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Influence of Sokoto Phosphate Rock on Some Soil Properties and the Growth and Yield of Cowpea [*Vigna Unguiculata* (L)Walp.] Varieties in Sudan Savanna of Nigeria

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Abstract
Phosphate rock has been used over the years as source of P fertilizer especial in acid soils. Sokoto state is rich in PR deposit and could be used to complement the conventional P fertilizer whose use by peasant farmers have been limited by high cost and scarcity. Sequel to this, an Experiment was conducted in 2009 at the Botanical Garden, Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto to determine the influence of Sokoto Phosphate Rock (SPR) on some chemical properties of soil, growth and yield of cowpea [*Vigna Unguiculata* (L)Walp.]. The treatments consisted of factorial combinations of two varieties (Dan Gusau (v_1) and IT90K-82-2 (v_2) and three levels of SPR at 0.062, 0.125 and 0.187g/5kg (25, 50, 75 kg ha^{-1}) as well as a control (without fertilizer). The experiment was laid out in a completely randomized design (CRD) replicated three times. SPR applied enhanced availability of nutrients in soil and the general performance of cowpea varieties which increased with increased rate of application. The results of the study indicated a significant difference ($p<0.05$) in soil available phosphorus, plant tissue phosphorus, soil total nitrogen and plant tissue nitrogen due to application of SPR. Significant difference was also observed in plant height at 2, 4, 6, and 8 weeks after planting (WAP). Similarly, the response of cowpea varieties, dry matter yield at harvest (8WAP) due to application of SPR was significant ($p<0.05$). Significant interaction effect between variety and applied SPR on plant height, number of branches and dry matter yield were also observed. The results of this investigation revealed that, increased rate of application of SPR progressively increased the growth and yield performance of cowpea and soil available phosphorus. However, absolute values were not high perhaps because of the weekly acidic nature of the soil which does not encourage fast solubilization of P from SPR. Therefore, application of SPR at a rate of 75kg ha^{-1} could improve cowpea production and therefore recommended.
Keywords: Sokoto phosphate rock; Soil parameters; Sudan savanna; Cowpea yield

1. Introduction

Cowpea *(Vigna unguiculata* (*L.) Walp)* has been in cultivation for use as human food since ancient times. Today, it is widely grown in tropical, sub-tropical and warm temperate regions of the world (Vanderborght and Baudoin, 2001). The importance of cowpea to the livelihood of millions of relatively poor people in less developed countries of the tropics cannot be over emphasized (Aliyu and Singh, 2008). Singh and Emechebe (1990) reported that cowpea contributes to sustainability of cropping system in semi-arid areas, through its fixation of nitrogen, ground cover and soil improvement. Despite these immense benefits of cowpea, per hectare production based on farmer's practices is still low. FAOSTAT (2005*)* reported 0.434 ton ha^{-1} in Nigeria.

Beside other factors like pests, low yield of cowpea obtained by farmers in Nigeria has been attributed to low phosphorus (P) content of the soils, especially in the semi-arid zone of Nigeria where the soils are deficient in P (Ntare and Bationo, 1992). Buresh *et al.* (1997) and FAO (2004) reported that soil P has been a major limiting factor for crop production in sub-Saharan Africa and its deficiency may be due to either inherent low levels or P depletion in soils. This P therefore, could be added in form of inorganic fertilizer to replenish the lost soil P, but unfortunately it is expensive and not easily available to the resource poor farmers of Nigeria who constitute the majority of the farming communities. Widespread phosphorus (P) deficiency is exhibited in most Nigerian soils with consequent sharp decrease in yield of agricultural crops (Akinrinde *et al.,* 2005*).*

Therefore, alternative source of phosphorus fertilizer that will reduce the dependence on imported ones remains importance. Therefore the need to exploit indigenous phosphate rock deposit such as SPR will reduce the burden. Sokoto state is rich in PR deposit (Adediran *et al.,* 1998) and therefore could be used to complement the conventional P fertilizer, whose use by peasant farmers have been limited by high cost and scarcity. Phosphate rocks with high relative reactivity are best suited for direct application to acid soils with low Ca and P concentrations. Sokoto Phosphate Rock is one of the high to medium reactive PKs that do not need any further modification, apart from fine grinding. In addition, some plants are able to increase the solubilization of P from PR through excretion of organic acids from their roots or through high uptake of Ca^{2+}. These crops include several legumes and crops from *Cruciferae* family (Sanginga *et al*., 2000). Sokoto Phosphate Rock is known to be a good source of phosphorus due to its high P_2O_5 (33.9%) and citrate soluble (3.1%), therefore with proper management it could be a sustainable source of P for increased cowpea production on the Entisols of Sokoto semi-arid zone (Aliyu and Singh, 2008). Furthermore, cowpea is one of the common legume crop grown in Sokoto State for grain, fodder as well as cover crop. In view of the above, this study was conceived to determining the influence of SPR on soils, growth and yield performance of cowpea under semi-arid conditions of Sokoto State, Nigeria.

2. Materials and Methods

2.1 Site Description

The experiment was conducted in 2009 at the Botanical Garden, Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto. Sokoto State is located between Latitudes $11^o\ 30^1$N and $13^o\ 50^1$N and Longitudes $4^o\ 0^1$E and $6^o\ 0^1$E, 315m above sea level. Sokoto falls in the Sudan savanna agro-ecological zone of Nigeria (Ojanuga, 2005) that is characterized by erratic and scanty rainfall that last for about four months (Mid June-September) and dry period (October- May). The annual rainfall of the area is highly variable over the years and averaged around 700mm (Singh, 1995) with minimum and maximum temperatures of the year fluctuating between 15 and 40^{o}C, respectively (Arnborg,1988).

2.2 Screen House Procedure and Soil Analysis

The soil sample used for this experiment was collected from a fallow land within the Faculty of Agriculture Teaching and Research Lowland Farm, Usmanu Danfodiyo University, Sokoto, at 0-15cm depth. The soil was air dried, crushed and passed through a 2mm sieve. A sub-sample was analyzed for physico-chemical properties using the methods described by IITA (1989). Particle size distribution was determined using the Buoyoucos hydrometer method. Soil pH was determined using glass electrode pH meter. Cation exchange capacity was determined by the neutral ammonium acetate saturation (NH_4OAC) method (Chapman, 1965). Organic carbon was determined using Walkley and Black method. Exchangeable calcium and magnesium were determined using EDTA titration method, while exchangeable sodium and potassium were determined using flame photometer. Total N was determined using micro Kjeldahl digestion method, and available P was determined by Bray No.1 method.

Five (5kg) kilograms each of the sieved soil was placed in plastic container (7.5L) according to the number of the treatments. Soil samples were also collected from each pot at 8 weeks after planting (WAP) and analyzed for pH, residual nitrogen and phosphorus contents. Oven dried above ground biomass was analyzed for phosphorus and nitrogen contents at six weeks after planting using molybdophosphoric yellow color on spectrophotometer and micro-Kjedahl method, respectively

2.3 Experimental Set-up, Data Collection and Analysis

Treatments consisted of three levels of SPR; 25, 50 and 75kg ha^{-1} and a control (0kg ha^{-1}) and two varieties of cowpea Dan Gusau (V_1) and IT90K-82-2 (V_2). The treatments were combined and laid out in a completely randomized design (CRD) replicated three times making a total of 24 treatments. The three levels of SRP were mixed evenly with soil and a starter dose of 20 kg N ha^{-1} was applied before planting using urea (46%N). Sokoto phosphate rock contains 25.2%P, 0.23% K, 1.23% Na, 0.32% Mg, 14.25% Ca, 6.75% Fe 3.04% Si (Imogie *et al.,* 2011) and neutral ammonium citrate solubility of 3.1-3.9% P_2O_5 (McClellan and Notholt, 1986 and Adediran *et al*., 1998). The experimental pots were watered to saturation and allowed to attain field capacity before planting. Three seeds per pot were sown and later thinned to two stands per pot at 2WAP. Weeds were controlled manually by hand picking and the plants were irrigated when necessary.

Plant height, leaf number and number of branches per plant were recorded at two, four, six and eight weeks after planting (WAP). The crops were harvested at 8 WAP. The shoot and roots were thereafter oven dried at 60^{0}C and their weights determined. The data generated were subjected to analysis of variance (ANOVA) using SAS (2003) procedure for CRD. Significant difference in the treatments means were further analyzed using least significant difference (LSD) (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Soil Physical and Chemical Properties

The physico-chemical properties of the surface soil used for the experiment is presented in Table 1.The soil at the experimental site was Loamy sand in texture and slightly acid in reaction (pHH_2O 6.7). The organic carbon and available phosphorus in the soil were very low. Total nitrogen, cation exchange capacity, calcium and magnesium values were medium, while other parameters such as potassium and sodium were very high based on the standard ratings of Esu (1991) indicating that the soil was low in fertility prior to planting.

3.2 Effect of SPR and Variety on Soil and Plant Chemical Properties

Results in Table 2 indicate a significant decrease in the soil pH, compared with the initial soil before planting. This might be attributed to the effect of plant varieties used. This finding agrees with that of Kamh *et al*. (1999), that legume has acidifying effect on the soils near the rooting zone due to nitrogen fixation. There was a significant difference (P<0.05) on the effect of varieties on soil pH. This also could be due to the difference in their genetic make-up as reported by Tebebe *et al.* (1995) and Sanginga *et al*. (2000). These researchers reported that plant genotype influences the effect of phosphorus on nodulation and hence the amount of nitrogen fixed in the soil, this in-turn cause variation in their effect on soil pH where they are grown. SPR applied did not show significant influence on soil pH.

There was a significant difference in soil available phosphorus when compared with the control. The various levels of SPR used for the experiment probably explain the difference. Available phosphorus in the soil increased consistently with increased rate of SPR application with the highest value of 0.95 mg kg^{-1} when 75kgP ha^{-1} was applied. There was no significant effect of varieties on soil available P. The P content in plant tissues increased significantly with increase in SPR levels. Varietal response also showed some marked difference with IT90K-82-2 (0.4 mg kg^{-1}) having numerically higher P content than Dan Gusau (0.33 mg kg^{-1}). Hocking *et al.* (2000) observed that, plant species differ in their ability to access sparingly forms of phosphorus that are unavailable to other plants. Helyer (1998) and Baligar e*t al*. (2001) noted that, plant varieties differ in phosphorus uptake demands and pattern as well as their ability to absorb soil solution phosphorus. Significant responses were observed for total nitrogen content in both soil and plant tissues, but the total nitrogen content in the soil was not significant between the plant varieties.

Table 3 shows the interaction between variety and applied SPR levels which indicates that there was no significant difference (P<0.05) in the values of soil pH, total N and plant tissue P although absolute values in these parameters vary substantially. There was significant difference in the values of available P and total N in plant tissue with the interaction of SPR and varieties. IT90K-82-2 and SPR rate of 75kg ha^{-1} used in the study recorded the highest results (Table 3). Aliyu and Singh (2008) reported similar response with SPR applied at 75kg ha^{-1} on pod yield $plant^{-1}$. Significant interaction was also observed between SPR levels and V_2 (IT90K-82-2) than with V_1 (Dan Gusau) in the values of total N in plant tissue.

3.3 Effect of SPR and Variety on Growth and Yield Components

Significant influence (P<0.05) of Sokoto phosphate rock on the plant height was observed (Table 4). This was more apparent as the plant aged. At 2WAP, SPR rate of 75kg ha^{-1} was statistically similar to the control, but differed significantly at 4, 6 and 8WAP. This is similar with the findings of Singh *et al*. (2009) and Owolade *et al*. (2006). Singh *et al*. (2009) recorded 25cm and 35cm at 8 and 12 WAP as P rates increased from 9 to 45 kg ha^{-1}. Aliyu and Singh (2008) also obtained a good response to SPR application at 75kg ha^{-1} on number of pods plant-[1]. This implies that, higher responses to SPR could be obtained by adding more SPR to phosphorus deficient soils. This is in line with the reports of Perrott *et al.* (1993), Rajan *et al.* (1996) and FAO (2004). The two varieties showed significant difference in their responses to the applied SPR in all the observations for plant height, where IT90K-82-2 was higher at all stages of growth compared to Dan Gusau. The interaction between variety and applied SPR on the plant height was significant at 2, 4, 6 and 8 WAP.

The influence of SPR levels on the number of branches was observed to be significant at 4 and 8WAP, compared to the control. Application of SPR rate increased the number of branches from 1.5 to 1.83 and 5.67 to 6.67 at 4 and 8 WAP respectively (Table 4). This is in agreement with the findings of Singh *et al*. (2009) who recorded between 9.9 and 13.3 branches as P rates increased from 9 to 45 kg ha^{-1}. There was no significant response in varietal differences with respect to number of branches. The interaction effect of variety and applied SPR on number of branches at 4, 6 and 8 WAP was statistically not significant.

The effects of SPR and variety on dry matter yield indicates that there was a significant response to applied SPR on shoot dry matter yield, where SPR at 75kg ha^{-1} showed marked influence on shoot weight with a value of 13.83g $plant^{-1}$ (Table 4). Local variety (Dan Gusau) showed significant response to applied SRP on shoot weight. This could be due to the fact that Dan Gusau is a variety native to the area and therefore has better adaptive features than IT90K-82-2 which is an improved variety introduced to the area. Local variety (Dan Gusau) differed significantly (p<0.05) in terms of shoot weight than the improved variety (IT90K-82-2). Addition of SPR did not significantly influence the formation of root system as the control gave a better value of 0.68, compared to 0.35g in the application of 75kg ha^{-1}. There was a decrease in the root dry weight with increased application of SPR, though the pattern was not consistent.

Conclusion

From the results of this study, it was observed that increase in the rate of application of Sokoto phosphate rock progressively increased the growth and yield performance of the cowpea varieties especially at 6WAP and 8WAP. Although, the absolute values were not very high relative to control which might be attributed to the nearly neutral reaction status of the soil (pH 6.7) used in this study. Improved variety (IT90K-82-2) performed better than the local variety (Dan Gusau) which was more obvious with increase in the application of SPR. Available phosphorus in the soil increased consistently with increase rate of SPR application and had the highest value of 0.95 mg kg^{-1}. Although the present phosphorus level is still low, residual benefits of SPR could be obtained when managed properly. It is therefore recommended that SPR should be applied on soils with pH less than 6.5 at a rate of 75kg ha^{-1} for cowpea production in Semi-arid zone of Nigeria.

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Table 1. Physico-chemical properties of the soil before planting

Parameter	Content
Sand (%)	78.00
Silt (%)	14.60
Clay (%)	7.40
Texture	Loamy sand
pH 1:1 (H_2O)	6.7
Organic carbon (g kg^{-1})	5.3
Total nitrogen (g kg^{-1})	0.4
Available phosphorus (mg kg^{-1})	0.30
CEC ($cmol_c$ kg^{-1})	8.20
Exchangeable K ($cmol_c$ kg^{-1})	1.59
Exchangeable Na ($cmol_c$ kg^{-1})	1.46
Exchangeable Ca ($cmol_c$ kg^{-1})	2.40
Exchangeable Mg ($cmol_c$ kg^{-1})	0.40

Table 2. Effect of variety and applied Sokoto phosphate rock on some chemical properties of soil and plant at 8WAP.

SPR levels	pH	Avail. Ps	Avail. Pp	Total Np	Total Np
		mg kg^{-1}		%	
0	5.9	0.12^d	0.17^d	0.165^b	0.117^b
25	5.75	0.56^c	0.24^c	0.195^a	0.09^c
50	5.82	0.85^b	0.47^b	0.135^c	0.09^c
75	5.37	0.95^a	0.57^a	0.193^a	0.155^a
SE±	0.08	0.0077	0.0082	0.005	0.0086
Sig.	ns	**	**	*	*
Variety					
Dan Gusau (V_1)	5.78	0.62	0.33^b	0.150^b	0.122
IT90K-82-2 (V_2)	5.58	0.62	0.40^a	0.197^a	0.110
SE±	0.113	0.011	0.012	0.007	0.012
Sig.	*	ns	*	*	ns

Means followed by same letter(s) in column are not significantly different ($P < 0.05$), ns= not significant, *significant at 5% level and ** significant at 1% level. P_s= soil phosphorus, P_p= plant phosphorus, N_p= plant nitrogen and N_s= soil nitrogen.

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Table 3. Interaction of SPR and Cowpea variety on pH, N, and P contents of soil and plant at 8 weeks after planting

Treatment	pH	Avail. Ps	Avail. Pp	Total Ns	Total Np
SPR x Variety		mg kg^{-1}		%	
V_1 X PR_0	5.90	0.14^f	0.15	0.120	0.11^e
V_1 X PR_{25}	5.90	0.60^e	0.22	0.103	0.18^c
V_1 X PR_{50}	6.00	0.82^c	0.42	0.083	0.12^e
V_1 X PR_{75}	5.53	0.90^b	0.53	0.180	0.19^b
V_2 X PR_0	5.70	0.10^f	0.18	0.113	0.22^a
V_2 X PR_{25}	5.60	0.52^e	0.26	0.080	0.21^{ab}
V_2 X PR_{50}	5.63	0.88^b	0.52	0.097	0.15^d
V_2 X PR_{75}	5.40	1.03^a	0.62	0.130	0.21^{ab}
SE$\pm$	0.16	0.015	0.016	0.017	0.009
Sig.	ns	*	ns	ns	*

Means followed by same letter(s) in column are not significantly different (P > 0.05), ns= not significant, *significant at 5% level and ** significant at 1% level. P_s= soil phosphorus, P_p= plant phosphorus, N_p= plant nitrogen and N_s= soil nitrogen

Table 4. Some growth parameters as influenced by SPR and Variety

Treatment	Plant height (cm)				Number of branches			Dry matter weight (g $plant^{-1}$)	
SPR level (kg ha^{-1})	2 WAP	4 WAP	6WAP	8WAP	4 WAP	6WAP	8WAP	Shoot weight	Root weight
0	8.65^a	10.10^b	11.10^c	11.55^c	1.5^b	3.50	5.67^b	8.38^b	0.68^a
25	8.25^a	10.03^b	11.85^b	12.25^b	1.5^b	3.17	4.67^b	11.63^b	0.4^b
50	5.18^b	9.17^b	10.93^d	10.60^d	0.5^c	3.17	3.17^c	13.00^a	0.25^c
75	8.38^a	11.85^a	13.03^a	13.37^a	1.83^a	2.50	6.67^a	13.83^a	0.35^b
SE$\pm$	0.55	0.38	0.21	0.21	0.08	0.25	0.62	0.41	0.05
Sig.	*	*	**	**	**	ns	*	**	**
Variety									
Dan Gusau (V_1)	6.63^b	9.17^b	10.07^b	10.41^b	1.42	2.83	4.58	13.42^a	0.36^b
IT90K-82-2 (V_2)	8.61^a	11.41^a	12.92^a	13.48^a	1.25	3.33	5.50	10.01^b	0.50^a
SE$\pm$	0.39	0.27	0.15	0.15	0.06	0.18	0.44	0.29	0.03
Sig.	*	**	**	**	ns	ns	ns	**	*

Mean followed by same letter(s) in column are not significantly different (P >0.05), ns= Not significant, *significant at 5% level. **significant at 1% level.