm)		Nos of branches		Stem Girth		Leaf Area	
P	Zn	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP	4WAP	6WAP
0	0	24.21^{a}	60.65^{a}	6.70^{a}	10.52^{a}	1.48^{a}	2.88^{a}	28.24^{a}	52.81^{a}
30	0	26.13^{a}	65.22^{a}	7.11^{a}	12.13^{a}	1.62^{a}	3.12^{a}	31.38^{a}	60.14^{a}
0	2	26.05^{a}	63.23^{a}	6.97^{a}	11.60^{a}	1.58^{a}	3.07^{a}	32.15^{a}	62.28^{a}
30	2	27.88^{a}	66.87^{a}	6.82^{a}	12.22^{a}	1.66^{a}	3.30^{a}	34.32^{a}	64.26^{a}
0	4	25.55^{a}	61.92^{a}	6.95^{a}	11.47^{a}	1.57^{a}	3.07^{a}	29.43^{a}	59.61^{a}
30	4	24.72^{a}	61.55^{a}	7.77^{a}	10.55^{a}	1.51^{a}	2.92^{a}	28.12^{a}	61.28^{a}
Table 3b	2007								
0	0	20.62^{b}	52.86^{c}	2.56^{c}	6.87^{bc}	1.44^{bc}	2.29^{bc}	16.72^{c}	49.94^{a}
30	0	25.40^{a}	62.29^{a}	4.25^{a}	9.96^{a}	1.68^{ab}	2.37^{abc}	29.62^{a}	57.63^{a}
0	2	25.37^{a}	61.92^{a}	3.54^{b}	11.05^{a}	1.81^{a}	2.71^{a}	30.42^{a}	59.08^{a}
30	2	25.68^{a}	65.52^{a}	3.15^{bc}	8.92^{ab}	1.61^{abc}	2.68^{ab}	31.24^{a}	59.63^{a}
0	4	22.98^{c}	56.00^{ab}	2.56^{c}	6.04^{c}	1.43^{c}	2.21^{c}	25.38^{b}	53.65^{a}
30	4	24.02^{ab}	56.40^{ab}	2.75^{c}	6.84^{bc}	1.53^{b}	2.37^{abc}	24.99^{b}	55.24^{a}

Means with the same letter in each column for each fertilizer types are not significantly different by DMRT.p<0.05
WAP=weeks after planting

Table 4: Effects of P, Zn, Fertilizer rates on Phosphorus and Zn uptake of soybeans in 2006 and 2007 cropping season

			2006		2007
Fertilizer	Rate kg/ha	Phosphorus Uptake (mg/kg)	Zinc uptake (mg/kg)	Phosphorus uptake mg/kg	Zinc uptake mg/kg
SSP	0	0.20^{b}	16.98^{b}	0.18^{b}	19.17^{a}
	30	0.84^{a}	26.63^{a}	0.76^{a}	29.66^{a}
ZnSO4	0	0.57^{a}	7.65^{a}	0.50^{a}	9.05^{a}
	2	0.54^{a}	27.97^{b}	0.50^{a}	26.55^{a}
	4	0.45^{a}	29.78^{a}	0.41^{a}	34.64^{a}

Means with the same letter in each column for each fertilizer types are not significantly different by DMRT.$p<0.05$

Table 5a Phosphorus and Zinc fertilizer interactions on dry matter yield of soybean in 2006 and 2007 cropping season

Fertilizers and rates (kgha^{-1})	Interaction	Leaf Dry Weight (g)		Stem Dry Weight (g)		Root Dry Weight (g)		Nos of Nodules (g)		Nodules Weight (g)	
P	Zn	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP	4WAP	6WAP	4WAP	6WAP
0	0	5.89^{bc}	9.12^{a}	0.82^{b}	4.24^{b}	0.71^{c}	1.80^{c}	13.00^{a}	24.00^{a}	0.43^{b}	0.90^{a}
30	0	8.39^{ab}	10.52^{a}	1.31^{ab}	4.69^{ab}	1.88^{ab}	2.27^{ab}	18.33^{a}	35.67^{a}	1.11^{ab}	1.44^{a}
0	2	5.98^{bc}	9.12^{a}	1.19^{b}	4.60^{ab}	1.48^{bc}	1.63^{bc}	17.50^{a}	35.00^{a}	0.69^{b}	1.33^{a}
30	2	9.05^{a}	12.74^{a}	1.82^{a}	5.22^{a}	2.56^{a}	2.86^{a}	23.83^{a}	36.83^{a}	1.50^{a}	1.93^{a}
0	4	6.62^{abc}	9.69^{ab}	1.11^{b}	4.51^{ab}	1.33^{bc}	1.50^{c}	16.10^{a}	28.50^{a}	0.63^{b}	1.19^{a}
30	4	6.92^{a}	10.33^{ab}	0.95^{b}	4.35^{b}	0.88^{c}	1.18^{c}	15.00^{a}	26.17^{a}	0.62^{b}	1.14^{a}
Table 4b											
0	0	5.14^{d}	8.61^{c}	6.73^{b}	5.59^{d}	0.85^{c}	1.64^{c}	14.50^{b}	27.00^{b}	0.47^{c}	1.23^{a}
30	0	10.20^{b}	25.88^{b}	9.56^{ab}	8.34^{b}	2.09^{b}	3.73^{b}	18.00^{a}	38.67^{ab}	1.69^{ab}	1.92^{ab}
0	2	11.43^{ab}	33.13^{a}	11.35^{a}	9.24^{b}	2.35^{b}	6.60^{a}	26.50^{a}	52.50^{a}	2.13^{a}	2.57^{a}
30	2	12.33^{a}	19.69^{c}	12.02^{a}	7.52^{c}	3.05^{a}	6.08^{a}	30.50^{a}	39.33^{ab}	1.67^{ab}	2.22^{a}
0	4	7.24^{c}	13.67^{d}	7.32^{b}	8.07^{c}	1.41^{a}	3.77^{b}	16.33^{b}	33.83^{b}	1.00^{bc}	1.42^{b}
30	4	7.89^{c}	11.09^{de}	9.09^{ab}	11.76^{a}	1.19^{c}	3.35^{b}	16.17^{b}	27.33^{b}	0.95^{c}	1.29^{b}

Means with the same letter in each column for each fertilizer types are not significantly different by DMRT.$p<0.05$

Table 6a: The P-Zn fertilizers interaction of yield component of soybeans in 2006 and 2007 cropping season

Fertilizers and rates kg/ha^{-1}	Interaction kg/ha	Pod yield/plant (g)	Grain yield per plant (g)	Grain yield per hectare (kg)
P	Zn	2006 experiment		
0	0	17.90^{c}	7.99^{d}	2009.3^{a}
30	0	23.17^{b}	13.52^{b}	2400.0^{a}
0	2	26.03^{a}	14.56^{a}	2518.5^{a}
30	2	21.46^{c}	13.31^{b}	2592.6^{a}
0	4	24.75^{a}	11.42^{c}	2185.2^{a}
30	4	19.97^{d}	10.67^{c}	2270.7^{a}
2007 Experiment				
0	0	19.04^{d}	12.18^{d}	1979.8^{bc}
30	0	27.11^{a}	16.28^{b}	2488.8^{a}
0	2	28.35^{a}	18.82^{a}	2863.1^{a}
30	2	25.11^{b}	15.99^{b}	2867.3^{a}
0	4	21.66^{c}	13.80^{c}	1985.7^{bc}
30	4	20.91^{cd}	13.06^{cd}	1858.2^{c}

Means with the same letter in each column for each fertilizer types are not significantly different by DMRT.$p<0.05$

The improved performance of the treatment combination of 30kg Pha^{-1} and 2kg Znha^{-1} showed the presence of Zn-P synergy which had been reported by other workers.

Conclusion

The results of the study indicated soybean responded to P,but the magnitude is low compared to zinc. There was significant($p<0.05$)interaction between Pand Zn in both years but the treatment containing the nutrients did not differ significantly from p and Zn application alone at 30kgpha^{-1} and 2kgZnha^{-1} . It was from that increase in P- level from 0 to 30kgPha-^{1}, also an increase Zn-level from 0 to 2kg Znha-^{1} resulted in taller and greater yield of soybean plants. It is also evident that applying Zn rates above 2kgha^{-1} may not be desirable for soybean even when soil test Zn is low. P-Zn interactions had significant ($p<0.05$) effects on the grain yield and the best combinations were 30kgPha^{-1} and 2kgPha^{-1} in both years of study.

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