Agricultural Journal 8 (2): 78-82, 2013
ISSN: 1816-9155

Phosphorus-Zinc Interaction for Soybean Production in Soil Developed on Charnockite in Ekiti State

[1]O.S. Shittu and [2]J.A. Ogunwale
[1]Department of Crops, Soil and Environmental Sciences, Ekiti State University, Ado Ekiti, Nigeria
[2]Department of Agronomy, University of Ilorin, Ilorin, Nigeria

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 2 levels of P (0 and 30 kg P ha^{-1}), three levels of Zn (0, 2 and 4 kg $ZnSO_4$ ha^{-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 2 kg Zn ha^{-1} application, which gave 111.2% yield advantage over the control treatment (0 kg Zn ha^{-1}). Fertilizer rate above 2 kg Zn ha^{-1} significantly ($p<0.05$) decreased P uptake. The 30 kg P ha^{-1} rate produced better growth which was not significantly different from 0 kg P ha^{-1} while increase in P and Zn uptake was significant. The P×Zn interaction was significant for grain yield and Zn uptake. The treatment combination that gave the highest yield was 30 kg P ha^{-1} and 2 kg Zn ha^{-1}.

Key words: Soybean, phosphorus, zinc, interaction, charnockite, Nigeria

INTRODUCTION

Soybean is a legume being integrated into the cropping systems of small holder 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, 2000). Differences in P sensitivity were associated with differences in P uptake. Some researchers claimed that applied P affects the absorption of Zn by roots by some way other than precipitation of an insoluble zinc phosphate (Chiezey and Yayock, 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 and Yayock, 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 at 70°29", long 50°13" during the rainy seasons of 2006 and 2007. Soybean (TGX 1440-LE), a determine variety that matures in 110 days was grown at a factorial combination of 2 levels of P (0, 30 kg P ha^{-1}) sourced from single superphosphate strong Zn and three levels of Zn (0, 2, 4 kg $ZnSO_4$ 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 30 cm before fertilizer application and analysed for physical and chemical properties using standard laboratory produces (Juo, 1979). Available P was determined by the Bray-1-method while exchangeable cations including Mn

Corresponding Author: O.S. Shittu, Department of Crops, Soil and Environmental Sciences, Ekiti State University, Ado Ekiti, Nigeria

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 10 cm spacing in rows and 75 cm apart to achieve a planting density 133,333 plants ha^{-1}. The fertilizers were side-banded at planting, 7.5 cm 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 2.25 kg a.i ha^{-1}. 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 Lazarod (1965) by multiplying the product of leaf length and breadth by a factor of 0.65. Nutrient uptake was obtained using the equation:

$$Nu = \frac{\text{Nutrient concentration} \times \text{Dry weight}}{100}$$

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

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).

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

Soil properties	Values
Sand (%)	83.24
Silt (%)	10.00
Clay (%)	7.300
Textural classification	Sandy
Organic carbon (%)	2.910
Total N (%)	0.240
Available P	5.400
Organic matter (%)	5.040
Exch. Bases (C mol kg^{-1})	-
Ca	2.600
Mg	0.200
K	0.250
Na	0.210
CEC	3.380
Ex. Acidity (C mol kg^{-1})	0.120
Micronutrients	
Zn (mg kg^{-1})	0.530
Fe (mg kg^{-1})	7.100
Mn (mg kg^{-1})	12.12
Cu (mg kg^{-1})	0.270
Base saturation (%)	90.41

Effect of P and Zn fertilizers and rates on growth parameters: Application of P had no significant effect on height at 4 and 8 weeks after planting in the 1st year while 30 kg P ha^{-1} produced tallest plants of 25.02 cm at 4 WAP in the 2nd year. At 8 WAP during the 2nd year, 30 kg P ha^{-1} application had slight increase in plant height which was not significantly different from control which also had little effect on plant height while 64.29 cm was obtained with 4 kg Zn ha^{-1} at 8 WAP in 2006 in 2007 mean plant height of 62.21 cm was obtained with 2 kg Zn ha^{-1} at 8 WAP.

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

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

P application had significant ($p<0.05$) effect on the number of nodules at 4 WAP in 2007 while 30 kg P ha^{-1} increased nodule number by 12.82%. At 6 WAP in 2007, highest nodules was obtained from 2 kg Zn ha^{-1} (Table 2). The fresh weight of nodules from plants receiving 30 kg P ha^{-1} were higher than 0 kg P ha^{-1} at 4 and 6 WAP in 2006 and 2007. Nodule weight from 2 kg Zn ha^{-1} was significantly ($p<0.05$) higher than 0 kg Zn ha^{-1} and 4 kg Zn ha^{-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 4 and 8 WAP in 2007. The best combination for the optimum performance of soybean was 30 kg P ha^{-1} and 2 kg Zn ha^{-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 30 kg P ha^{-1} was significantly $p<0.05$ higher than the 0 kg P ha^{-1} rate. Application of Zn fertilizer at Zn ha^{-1} increased P uptake up to 2 kg Zn ha^{-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 30 kg ha^{-1} in 2006 and 2007 significantly increased Zn uptake. Application of 4 kg Zn ha^{-1} significantly increased Zn uptake in both years, especially the 0 kg Zn ha^{-1} rate (Table 4).

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

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

Fertilizers	Rate (kg ha^{-1})	Plant height		No. of branches		Stem girth		Nodule weight		No. of nodules	
		4 WAP	8 WAP	4 WAP	8 WAP	4 WAP	8 WAP	4 WAP	6 WAP	4 WAP	6 WAP
2006											
SSP	0	25.89^{a}	63.88^{a}	6.39^{a}	11.60^{a}	1.56^{a}	3.10^{a}	0.80^{a}	1.16^{a}	16.94^{a}	29.39^{a}
	30	25.63^{a}	62.59^{a}	7.10^{a}	11.21^{a}	1.59^{a}	2.98^{a}	0.85^{a}	1.48^{a}	17.61^{a}	32.67^{a}
$ZnSO_4$	0	25.13^{a}	61.10^{a}	6.73^{a}	10.53^{b}	1.57^{a}	3.13^{a}	0.62^{a}	1.54^{a}	15.50^{a}	32.67^{a}
	2	25.84^{a}	64.23^{a}	7.27^{a}	11.88^{a}	1.60^{a}	3.09^{a}	1.31^{a}	1.38^{a}	20.67^{a}	35.33^{a}
	4	26.30^{a}	64.39^{a}	7.03^{a}	11.80^{a}	1.54^{a}	2.90^{a}	0.56^{a}	1.05^{a}	15.67^{a}	25.08^{a}
2007											
SSP	0	22.99^{b}	56.93^{a}	2.89^{b}	07.99^{a}	1.56^{a}	2.40^{a}	1.20^{a}	1.74^{a}	19.11^{b}	35.11^{a}
	30	25.02^{a}	59.92^{a}	3.38^{a}	08.57^{a}	1.61^{a}	2.47^{a}	1.44^{a}	1.81^{a}	21.56^{a}	37.78^{a}
$ZnSO_4$	0	23.07^{b}	57.58^{a}	3.41^{a}	08.42^{b}	1.56^{b}	2.33^{a}	1.08^{a}	1.57^{b}	16.25^{b}	32.83^{b}
	2	25.51^{a}	62.21^{a}	3.35^{a}	09.98^{a}	1.71^{a}	2.69^{a}	1.90^{a}	2.40^{a}	28.50^{a}	45.96^{a}
	4	23.49^{b}	58.20^{a}	2.69^{b}	06.44^{c}	1.48^{b}	2.29^{b}	0.98^{b}	1.36^{b}	16.25^{b}	30.58^{b}

Table 3: Phosphorus and zinc fertilizers interaction on growth parameters in 2006 and 2007 cropping season

Fertilizer rate (kg ha^{-1})		Plant height (cm)		No. of branches		Stem girth		Leaf area	
P	Zn	4 WAP	8 WAP	4 WAP	8 WAP	4 WAP	8 WAP	4 WAP	6 WAP
2006									
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}
2007									
0	0	20.62^{b}	52.86^{c}	2.56^{c}	06.87^{bc}	1.44^{bc}	2.29^{bc}	16.72^{c}	49.94^{a}
30	0	25.40^{a}	62.29^{a}	4.25^{a}	09.96^{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}	08.92^{ab}	1.61^{abc}	2.68^{ab}	31.24^{a}	59.63^{a}
0	4	22.98^{c}	56.00^{ab}	2.56^{c}	06.04^{c}	1.43^{c}	2.21^{c}	25.38^{b}	53.65^{a}
30	4	24.02^{ab}	56.40^{ab}	2.75^{c}	06.84^{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	
Fertilizers	Rate (kg ha^{-1})	Phosphorus uptake (mg kg^{-1})	Zinc uptake (mg kg^{-1})	Phosphorus uptake (mg kg^{-1})	Zinc uptake (mg kg^{-1})
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}
$ZnSO_4$	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 5: Phosphorus and zinc fertilizer interactions on dry matter yield of soybean in 2006 and 2007 cropping season

Fertilizers and rates (kg ha^{-1})	Interaction	Leaf dry weight (g)		Stem dry weight (g)		Root dry weight (g)		No. of nodules (g)		Nodules weight (g)	
P	Zn	4 WAP	8 WAP	4 WAP	8 WAP	4 WAP	8 WAP	4 WAP	6 WAP	4 WAP	6 WAP
2006											
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}
2007											
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}

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

Fertilizers and rates (kg ha^{-1}) P	Interaction (kg ha^{-1}) Zn	Pod yield/plant (g)	Grain yield per plant (g)	Grain yield ha^{-1} (kg)
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; $p<0.05$

and 2 kg Zn ha^{-1}. P-Zn interactions had significant ($p<0.05$) effects on the grain yield and the best combination were 30 kg P ha^{-1} and 2 kg Zn ha^{-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, 1981). The available P content is critically low compared to 15 mg kg^{-1} considered as the critical level for soybean production (Staton and Damy, 2007). The soil is clearly deficient in available Zn about 50% of the critical level established for some soils in Southwestern 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, 30 kg P ha^{-1} application was not different from 60 kg P ha^{-1} on pod number, pod weight and grain weight suggesting that applying P at rates above 30 kg P ha^{-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 30 kg P ha^{-1} and 2 kg Zn ha^{-1} gave the tallest plants at 65.52 cm while application of Zn alone at 2 kg Zn ha^{-1} increased plant height compared with other P and Zn fertilizer combinations. The improved performance of the treatment combination of 30 kg P ha^{-1} and 2 kg Zn ha^{-1} showed the presence of Zn-P synergy which had been reported by other researchers.

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 P and Zn in both years but the treatment containing the nutrients did not differ significantly from p and Zn application alone at 30 kg p ha^{-1} and 2 kg Zn ha^{-1}. It was from that increase in P- level from 0-30 kg Pha^{-1}, also an increase Zn-level from 0-2 kg Zn ha^{-1} resulted in taller and greater yield of soybean plants. It is also evident that applying Zn rates above 2 kg ha^{-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 30 kg P ha^{-1} and 2 kg P ha^{-1} in both years of study.

REFERENCES

Adeoye, G.O. and A.A. Agboola, 1985. Critical level for soil pH, available P, K, Zn and Mn and maize earleaf content of P, Cu, Zn and Mn in sedimentary soils of Southwestern Nigeria. Nutr. Cycl. Agroecosyst., 6: 65-71.

Chiezey, V.F. and J.Y. Yayock, 1999. Effect of phosphorus magnesium and zinc fertilizers on the yield and yield components of soybean (*Glycine Max* (L) Merill) in the Northern guinea savanna of Nigeria. Trop. Soil Seeds J., 4: 1-5.

Fort, A.W. and S.B. Ellis, 1997. Fertilizer Institute. Soil Test Interpretation Publication, Washington, DC., USA.

Greenland, D.J., 1981. Characterization of Soil and Relation to their Classification and Management. Clarendon Press, Oxford..

Hague, I., L.A. Nnadi and M.A. Mohamed-Saleem, 2008. Phosphorus management with special reference to forage legumes in Sub-Saharan Africa. Food and Agriculture Organization, http://www.fao.org/wairdocs/ilri/x5488e/x5488e0a.htm.

Hopkins, B. and J. Elisworth, 2003. Idaho potato commission research and extension. Progress Report University of Idaho.

Howell, R.W., 1954. Phosphorus nutrition of soybeans. Plant Physiol., 29: 477-483.

Juo, A.S.R., 1979. Selected Methods for Soil and Plant Analysis: Manual Series No. 1. International Institute of Tropical Agriculture, Ibadan, Nigeria, Pages: 70.

Lazarod, R., 1965. Coefficients for determining leaf area in certain agricultural crops. Rast Nauski, 2: 27-37.

Ogoke, I.J., A.O. Togun, R.J. Carsky and K. Dashiell, 2004. Effect of phosphorus fertilizer on soybean pod yield in the Guinea Savanna. Niger. Agric. J., 35: 40-50.

Ojanuga, A.G., 1971. A study of soils and soil genesis in the South Western Upland in Nigeria. Ph.D. Thesis, University of Wisconsin, Madison, USA.

Osiname, O.A., E.E. Schutte and R.B. Corey, 1973. Micronutrients response of oats grown on sandy inceptisols. J. Food Sci. Agric., 24: 1341-1349.

Soil Survey Staff, 2003. Keys to Soil Taxonomy SMS Tech Monograph. 9th Edn., Virginia Polytechnic Institute State University, Virginia, Pages: 422.

Staton, M. and L.W. Damy, 2007. Fertilizing soybeans TI Michigan soybean facts. Michigan Soybean Promotion Committee P.O. Box 267, Frankenmouth MI 48735.

Vaughan, N.O., 2000. Trace Elements in Soils and Plants. 3rd Edn., CRC Press, Boca Raton, FL., USA.

Zhimini, Y., S. Zheng and T.H. Ai, 1999. Zinc nutrition and metabolism of olants as influenced by supply of phosphorus and zinc. Pedosphere, 9: 265-274.