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Effect of Cover Crops, Lime and Rock Phosphate on Maize (*Zea mays* L.) in an Acidic Soil of Northern Guinea Savanna of Nigeria

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Abstract

Phosphorus deficiency is the major constraint to maize production in acidic soil of Heipang (9^{o}38', 8^{o}53') in Northern Guinea Savanna of Nigeria. The soil is high in sesquioxides and soluble aluminum and has high phosphate sorption capacity. To address this problem, a field trial was conducted between 1996-1997 to assess the responses of six tropical cover crops and maize to lime and applied rock phosphate and to evaluate the effect of these treatments on the performance and P nutrition of succeeding maize. Results of the trial showed that planting *Chamaecrista rotundifolia*, *Lablab purpureus*, *Mucuna pruriens*, and maize-*Chamaecrista rotundifolia* intercrop reduced the leaf Al concentration of succeeding maize by more than 38%. Although none of the six cover crops significantly increased grain yields of succeeding maize, *C. rotundifolia* was the most consistent in improving maize performance while *Glycine max* produced the least performance. Concentration of Mn in the index leaves of maize was significantly higher on plots where *G. max* preceded maize, thus accounting for the poor performance of maize on these plots. Application of Sokoto Phosphate Rock at 30 kg ha^{-1} to cover crops produced very significant improvement in the yields of succeeding maize. While liming with 1.35 t CaO ha^{-1} in 1997 raised the soil pH value by 0.2 and significantly improved total P uptake by maize.

Keywords: P deficiency, rock phosphate, liming, cover crops, maize yield

1 Introduction

About 1.8 billion hectares of land, representing one-third of the total land area in the tropics, have strong enough soil acidity for soluble aluminum to be toxic to most crop species (Sanchez, P. A. and Logan, T.J., 1992). According to Nicholaides, J. J. *et al.* (1983) as reported by Oguntoyinbo, F. I. *et al.* (1996), acid soils cover about 17 million hectares of land in Nigeria. In the southern region and some areas of the middle belt high levels of sesquioxides; toxic levels of soluble Al and Mn; and deficient levels of phosphorus cause severe limitations to soil productivity (Udo, E.J. and Uzo, F.O., 1972; Mokwunye, A. *et al.*, 1986; Jibrin, J. M., 1999). There is no evidence that any tropical plant species of agricultural importance are adapted to all

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factors of acid soil infertility. The general practice for correcting soil acidity and nutrient deficiency especially of P is by lime and P fertilizer application respectively. However, in Nigeria where several factors limit the use of inorganic P fertilizers (most of which are imported), the key to sustainable food production in low activity clay soils with high P sorption capacity and low organic matter content is the development of a cropping system that makes greater use of locally-sourced inputs. Important components of such a strategy include greater sourcing and use of locally available rock phosphates; choice of P efficient and Al- and Mn-tolerant plant species, and the proper management of soil organic matter through green manuring, cover cropping and return of crop residues. Horst, W. J. (1992) described this approach as a "low external input high efficiency strategy". The objective of this study was to evaluate the effect of lime and phosphate rock application to cover crops on subsequent maize growth, yield and P uptake in acidic soil in Nigeria. The role of some tropical cover crops in reducing the impact of soil acidity on succeeding food crops was also examined.

2 Materials and methods

2.1 Study area

The experiment was conducted on a Typic Plinthustult at Heipang (9^{o}38', 8^{o}53'), Northern Guinea Savanna of Nigeria during the 1996 and 1997 cropping seasons. The soil has high contents of Fe, Al and Mn oxides, with very high P fixing capacity. Characteristics of the soil are presented in Table 1.

2.2 Experimentation

The experiment was initiated in 1996 in a split-split plot design with 4 replications. The sub-sub plots of 4 x 5.25 m^2 comprised of 0 kg P ha^{-1}, 30 kg P ha^{-1} in form of Sokoto Phosphate Rock (SPR), and 30 kg P ha^{-1} in form of Single Superphosphate (SSP). The sub plots measuring 4 x 13 m^2 received 0 and 250 kg CaO ha^{-1}. The main plots of 13 x 11 m^2, had the following crop treatments:

1. *Zea mays* L. (crop residue removed after grain harvest)
2. *Zea mays* L. (crop residue incorporated into soil after grain harvest)
3. *Phaseolus vulgaris*
4. *Cajanus cajan*
5. *Glycine max*
6. *Chamaecrista rotundifolia*
7. *Lablab purpureus*
8. *Mucuna pruriens*
9. *Zea mays* L. intercropped with *Chamaecrista rotundifolia*
10. *Zea mays* L. intercropped with *Cajanus cajan*

All maize plots received urea at the rate of 120 kg N ha^{-1} in split doses, half at planting and the rest 6 weeks later. The legumes were given a maintenance dose of 20 kg N ha^{-1} at 5 weeks after planting. All plots were treated with 50 kg K ha^{-1} in form of KCl. At the end of the growing season all the crop residues were incorporated into the soil after seed harvest, except in treatment 1 above.

Table 1: Characteristic of Heipang soil

Soil Property	Value
Clay	520 g kg^{-1}
Sand	240 g kg^{-1}
Silt	240 g kg^{-1}
Texture	Clay
pH (H_2O; 1:2.5 w/v)	5.4
pH (0.01m $CaCl_2$; 1:2.5 w/v)	4.4
Total P	473 mg kg^{-1}
Bray 1 P	0.69 mg kg^{-1}
Anion resin extractable P	2.03 mg kg^{-1}
Water soluble Al*	23.2 mg kg^{-1}
Organic C	13.0 g kg^{-1}
Total N	1.6 g kg^{-1}
CEC	16.3 Cmol kg^{-1}
Exchangeable acidity	0.9 Cmol kg^{-1}
Exchangeable Al	0.6 Cmol kg^{-1}
Free oxides (CBD method)	
Fe	61.8 g kg^{-1}
Al	7.5 g kg^{-1}
Mn	0.4 g kg^{-1}

* water soluble Al was determined after shaking 1g soil in 60ml water for 16 hours

During the 1997 cropping season, the sub-sub plots were further split into two with one half receiving a fresh P treatment of 60 kg P ha^{-1} in form of SSP. Additional 1.35 t CaO ha^{-1} based on the soils liming requirement was applied to all previously limed plots to maintain the pH at around 5.5. Maize (*Zea mays* cv. 8644-27) was the test crop on all plots. All plots were treated with 120 kg N ha^{-1} in split doses as in 1996 and 50 kg K ha^{-1} at planting.

2.3 Soil and plant tissue analysis

Plant and soil tissue analyses were carried out according to the procedures documented by Juo, A.S.R. (1979).

2.4 Statistical analysis

All the data collected were subjected to analysis of variance (ANOVA) using the GENSTAT V package for statistical analysis (Lawes Agricultural Trust, 1993).

3 Results and discussion

3.1 Grain and stover yields

Maize grain yield response to preceding cover crop treatments and lime application in 1997 was not statistically significant (Figs. 1&2b). Although not statistically significant the results also showed that G. max depressed maize grain yield. Application of both SPR and SSP in 1996 produced significant maize grain yield increases in 1997, with SSP being superior to SPR. The ability of SPR to significantly increase maize grain yield on this soil confirms its suitability on soils with low available P content. Fresh application of 60 kg P ha^{-1} in 1997 produced about 130% increase in grain yield. There were significant interaction effects of 1996 and 1997 P treatments on grain yields, with plots treated with SSP in 1996 and fresh 60 kg P ha^{-1} in 1997 producing the highest yields. This indicates that even the application of 60 kg P ha^{-1} was not sufficient enough to give maximum yield on this soil.

Maize stover yields were significantly raised where maize was preceded by *C. rotundifolia*, *C. cajan*, maize intercropped with *C. cajan*, and maize intercropped with *C. rotundifolia* (Fig. 1). *Glycine max* produced the least amount of stover. Effect of liming on stover yield was not obvious (Fig. 2). Both 1996 and 1997 phosphate application produced significant maize stover yield increases in 1997.

3.2 Tissue nutrient contents

Preceding crops had no significant effect on P concentration of maize index leaves at 50% flowering, nor on total P uptake at harvest (Fig. 1). Application of lime significantly raised the P concentration of index leaves and the total P uptake. Both SSP and SPR application in 1996 and fresh P application in 1997 resulted in significant increases in tissue P concentration and total P uptake.

Magnesium concentrations of maize index leaves at 50% flowering were significantly ($P = 0.05$) raised where *C. rotundifolia*, *M. pruriens*, *P. vulgaris* and maize intercropped with *C. rotundifolia* preceded maize (Table 2). *Glycine max*, on the other hand, significantly lowered Mg and raised Mn contents of index leaves of succeeding maize. This explains the lower performance of maize observed on plots preceded by *G. max*. *Glycine max* tended to accumulate toxic levels of Mn in its tissue, and indeed Mn tocity symptoms were observed on the leaves of the plant during growth. This high level of Mn must have been released in to the soil solution upon decomposition of the crop residue, thus raising the level of Mn taken up by succeeding maize.

Although statistically, the Al concentrations of maize index leaves were not significantly lowered by preceding crop treatments, there were 42.2, 41.4, 39.1, and 38.4% reductions in Al concentrations where maize was preceded by *M. pruriens*, maize-*C. rotundifolia*, intercrop, *L. purpureus* and *C. rotundifolia* respectively. This indicates the ability of some crop residues in lowering the concentrations of Al in soil and reducing the impact of soil acidity. Similar effect was reported by Kretzschmar, R.M. *et al.* (1991) who observed more than 44% decrease in total and labile Al concentrations in the soil solution of an acid Psammentic Paleustalf in Niger republic after incorporating millet residue.

Liming significantly raised the concentrations of Ca and Mg and lowered the Mn concentrations of index leaves (Table 3).

3.3 Soil and available P

At the beginning of 1997 season (before application of fertilizers and lime) the effects of 1996 treatments did not manifest on available (Bray 1) P. The values for available soil P were extremely low, ranging from 0.5 to 1.44 mg kg^{-1} soil. At mid-silking, effects of preceding crops, liming and 1996 P treatments did not also significantly influence the concentration of available P in soil (Figs. 1&2). However, the application of 60 kg P ha^{-1} in 1997 significantly increased the concentration of Bray 1 P from 0.44 to 1.73 mg kg^{-1}. The extremely low concentration of available soil P even with the application of 60 kg P ha^{-1} in 1997 further confirms the very high P sorption capacity of this soil. The mean effects of the liming on soil pH at mid-silking showed that lime application raised soil pH by 0.2. The effects of preceding crops and phosphate application on soil pH were not evident.

Table 2: Effect of preceding crops on nutrient element concentrations in index leaves of maize at 50% silking in 1997

Preceding crop	Al mg kg^{-1}	Mn mg kg^{-1}	Fe mg kg^{-1}	Mg g kg^{-1}	Ca g kg^{-1}
Maize-residue	151	33.44	109	2.53	4.00
Maize + residue	117	38.17	104	2.60	4.00
Maize + *C. rotundifolia*	89	36.5	103	2.87	4.23
Maize + *C. cajan*	111	35.05	106	2.51	4.01
G. max	169	41.16	116	2.27	3.54
C. rotundifolia	93	34.40	105	2.93	4.38
L. purpureus	92	33.05	101	2.73	4.13
M. pruriens	87	32.35	101	2.81	4.11
P. vulgaris	109	38.00	104	2.81	4.08
C. cajan	104	31.19	105	2.63	4.16
F ratio	ns	*	ns	**	ns
SE±	-	3.811	-	0.86	-
%CV	-	10.80	-	5.1	-

Table 3: Effect of liming on nutrient element concentrations in index leaves of maize at 50% silking in 1997

Treatment	Al mg kg^{-1}	Mn mg kg^{-1}	Fe mg kg^{-1}	Mg g kg^{-1}	Ca g kg^{-1}
Unlimed	107	38.61	104	2.60	3.83
Limed	118	32.06	107	2.73	4.29
F ratio	ns	**	ns	*	**
SE±	-	4.971	-	0.287	0.435
%CV	-	14.1	-	10.7	10.7

Figure 1: Effect of preceding crops on maize yields, P contents and available soil P and pH in 1997

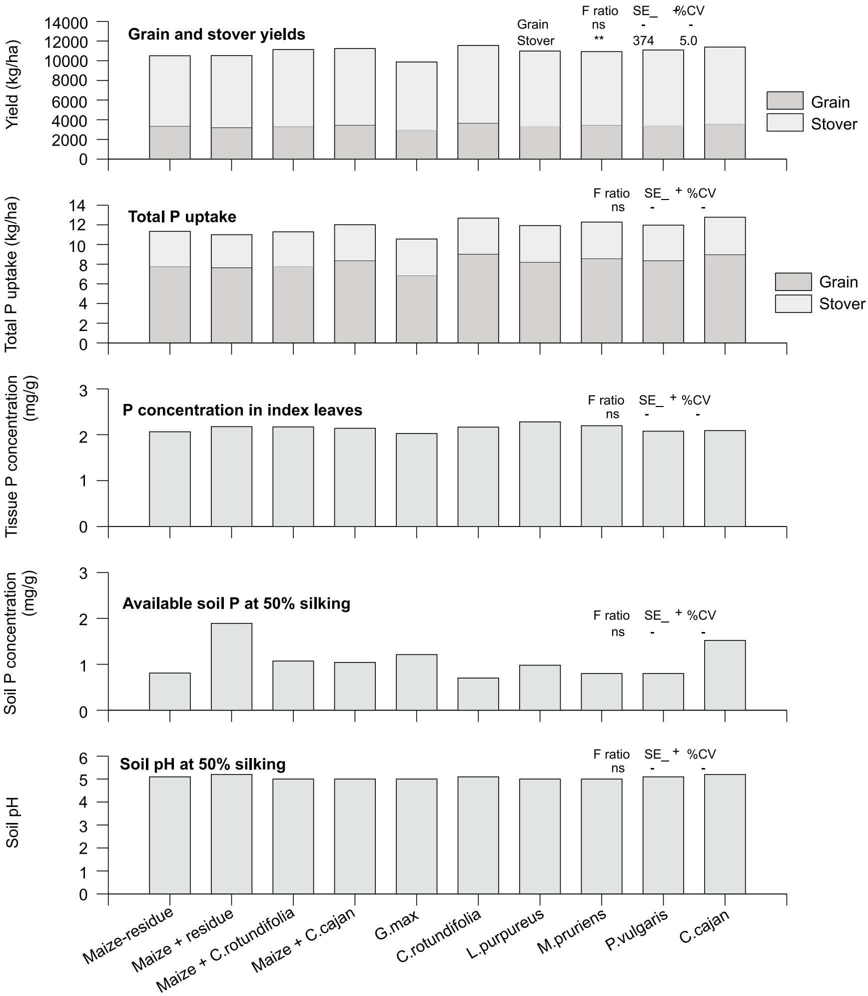
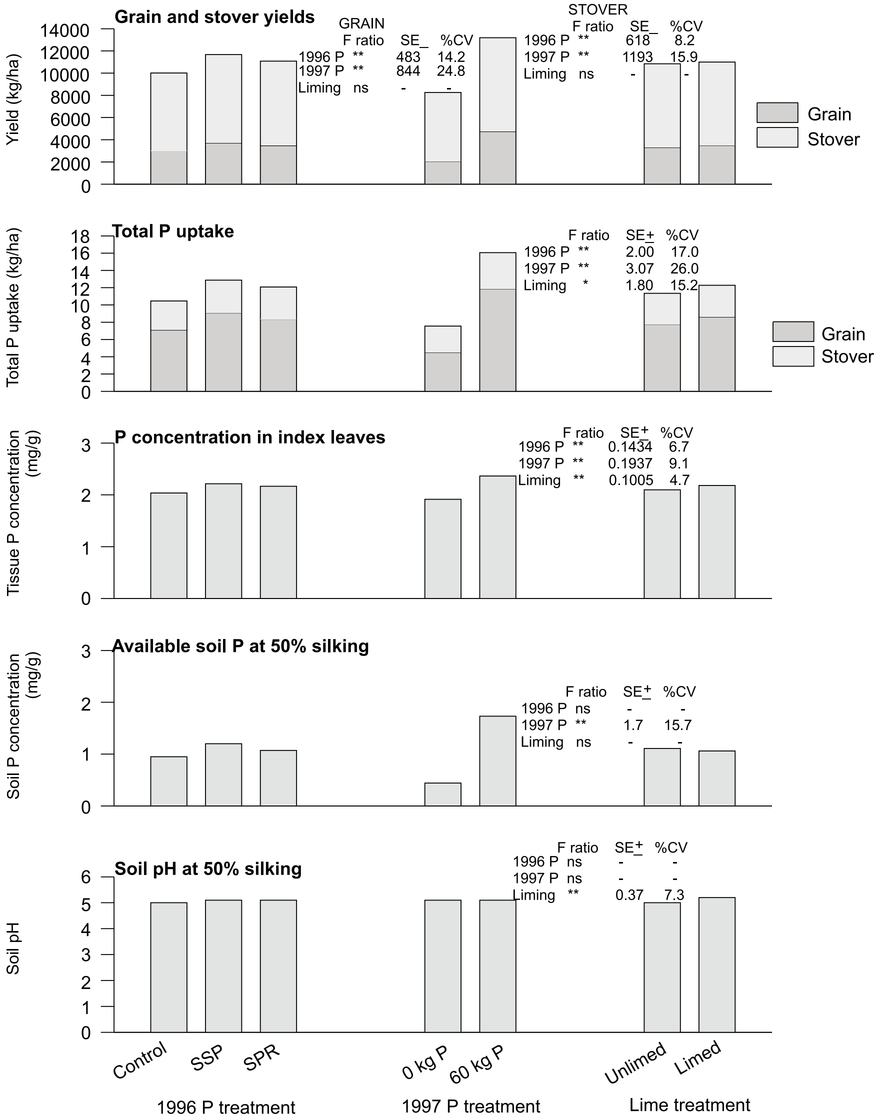


Figure 2: Mean effect of P treatments and liming on maize yields, P contents and available soil P and pH in 1997



4 Conclusion

The P uptake of maize on a Typic Plinthustult with high P sorption is significantly improved with liming. Application of SPR to cover crops could produce significant yield increases in succeeding maize. Planting *C. rotundifolia*, *L. purpureus*, *M. pruriens* and maize-*C. rotundifolia* intercrop could reduce the impact of soil acidity on succeeding maize by reducing the amounts of Al and Mn taken up by maize while *G. max* may exacerbate the problems of acidity.

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