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Effect of Phosphorus Fertilizer on Nitrogen Fixation by Some Grain Legume Varieties in Sudano – Sahelian Zone of North Eastern Nigeria.

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ABSTRACT: Nitrogen fixation by grain legumes contributes N to tropical soils. But in Sudano – Sahelian region of North-eastern Nigeria, low phosphorus content of the soil may restrict rhizobia population and legumes root development, which in turn, can affect their N_2 fixing potential. A two- years field experiment was conducted at the Department of Soil Science Teaching and Research Farm University of Maiduguri North-eastern Nigeria during 2005 and 2006 cropping sessions to evaluate the influence of phosphorus (P) on N_2 fixation by groundnut (*Arachis hypogaea* L.), cowpea (*Vigna unguiculata* L.) and bambara groundnut (*Vigna subterranean* L.). The legume crops and a sorghum variety (Paul Biya) were applied 0, 20 and 40 Kg Pha^{-1} and grown for 50 days, after which they were harvested and the amount of N fixed was determined. P fertilization significantly increased the amount of N fixed by the crops. Application of 40 $KgPha^{-1}$ increased N fixation in cowpea, groundnut and bambara groundnut by 378, 169 and 138% respectively, over the control. Cowpea differed significantly from groundnut and bambara groundnut in the amount of N fixed ($P<0.05$). Cowpea fixed (54.19 $KgNha^{-1}$), groundnut (39.16 $KgNha^{-1}$) and bambara groundnut fixed (28.42 $KgNha^{-1}$). Cultivation of Bornoji red cowpea variety with application of 40 $KgPha^{-1}$ would improve the soil N status.
Key words: Phosphorus fertilizer; N_2-fixation; Grain legumes;Sudano-Sahelian

INTRODUCTION

Low soil N fertility is one of the major constraints to crop production in Sudano – Sahelian zone of north – eastern Nigeria (Rayar, 2000). Unfortunately, chemical fertilizers are unaffordable to the resource – poor farmers who constitute the majority in the region. Consequently, the farmers include grain legume crops in their cropping systems to improve the soil fertility status. In addition, the grain legumes serve as sources of cash, protein and edible oil to the farmers and fodders for livestocks. Biological N fixation is cheaper means of improving soil fertility and productivity. The use of biological N fixation provides continuous supply of N for plant growth and add organic matter to the soil. The contribution of the grain legume crops to the soil fertility in the tropics has been reported by several researchers. In the Southern Guinea Savanna of Nigeria, promiscuous soybean (*Glycine max* L.) was reported to fix 38-126 $KgNha^{-1}$ (Sanginga *et al.*, 2001). It was reported by Yusuf et al, (2006) that cowpea fixed 16-34 $kgNha^{-1}$ and soybean fixed between 41-50 $kgNha^{-1}$ in northern Guinea savanna zone of Nigeria. Studies conducted under Sudan Savanna conditions (Rayar, 1986a) indicated that groundnut fixed about 85-100kgN/ha/year. Giller (2001) reported the N-fixing potential of cowpea, groundnut and soybean as 9-201; 21-206 and 55-188 $kgNha^{-1}year^{-1}$, respectively. However, low phosphorus content of the soil in Sudano-Sahelian region may restrict *rhizobia* population and legume root development, which in turn can affect their N_2 fixing potential (Kwari, 2005). Studies conducted by researchers in Savanna regions of Nigeria showed that application of P at the rate 20-40 $kgha^{-1}$ significantly improved the performances of the grain legumes, groundnut (Balasubramanian and Nnadi 1980) ; bambara groundnut (Balarabe *et al.*, 1998); cowpea (Uzoma *et al.*, 2006) and soybean (Kamara *et al.*, 2007). However, information on the P requirements of the grain legumes for optimum N_2 fixation in Sudano-sahelian agro-ecological zone is lacking. Therefore this study was carried out to evaluate the influence of P on N_2 fixation by cowpea, groundnut and bambara groundnut in Sudano-sahelian zone of North-eastern Nigeria..

MATERIALS AND METHODS

A two- year field experiment was conducted at the Department of Soil Science Teaching and Research Farm, University of Maiduguri (11^0 51^1 N, 13^0 15^1 E) during 2005 and 2006 cropping seasons. The total amount of rainfall for 2005 and 2006 were 830 and 423mm, respectively.

The treatments consisted of three grain legume varieties; cowpea (var, Bornoji – red); groundnut (var, Kolji kanuri); bambara groundnut (var.Mallum karekare); sorghum (var. Paul Biya) and three levels of P fertilizer (0, 20, and 40 KgPha-1). Soil characterization was carried out prior to the treatments application (Van Reeuwiik,1992). The treatments were arranged in randomized complete block design and replicated three times. The land was ploughed, harrowed and plots were laid out into plot sizes of 4 m long and 3 m wide. Three seeds were sown per hole according to BOSADP (1993) recommended spacing. Seedlings were thinned down to two per hill two week after sowing. Phosphorus was applied as superphosphate by banding. Weeding was done with hoe. At 50 days after sowing, the crops were harvested from a 1 m^2 (quadrant) subplots. Post harvest soil samples were also taken from each plot and analyzed for total N as described by van Reeuwiik (1992). Number of nodules were counted and the plant materials were oven dried at 65^0C, weighed and analyzed for the N concentrations (Marr and Cresser, 1983).

The amount of N fixed and percent N derived from biological fixation were estimated by the equations of Mary *et al.* (1995).

Collected data were subjected to analysis of variance (ANOVA) and the means with significant difference between treatments were separated using Duncan's multiple range test (DMRT) at 5% probability level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The soil of the experimental site is sandy loam in texture, neutral in reaction and low in organic carbon, total N and available P according to soil fertility ratings by FPDD (2002)(Table 1).

Table 1. Texture and some selected chemical characteristics of soil of the experimental site

Parameter	Values
Sand (g/kg)	700
Silt (g/kg)	150
Clay (g/kg)	150
Texture	Sandy loam
pH	6.71
Organic carbon (g/kg)	4.40
Total nitrogen (g/kg)	0.50
Available phosphorus (mg/kg)	5.30

The effect of phosphorus on cowpea, groundnut, and bambara groundnut in the years 2005 and 2006 cropping seasons are presented in Tables 2 and 3, respectively.

The results of the two cropping seasons followed similar trends but the values of 2006 were consistently higher than those of 2005. This perhaps it is as a result of residual effect of P fertilizer. Fertilizer was applied in 2005 and 2006 at equal amount, yet 2006 was better despite the low rainfall recorded. Averaged over the two years, the results presented in Table 4 shows that application of phosphorus significantly enhanced all the parameters tested in the legume crops but differed significantly ($P < 0.05$) in their responses to P fertilizer. There were significant interaction effects in all the parameters except on soil N. Application of 40 $KgPha^{-1}$ to cowpea gave the highest interaction effect. These results confirm the observation made by Weber (1996) that in the Northern Guinea Savanna of Nigeria, legumes require about 30 $kgPha^{-1}$ for optimal growth and N_2-fixation. However, higher rate of the P (40 $kgha^{-1}$) was used in this study because of the lower P level in the Sudan Savannah soils than that of Guinea Savannah coupled with continuous depletion of P in Savanna soils in recent years. The legume crops require large quantities of P because of the growth of the whole plant, development of a population of free-living *rhizobia* in the rhizosphere, nodules initiation and development and the process of biological N_2 fixation by nodules of the plants. The significant (P<0.05) difference observed among the crop species in their responses to P fertilizer was in line with the findings of Fohse *et al*. (1998) and Paul and Giller (2002) who observed species and varietal differences in the ability of legumes to extract soil P. This may depend upon the potential of roots to absorb P, their active life time, the amount of root per unit of shoot, and the nature of organic acid exude by roots. For example, pigeonpea (*Cajanus cajan* L.) solubilizes soil P by exudation of organic acid (Ae *et al.*, 1990).

The increase of whole plant growth and plant nitrogen concentration in response to increased soil P supply has been noted for several leguminous species including groundnut (Rebafka *et al*, 2003) soybean (Kwari 2005) and cowpea (Uzoma *et al,* 2006). However, Tsvetkova and Georgier (2003) observed that oversupply of P caused decrease in plant growth, nodulation and acetylene reduction in soybean. In this study, phosphorus application at 20 and 40 $kgPha^{-1}$ improved the performances of cowpea significantly (P<0.05). Application of 40 $kgPha^{-1}$ increased the nodule number by 153%, N content in the plant tissue by 288%, and amount of N fixed by 378% over the control. These findings were in agreement with the reports of Uzoma *et al*. (2006) that P application at 20 and 40 $kgPha^{-1}$ improved nodulation, N accumulation and grain yield of cowpea in Guinea Savannah of Nigeria. The best performance was obtained with 40 $kgPha^{-1}$. In contrast, Tewari (1965) in a field trial in Southeastern Nigeria failed to observe any significant effect of P application on nodulation of cowpea, although the number of effective nodules tended to increase. This might be due to the high level of native P in the soil (FPDD, 2002),which was sufficient to cowpea.

Treatment effect on percentage nitrogen derived from fixation (%NDFA) was significant (P<0.05). It increased from 69.33 in control to 85.01 in cowpea that received 40 $kgPha^{-1}$, which is 85.01% of the total N in the plant. This result agrees with Cadish *et al* (1989) who reported that P fertilization increased the percentage NDFA in legumes grown in native Savannah. On the other hand, there was marked decrease in percentage NDFA in the legume where extreme deficiency of P occurs. This proves the specific roles of P in nodule formation and functioning in grain legumes.

The study also showed that there was increase in available N in the soil under P-treated cowpea compared to control. This indicates that P fertilization enhanced N_2-fixation as well as nitrogen secretion by cowpea which in turn, improved the N economy of the soil as earlier reported by Agboola and Fayemi (1972).

Application of the 40 $kgPha^{-1}$ to groundnut increased nodule number by 160%, N content by 147% and amount of fixed N by 169% over the control. These results agree with Balasubramanian and Nnadi (1980) who reported that application of 30 $kgPha^{-1}$ increased numbers and dry weight of nodules, N accumulation and amount of N fixed in groundnut in Guinea Savannah soils. Similarly, Aulakh and Pasricha (1999) in field trials in subtropical region of India observed a positive response of groundnut to application of P up to 20 $kgPha^{-1}$. However, in a three-years experiment on an acid soil in Niger Republic, Rebafka *et al*, (2003) reported that annual application of 16$kgPha^{-1}$ as single superphosphate caused decrease in total N uptake and induced Mo deficiency in groundnut. The remarkable response to P fertilizer observed in this study may be due to low native P of the soil coupled with the specific role of phosphorus in nodule initiation, growth and functioning.

Table 2 Effect of phosphorous rate on nodulation, nitrogen content and N_2 fixation by cowpea, groundnut and bambara groundnut, 2005

	Rate (kg P/ha)			
Crops	0	20	40	Mean
		Nodules/plant		
Cowpea	20.00	23.00	53.00	32.00 [c]
Groundnut	32.33	72.33	86.67	63.78 [a]
Bambara groundnut	35.67	43.67	62.33	47.22 [b]
Mean	29.33 [c]	46.67 [b]	67.33 [a]	
SE±	1.34 (rate)			
SE±	1.34 (crop)			
SE±	2.33 (interaction)			
		Total N in plant (kg/ha)		
Cowpea	16.05	46.76	82.76	48.52 [a]
Groundnut	14.38	26.46	53.61	31.48 [b]
Bambara groundnut	11.36	22.14	46.37	26.62 [c]
Sorghum	4.48	7.65	16.42	7.59 [d]
Mean	11.60 [c]	25.75 [b]	48.54 [a]	
SE±	1.12 (rate)			
SE±	1.30 (crop)			
SE±	2.25 (interaction)			
		N-fixed (kg/ha)		
Cowpea	11.48	39.11	71.34	40.64 [a]
Groundnut	9.80	18.81	42.19	23.60 [b]
Bambara groundnut	6.78	14.49	35.20	18.82 [c]
Mean	9.36 [c]	24.14 [b]	49.57 [a]	
SE±	1.51 (rate)			
SE±	1.51 (crop)			
SE±	2.63 (interaction)			
		% NDFA		
Cowpea	71.14	83.58	86.06	80.26 [a]
Groundnut	75.07	70.13	78.69	74.63 [b]
Bambara groundnut	58.31	65.07	75.88	66.42 [c]
Mean	68.18 [c]	72.93 [b]	80.21 [a]	
SE±	1.47 (rate)			
SE±	1.47 (crop)			
SE±	2.55 (interaction)			
		% Soil N		
Cowpea	0.056	0.065	0.070	0.067 [b]
Groundnut	0.056	0.070	0.089	0.075 [a]
Bambara groundnut	0.047	0.042	0.051	0.047 [c]
Sorghum	0.025	0.028	0.023	0.025 [d]
Mean	0.051	0.051	0.058NS	
SE±	0.0028 (rate)			
SE±	0.032 (crop)			
SE±	0.006 (interaction)			

Means in columns and rows followed by similar letter(s) are not significantly different at the 5% probability level of the Duncan's Multiple Range Test (DMRT).

Table 3. Effect of phosphorous rates on nodulation, nitrogen content and N_2 fixation by cowpea, groundnut and bambara groundnut in 2006 cropping season.

	Rate (kg P/ha)			
Crops	0	20	40	Mean
		Nodules/plant		
Cowpea	23.00	26.00	56.67	35.33 ^{c}
Groundnut	36.00	76.33	90.67	67.67 ^{a}
Bambara groundnut	40.00	48.67	65.33	51.33 ^{b}
Mean	33.11 ^{c}	50.33 ^{b}	70.89 ^{a}	
SE±	1.54 (rate)			
SE±	1.54 (crop)			
SE±	2.67 (interaction)			
		Total N in plant (kg/ha)		
Cowpea	35.57	97.02	117.64	83.41 ^{a}
Groundnut	43.63	78.10	89.45	70.39 ^{b}
Bambara groundnut	38.87	57.11	65.04	53.67 ^{c}
Sorghum	11.47	16.71	18.84	15.67 ^{d}
Mean	32.38 ^{c}	62.24 ^{b}	72.74 ^{a}	
SE±	1.98 (rate)			
SE±	2.27 (crop)			
SE±	3.93 (interaction)			
		N-fixed (kg/ha)		
Cowpea	24.10	80.31	98.8	67.74 ^{a}
Groundnut	32.16	61.39	70.61	54.72 ^{b}
Bambara groundnut	27.40	40.46	46.20	38.02 ^{c}
Mean	27.88 ^{c}	60.72 ^{b}	71.87 ^{a}	
SE±	4.47 (rate)			
SE±	2.58 (crop)			
SE±	4.47 (interaction)			
		% NDFA		
Cowpea	67.51	82.62	83.96	78.03 ^{a}
Groundnut	73.95	80.35	78.82	77.71 ^{a}
Bambara groundnut	69.90	70.75	70.92	70.53 ^{b}
Mean	70.48 ^{b}	77.90 ^{a}	77.90 ^{a}	
SE±	1.74 (rate)			
SE±	1.74 (crop)			
SE±	3.01 (interaction)			
		% Soil N		
Cowpea	0.075	0.079	0.081	0.078 ^{a}
Groundnut	0.070	0.078	0.080	0.076 ^{a}
Bambara groundnut	0.051	0.051	0.077	0.060 ^{b}
Sorghum	0.032	0.023	0.019	0.025 ^{c}
Mean	0.057 ^{a}	0.058 ^{a}	0.064 ^{a}	
SE±	0.003 (rate)			
SE±	0.004 (crop)			
SE±	0.003 (interaction)			

Means in columns and rows followed by similar letter(s) are not significantly different at the 5% probability level of the Duncan's Multiple Range Test (DMRT).

Table 4. Effect of phosphorous rate on nodulation and nitrogen content and fixation by cowpea, groundnut and bambara groundnut, combined for two years

	Rate (kg P/ha)			
Crops	0	20	40	Mean
		Nodules/plant		
Cowpea	21.67	24.50	54.83	33.67 ^{c}
Groundnut	34.17	74.33	88.67	65.72 ^{a}
Bambara groundnut	37.83	46.17	63.67	49.22 ^{b}
Mean	31.22 ^{c}	48.33 ^{b}	69.06 ^{a}	
SE±	1.14 (rate)			
SE±	1.14 (crops)			
SE±	1.97 (interaction)			
		Total N in plant (kg/ha)		
Cowpea	25.81	71.89	100.20	66.00 ^{a}
Groundnut	29.00	52.28	71.53	50.94 ^{b}
Bambara groundnut	25.11	39.63	55.70	40.15 ^{c}
Sorghum	8.03	12.18	15.13	11.78 ^{d}
Mean	21.99 ^{c}	44.00 ^{b}	60.64 ^{a}	
SE±	1.13 (rate)			
SE±	1.30 (crops)			
SE±	2.25 (interaction)			
		N-fixed (kg/ha)		
Cowpea	17.79	59.71	85.07	54.19 ^{a}
Groundnut	20.98	40.10	56.40	39.16 ^{b}
Bambara groundnut	17.09	27.48	40.70	28.42 ^{c}
Mean	18.62 ^{c}	42.43 ^{b}	60.72 ^{a}	
SE±	1.46 (rate)			
SE±	1.46 (crops)			
SE±	2.53 (interaction)			
		% NDFA		
Cowpea	69.33	83.10	85.01	79.15 ^{a}
Groundnut	74.51	75.24	78.76	76.17 ^{a}
Bambara groundnut	64.11	67.92	73.40	68.47 ^{b}
Mean	69.31 ^{c}	75.42 ^{b}	79.06 ^{a}	
SE±	1.14 (rate)			
SE±	1.14 (crops)			
SE±	1.79 (interaction)			
		% Soil N		
Cowpea	0.070	0.072	0.076	0.073 ^{a}
Groundnut	0.068	0.074	0.084	0.075 ^{a}
Bambara groundnut	0.049	0.058	0.064	0.057 ^{b}
Sorghum	0.028	0.026	0.021	0.025 ^{c}
Mean	0.054 ^{a}	0.058 ^{a}	0.061 ^{a}	
SE±	0.003 (rate)			
SE±	0.004 (crops)			
SE±	0.009 (interaction)			

Means in columns and rows followed by similar letter(s) are not significantly different at the 5% probability level of the Duncan's Multiple Range Test (DMRT).

P fertilization showed a positive effect on the available N in the soil under P-treated groundnut, indicating that P enhanced nitrogen fixation by groundnut into the soil. A similar result was reported by Bationo and Ntare (2000) that in groundnut – millet rotation in Semi-arid tropics, groundnut increased not only the yield of the succeeding millet but also the nitrogen use efficiency. The beneficial effect of the legume on millet is usually as a result of N_2 fixation.

It was also observed from this study that phosphorus fertilization at the rate of 40 $kgha^{-1}$ to bambara groundnut caused increases in number of nodules by 68%, N content of the crop by 122% and amount of N fixed by 155% over the control. These results in line with the report of Ramolemane *et al.* (1996) that nodulation and dry matter accumulation by bambara groundnut increased with P application. Similarly, Balarabe *et al.* (1998) in a field trial in Guinea Savanna of Nigeria observed that application of 11-22 $kgPha^{-1}$ enhanced the performance of bambara groundnut. The best performances were at 13 $kgPha^{-1}$, which was by far lower than the amount used in this study. This is due to the fact that the native soil P in the Guinea Savanna is likely higher than that of semi-arid soils, and so higher rates of P fertilizer is required in semi-arid region than in Guinea Savannah in order to achieve the same goal. According to FPDD (2002) the native soil P increases from semi-arid region to the humid forest zone.

Conclusion: In this study, application of 40 $kgPha^{-1}$ increased the amount of N fixed by cowpea, groundnut and bambara groundnut by 378, 169 and 138%, respectively over the control. Cowpea fixed the highest amount of N (54.19$kgha^{-1}$). Therefore, cultivation of cowpea variety (Bornoji-red) with application of 40 $kgPha^{-1}$ would greatly increase the level of available N in the soil of Sudano-sahelian zone of Nigeria.

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