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RESPONSE OF TWO COWPEA VARIETIES TO SOKOTO ROCK PHOSPHATE IN NORTH-WESTERN NIGERIA.

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ABSTRACT

A pot experiment was conducted during the 2009 / 2010 dry season at the Teaching and Research Botanical Garden, Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto, to study the response of two cowpea varieties (Danzafi and IT89KD-288) to Sokoto rock phosphate (SRP). Four rates (0, 25, 50 and 75 kg ha^{-1}) of SRP were used, making eight treatment combinations which were laid out in a completely randomized design (CRD) repeated three times. The parameters measured included plant height, number of leaves, number of branches, shoot and root dry matter yields, plant tissue and residual nitrogen and phosphorus concentrations. The results showed significant ($P < 0.01$) differences among the rates of SRP and between the cowpea varieties with respect to plant height, number of leaves, number of branches, shoot and root dry matter yields and N and P concentrations in the plant tissues. Most of the parameters measured progressively increased significantly with increased SRP application and the 75 kg ha^{-1} rate of application, led to the best performance of the cowpea varieties. Danzafi had higher shoot and root dry matter yield and plant tissue N and P concentrations, while ITA89KD-288 was taller, had higher number of leaves and shoot-root ratio. These are important indications of the optimal rate of application of SRP in the environment and an advantage of IT89KD - 288 over Danzafi. However, the experiment needs to be conducted under field conditions for validation purpose.

Keywords: Sokoto rock phosphate; Cowpea growth and yield.

INTRODUCTION

The generally poor food situation in Africa is related to low soil fertility, especially low N and P levels. Soil fertility appears to be more limiting to crop and fodder production than rainfall and the use of fertilizer also increases water use efficiency (Breman and de Wit, 1983). Total and available P levels are both very low hence; P deficiency is the most limiting soil fertility factor for cowpea production. Apart from low P stocks, the low activity nature of these soils results in a relatively high capacity to fix even applied P (Batiano *et al.*, 1995).

The use of commercial P fertilizers is limited due to high cost of importion, despite the high need for phosphorus application. Ground rock phosphate itself has been used as a source of P, especially in acid soils. Though, this has been curtailed by low availability of P in this native material, high transportation costs and low crop responses, very little indigenous rock phosphate (RP) is currently used for direct application in agricultural soils. However, this could be an alternative to the use of more expensive water-soluble P fertilizers (Bationo *et al.,* 1995), since apatite found in RP deposits is the primary source of P in the fertilizers, another quality that makes it a good alternative or complement to commercial soluble phosphates (Bollard and Gilkes, 1990). Moreover, the response of crops to rock phosphate depends not only on its solubility, but also on the type of soil and its solubulization by micro-organisms that mediate the process (Lalljee, 1998). Nearly all strains of rhizobium and Bradyrhizobium already existing in soils assist in solubilizing RP (Halder *et al.,* 1990).

Legumes such as cowpea have high P requirement, which is reported to stimulate root growth, initiate nodule formation, and the efficiency of the rhizobium legume symbiosis and is involved in energy transfer reactions (Israel, 1987). Phosphorus is also necessary for seed germination, photosynthesis, protein formation, essential for flower and fruit formation and almost all aspects of growth and metabolism in plants (Morgan, 1998).

Cowpea (*Vigna unguiculata* (L.). Walp) has been considered as one of the most important grain legume crops in the semi-arid zone of West Africa, as it is an important food, fodder and cover crop in the region. Phosphorus fertilizer remains the primary limitation to cowpea production in the tropics despite its economic importance (Sanchez *et al.,* 1997). This calls for the introduction of improved cowpea varieties, known to be vigorous and high yielding, usually cultivated along with local cultivars. This study was initiated to determine the response of two cowpea varieties to Sokoto rock phosphate, the optimum rate of application and compare a local cultivar (*Danzafi*) and an exotic variety (IT89KD-288).

MATERIALS AND METHODS

Study Area

The experiment was conducted in a screen house at the Teaching and Research Botanical Garden, Department of Biological Sciences of Usmanu Danfodiyo University, Sokoto during the 2009 / 2010 dry season. Sokoto is located in the North-western part of Nigeria between latitudes $11^o 30'$ - $13^o 50'$ N and longitudes $4\ ^o\ 0'$ - $6\ ^o\ 0'$ E (Kowal and Knabe, 2002), 308 m above sea level and lies within the Sudan savanna belt (Reuben, 1981). The annual rainfall varies from 880 mm to 889 mm decreasing northwards. Ambient temperature ranges from 14^oC during the harmattan period to 38^oC during the hot season, with 15 - 20% relative humidity during the dry season and up to 70 - 75% during rainy season (Arnborg, 1988).

Soil Sample Collection, Preparation and Analyses

The soil used for the experiment was collected from a long time fallow plot within the Vegetable Research Farm behind the Convocation Ground in Usmanu Danfodiyo University, Sokoto, at a depth of 0 - 15 cm. The soil sample was air-dried, crushed and sieved through 2 mm sieve, and a sub-sample was taken for charactrization. The following physical and chemical properties were determined; the pH using a pH meter in 1:1 soil: water ratio (Bates, 1954), organic carbon by dichromate oxidation method (Nelson and Summers, 1982), total N by micro-kjeldahl method (Jackson, 1962), available P by Bray No. 1 method (Bray and Kurtz, 1945), CEC by ammonium acetate saturation method (Chapman, 1965). The exchangeable bases were determined by extraction with 1 N ammonium acetate at pH 7 (Kundsen *et al*., 1982), K and Na were analysed by flame photometry while Mg and Ca were determined using EDTA method. Particle size analysis was carried out using Bouyoucos hydrometer method (Gee and Bauder, 1986). The data obtained were fitted into textural triangle to arrive at the textural class.

Treatments and Experimental Design

The treatments consisted of four levels (0, 25, 50 and 75 kg ha^{-1}) of Sokoto rock phosphate (SRP) and two varieties of cowpea: (ITA89KD-288, a hybrid variety obtained from Institute for Agricultural Research, Ahmadu Bello University, Zaria and *Danzafi,* a cultivar locally grown in Dundaye village in Sokoto State). These were factorially combined to give eight treatment combinations laid out in a completely randomized design (CRD) repeated three times making a total of 24 treatment combinations.

Screenhouse Proceedures and Measurements

Five kilogrammes of the sieved soil was weighed into each of 24 plastic experimental pots. The pots had earlier been perforated at the bottom to allow for adequate drainage. The covers were put underneath the pots to collect back nutrients that may be drained out of the pots. The soils in the pots were wetted to saturation and then left to drain to field capacity (FC). Three seeds were sown in each pot. Two weeks after sowing (WAS) the seedlings were thinned to two plants per pot. The parameters taken biweekly included; plant height, number of leaves, and number of branches. Shoot dry matter, root dry yield and residual N and P concentrations were determined at the end of the experiment (8 WAS). Plant tissue N and P concentrations were determined from samples collected at 6 WAS. The shoot-root ratio was calculated as shoot dry matter yield divided by root dry matter yield for each treatment.

Plant Analyses

The plant samples were washed, rinsed with distilled water, put in envelopes and oven dried at 65^{o}C for 48 hours. The oven-dried samples were weighed and ground with mortar and pestle. The ground samples were digested in a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids on a hot plate (Juo, 1979). Phosphorus from the digest was determined using spectrometer, while total N was determined using the micro - kjeldahl method.

Statistical Analysis

The data collected from the experiment were subjected to analysis of variance (ANOVA) procedure to test for significance. Where the F values were significant, the treatment means were separated using Duncan’s Multiple Range Test (DMRT). The analysis was done using SAS (1998).

RESULTS AND DISCUSSION

Properties of the Experimental Soil

Values of the soil physico-chemical properties prior to cropping (Table 1) indicated that the soil falls within low to medium fertility class and sandy loam in texture. The soil reaction was slightly acid (6.7). The organic C, total N, available P and CEC were 5.31, 0.35 g kg^{-1}, 0.27 mg kg^{-1} and 3.82 cmolc kg^{-1}, respectively, with medium level of exchangeable bases. These could be due to low level of organic matter and the low activity clays (1:1 clay minerals) associated with the soils, as observed by Bationo *et al.* (1995) that these factors among others, lead to low levels of the chemical properties observed in the soils. The low level of organic matter could also be attributed to bush burning and removal of crop residues as earlier indicated by Ahmad (1995). The low level of available phosphorus in the soil is probably worsened by its fixation in the soils due to the relatively high levels of calcium, which may have facilitated the observed response of the crops upon P application.

Table 1. Some characteristics of the soil used for the experiment

Parameter	Amount
pH 1:1(H_2O)	6.70
Organic C (g kg^{-1})	5.31
Tatal N (g kg^{-1})	0.35
Available P (mg kg^{-1})	0.27
CEC ($cmol_c$ kg^{-1})	3.82
Exchangeable Ca ($cmol_c$ kg^{-1})	1.35
Exchangeable Mg ($cmol_c$ kg^{-1})	0.80
Exchangeable K ($cmol_c$ kg^{-1})	0.89
Exchangeable Na ($cmol_c$ kg^{-1})	0.12
Sand (g kg^{-1})	780
Silt (g kg^{-1})	150
Clay (g kg^{-1})	70
Textural Class	Sandy loam

Growth and Yield Components

The varying levels of rock phosphate application had significant ($P < 0.01$) effect on the plant height, number of leaves and number of branches of the cowpea varieties across the treatments and the crops were taller with higher number of leaves and branches compared to the control (Table 2). The parameters, except plant height at 2WAS, progressively increased with increased SRP application to the highest rate (75 kg ha^{-1}) which had a mean of 17.38 cm plant height, 23.58 leaves and 12.58 branches at 8WAS, while the control had 13.38 cm height, 12.50 leaves and 7.00 branches at a similar period of the experiment. There was no significant response at 2WAS, most likely owing to lack of proper establishment of treatment effect.

The shoot and root dry matter weights of the cowpea varieties also followed similar trends. However, the effect of the control and 25 kg ha^{-1} rate of application were statistically similar, so also were the 50 and 75 kg ha^{-1} rates of application on the shoot dry matter weight (Table 3). The significant effect of the rock phosphate on the yield and yield components do not tally with the findings of Bollard and Gilkes (1990), who showed rock phosphate response of crops to be low, which Lalljee (2009) linked it to slow dissolution of rock phosphate.

Table 2. Some growth parameters of two cowpea varieties as influeced by rock phosphate application at Botanical Teaching and Research Garden, Usmanu Danfodiyo University, Sokoto, during the 2009/2010 dry season

Treatment	Plant height (cm)				Leaf number per plant			
	2	4	6	8	2	4	6	8
Variety								
Danzafi	11.29	11.96b	12.93b	15.35	5.21	6.33a	5.33b	17.17b
IT89KD-288	11.08	13.23a	13.35a	15.82	5.13	5.54b	7.17a	21.58a
SE	0.15	0.94	0.74	0.22	0.26	0.16	0.16	0.53
Significance	NS	**	**	NS	NS	**	**	**
RP level (kg ha^{-1})								
0	10.32c	11.43c	12.17c	13.38c	3.83c	4.25d	4.00d	12.50c
25	10.98b	12.52b	12.97b	15.42b	5.00b	5.50c	5.67c	20.50b
50	11.42ab	13.17a	13.56a	16.18b	5.58ab	6.33b	6.67b	21.25b
75	12.03a	13.25a	13.87a	17.38a	6.25a	7.67a	8.67a	23.58a
SE	0.22	0.13	0.10	0.32	0.37	0.23	0.22	0.75
Significance	**	**	**	**	**	**	**	**
CV	4.78	2.60	1.96	4.98	17.67	9.42	8.64	9.48
V x RP	NS	NS	NS	*	NS	NS	*	NS

	Number of branches per plant		
	4	6	8
Variety			
Danzafi	3.08a	3.58a	10.46
IT89KD-288	2.67b	3.00b	9.75
SE	0.13	0.10	0.33
Significance	*	**	NS
RP level (kg ha^{-1})			
0	1.67c	2.00c	7.00d
25	2.17c	2.17c	9.67c
50	3.17b	3.67b	11.17b
75	4.50a	5.23a	12.58a
SE	0.19	0.14	0.46
Significance	**	**	**
CV	15.88	10.74	11.20
V x RP	NS	*	NS

Means within a column and treatment followed by same letters are not significantly different ($P<0.05$), **: Significant ($P<0.01$), NS: not significant ($P>0.05$). WAS: weeks after sowing

Possible explanation for the findings in the present study is the controlled environment (Screen house) under which the experiment was conducted. Also, the grinding of the rock phosphate to powder could have increased the surface area for reaction and the rate of release for phosphorus from the rock phosphate, causing a more prominent effect (Ezeinma *et al.*, 1980). This increases the level of dissolution and enables rock phosphate to be used as a subtitute of soluble phosphorus fertilizers like single super phosphate (Bationo *et al.*, 2009; Sokoto and Singh, 2008). Sokoto rock phosphate is known to be a good source of phosphorus due to its high P_2O_5 (33.9%) and citrate soluble P (3.1%) (Sokoto and Singh, 2008). Significant responses of cowpea to phosphorus application had been reported by several workers (Israel, 1987; Okeleye and Okelena, 1997; Krasilnikoff *et al.*, 2003). Similar effects were reported with the application of rock phosphate to cowpea varieties by Sokoto and Singh (2008) and Lalljee (2009). The interaction between the cowpea variety and the rock phosphate application rate was not significant for plant height, number of leaves and branches, except at 8, 6 and 6 WAS for plant height, numbers of leaves and branches, respectively (Table 2).

The root and shoot dry matter yields, N and P concentrations in plant tissues were also significantly ($P < 0.01$) influenced by the application of the rock phosphate (Table 3). Phosphorus concentration was lowest in the control and progressively increased with increased rock phosphate application rate. This indicates the relationship between the increased rate of P released to the plants rhizosphere from the increasing rate of rock phosphate application and P uptake by the plants. A similar trend was observed with the root dry matter weight, indicating the influence of phosphorus uptake by plants' root growth. This has a special positive implication particularly in leguminous plants, known in nodule formation and enhancing nitrogen fixation. The N concentrations in the plant tissues were similar for the control and the 25 kg ha^{-1} and for the 50 kg ha^{-1} and the 75 kg ha^{-1} SRP application rates.

Table 3. Shoot and root dry matter yield, plant N, P and residual N and P concentrations.

Treatment	Shoot DMW (g)	Root DMW (g)	Plant N conc. (g kg^{-1})	Residual N conc. (g kg^{-1})	Plant P conc. (mg kg^{-1})	Residua P conc (mg kg^{-1})
Variety						
Danzafi	5.49a	0.32	20.23a	0.38	0.54b	0.58a
IT89KD-28	5.21b	0.28	16.08b	0.39	5.46a	0.47b
SE	0.04	0.02	0.90	0.01	0.01	0.02
Significance	**	NS	*	NS	**	**
RP levels (kg ha^1)						
0	5.19b	0.15d	11.85b	0.23d	0.41d	0.35c
25	5.23b	0.25c	12.28b	0.38c	0.47c	0.52b
50	5.48a	0.35b	22.77a	0.41b	0.54b	0.62a
75	5.52a	0.45a	25.72a	0.51a	0.59a	0.62a
SE	0.06	0.02	1.27	0.01	0.01	0.02
Significance	**	**	**	**	**	**
CV	2.59	19.25	17.19	6.64	0.59	10.92

V x RP	NS	NS	NS	*	*	NS

Means within a column and treatment followed by same letter are not significantly different ($P < 0.05$), **: Significant ($P<0.01$), NS: not significant ($P>0.05$).

The same trend was portrayed by the shoot dry matter weight, indicating a strong relationship between tissue N assimilation and the development of shoot dry matter in the plant. This is possibly due to N_2 fixation by the plants, known to be influenced by phosphorus uptake (Bottomley, 1991). The interaction between the cowpea variety and the rock phosphate rate of application was not significant except for the residual N and plant tissue P concentration (Table 3).

Response of the Cowpea Varieties

Results showed significant ($P < 0.01$) differences betweeen the two cowpea varieties and SRP application rates with respect to plant height at 4 and 6 WAS, number of leaves at 4 - 8WAS and number of branches at all sampling periods (Table 2). ITA89KD - 288 was taller, had higher number of leaves and shoot - root ratio of 18.6 as against 17.1 of the *Danzafi*. A decrease in shoot - root ratio is one of the most commonly observed effects of nutrient deficiencies on plant development (Chapin, 1980), indicating an advantage of the improved variety. However, *Danzafi* proved superior in shoot and root dry matter yields and plant tissue N and P concentrations, probably due to its long time adaptation to the environment. The existence of genetic variability in tolerance to environmental stress factors in leguminous plants had been shown in a review by Serraj and Adu-Gyamfi (2004). The higher root development of *Danzafi* given the same treatment with IT89KD - 288 may be attributed to its possible acess to more immobile nutrients and higher symbiotic association with *Rhizobia*, which could have had significant influence on its nutrient uptake efficiency as reported by Gahoonia and Nelson (1997).

CONCLUSION

The two cowpea varieties responded to sokoto rock phosphate (SRP) with regard to plant height, number of leaves, number of branches, shoot and root dry matter yields, plant tissue and residual N and P concentrations. Plants treated with different levels of SRP had higher growth parameters than those in the control. There was a progressive increase in the response of most parameters measured with increased SRP rates of application, and 75 kg SRP ha^{-1} stimulated the highest response. There was also a significant difference between the varieties in the parameters measured. *Danzafi* had higher shoot and root dry matter yields and plant tissue N and P concentrations, ascribed to an advantage of its adaptation to the environment, while IT89KD-288 was taller, had higher number of leaves and shoot - root ratio, which could be due to its improved hybrid nature. These are important indications of the optimal rate of application of SRP in the environment and an advantage of IT89KD - 288 over *Danzafi*. However, the experiment needs to be conducted under field conditions for more reliable conclusions.

REFERENCES

Ahmad, K (1995). Some constraints to crop production and rehabilitation in North-western Kano State. *Journal of Social and Management Studies*, 1:1-14.

Arnborg, T. (1988). *Where Savannah turns into Desert. Experience from the Sudan zone in Sokoto State, Nigeria.* Rural Development Studies, Swedish University of Agricultural Science, Uppsala.

Bates, R. C. (1954). *Electrometric pH Determination.* John Wiley and Sons Inc. New York.

Batiano, A., A. Buerkert, M. P. Sedogo, B. C. Christianson and A. U. Mokwunye (1995). A critical review of crop residue use as soil amendment in the West African Semi-arid Tropics. *In*: T.M., Fernandez S., Rivera T.O., Williams O. and C. Reynard (Eds.). *Livestock and Sustainable Nutrient Cycling in Mixed Farming System of Sub-Saharan Africa*. Proceedings of International Conference, ILCA, Addis Ababa, Ethiopia, 1994. pp. 305 - 322.

Bationo, A., B. R. Ntare, S. A. Tarawali and R. Tabo (2009). Soil fertility management and cowpea production in the semi arid tropics. http://www. iita. org/ details /cowpea_ pdf/cowpea_4.pdf (Accessed:18/3/2010).

Bollard, M. and R. J. Gilkes (1990). The poor performance of rock phosphate fertilizers in Western Australia. Part 1. The crop and pasture response. *Agricultural Science,* 3 (1): 43 - 48.

Bottomley, P. (1991). Ecology of Rhizobium and Bradyrhizobium. *In*: G. Stacccy, R. H. Burris and H. J. Evans (Eds.) *Biological Nitrogen Fixation*. Chapman and Hall, Newyork, N. Y.

Bray, R. H and L. T. Kurtz (1945). Determination of total, organic and available forms of phosphorus in soil. *Soil Science*, 59:39 – 45.

Breman, H. and C. T. De Wit (1983). Rangeland productivity and exploitation in the Sahel. *Science*, 221:1341-1347.

Chapin, F. S. I. (1980). The mineral nutrition of wild plants. *Annu. Rev. Ecol. Syst.* 11:233-260.

Chapman, H. D. (1965). Cation Exchange Capacity. In: Page, A. L., R. A. Miller and D. R. Keeney (Eds.). Methods of Soil Analysis, Part II, *Agronomy.* Madison, Wisconsin pp. 891-901.

Ezeinma, K. C., P. Brayor, S. J. and A. S. Ulysses (1980). *Fertilizers and Soil Fertility*. Reston Publications. Camp Virginia. 356 p.

Gahoonia, T. S. and N. E. Nelson (1997). Variation in root hairs of barley cultivars doubled soil phosphorus uptake. *Euphytica*, 98: 177-182

Gee, G. W. and J. W. Bauder (1986). Particle size analysis. *In*: Aklate (Ed.) *Methods of Soil Analysis*. 2nd ed. No. 9 ASA. Inc. SSSA Madison, Washington D.C. pp. 383- 409.

Halder, A. K., A. K. Mishra, P. Battacharya and P. K. Chakraborthy (1990). Solubilization of rock phosphate by rhizobium and bradyrhizobium. *J. General and Applied Microbiology*, 36 (1):81-92.

Israel, D. N. (1987). Investigation of the role of P in symbiotic nitrogen fixation. *Plant physiology*. 54:835 - 840.

Jackson, M. L. (1962). Soil Chemical Analysis. IITA. Manual Series No.1, 70p

Juo, A. S. R. and B. T. Kang (1989). Nutrients effect of modification of shifting cultivation in West Africa. In: Proctor, J. (Ed.). *Mineral Nutrients in Tropical Forest and Savanna Ecosystems.* Blackwell Scientific Publishers pp 289 - 300.

Kowal, J. M. and D. T. Knabe (2002). *An Agroclimatological Atlas of the Northern States of Nigeria*. ABU press, ABU, Zaria, 128 p.

Krasilnikoff, G., T. Gahoonia and E. N. Nielson (2003). Variation in P uptake efficiency by genotypes of cowpea (*Vigna unguiculata L.*) due to differences in root and root hair length and induced rhizosphere process. *Plant and Soil*, 251:83-91.

Kundsen, D., G. A. Peterson and P. F. Prett (1982). Lithium, Sodium, Potassium. In: A. L. Page, R. A. Miller, D. R. Keeney (eds). *Methods of analysis*. Part II. *Amer. Soc. Agron. Inc.* Madison Wisconsin, pp. 225-246.

Lalljee, B. (1998). Phosphorous fixation as influenced by soil characteristics of some Mauritius soils. In Lalouette I. A. *et al.* (eds.) *Proceedings of the 2nd Annual Meeting of Agricultural Scientist*. August, 1977, Mauritius. pp. 115-121.

Lalljee, B. (2009). Rock phosphate as an alternative to soluble phosphatic fertilizers in acid soils: The effect of pH on the dissolution of rock phosphate. University of Mauritius. *www.gov.mu/portal/sites/s15.htm* (Accessed:30/4/2009).

Morgan, D. (1998). What is plant nutrition?. The role of essential and beneficial mineral nutrients that are crucial for growth. *http://retirees. uwaterloo.ca/ jerry/ orchirds /nutri. html. (Accessed: 9/1/2000).*

Nelson, D. W. and L. E. Sommers (1982). Total carbon, organic carbon and organic matter.. In: A. L. Page, R. A.Miller, D. R. Keeney (eds.) *Methods of Soil Analyses.* Part II 2nd Ed. Manager 9 ASA and SSSA Madison, Wisconsin. pp 530 - 577.

Okeleye, K. A. and M. A. O. Okelena (1997). Effects of P-fertilizers on nodulation, growth and yield of cowpea (*Vigna unguiculata)* varieties. *Indian Journal of Agric Sci.,* **67** (1): 10-12.

Reuben, K.U. (1981). *Geographical Regions of Nigeria.* Heinemann, London.

Sanchez, P. A., M. J. Soule, F. M., Place, R. J. Buresh, A. N. Izac, A. U. Mokwunye, F. R. Kwesiaga, C. G. Ndintu and P. L. Woome (1997). Soil Fertility Replenishment in Africa: An investment in natural resources capital. In: R.J. Burest, P.A. Sanchez and F. G. Caltoun (Eds.) *Replenishing Soil Fertility in Africa*. ASA, SSSA, Madison, WI. pp. 1- 46.

SAS (1998). The GLM Procedure in SAS/STAT users Guide, Release 6.12 ed. SAS Wist.Cary, N.C.

Serraj, R. and J. Adu-Gyamfi. (2004). Role of symbiotic nitrogen fixation in the improvement of legume productivity under stressed environments. *West African J. of Applied Ecology,* 6:95-109.

Sokoto, A. L. and A. Singh (2008). Yield and yield components of cowpea (*Vigna unguiculata L.*) Walp.) as influenced by Sokoto rock phosphate and placement methods in the semi-arid zone of Nigeria. *Nutr. Cycl. Agroecocyst.,* 81:255-265.