Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 4 (5): 513-518, 2005
ISSN 1682-3974

Evaluation of Ground Phosphate Rocks for Growth and Yield of Maize (*Zea mays*) and Soybean (*Glycine max*) on a Tropical Alfisol in Nigeria

Ezekiel Akinkunmi Akinrinde, Emmanuel Teboh and Gabriel Olufemi Obigbesan
Department of Agronomy, University of Ibadan, Ibadan, Nigeria

Abstract: Experiments were conducted to study the best time of application and the effects of four phosphorus (P) fertilizer sources on crop production. The soil was a slightly acidic (pH 6.7), loamy sand alfisol (Haplic Luvisol/Arenic Haplustalf). The Application Times (AT) were one week before planting (1 WBP), at planting (AP), one week after planting (1 WAP) and 2 WAP. The phosphorus sources, PS [Ogun Rock Phosphate (ORP), 31.4% P_2O_5; Crystallizer (Cryst), 20.2% P_2O_5; Sokoto rock phosphate (SRP), 34.2% P_2O_5 and Single Super Phosphate (SSP), 18% P_2O_5] were applied at a rate of 50 kg ha^{-1} apart from the control. The resulting 20 treatment combinations (AT * PS = 4 * 5) were replicated three times in a split-plot with randomized complete block design. Maize (*Zea mays*) was grown in the first experiment while soybean (*Glycine max*) was the test crop in the second and third experiments. No fertilizer was applied in the last experiment. In the first experiment, crop yields were highest when ORP, Cryst and SSP were applied 1 WAP while it was best at 2 WAP with the application of SRP. For the second experiment, crop yields were highest for Cryst and ORP applied 1 WBP and 1 WAP for SRP and SSP. Considering the effectiveness of the rock phosphate, ORP performed best in both the first and second experiments apart from SSP in the first experiment. The decreasing order of crop yield in the third experiment was Cryst >ORP> SRP and SSP even though there was no significant difference (p = 0.05). Since significant differences could not be established for the P sources, times of application or for the residual effect, any of the RP could be used as P source and also for residual effect. Similarly, any of the times of P application was suitable for both crops.

Key words: Main and residual effects, fertilizer application times, loamy sand alfisol, haplic luvisol/arenic haplustalf

INTRODUCTION

Phosphorus (P) is crucial for optimum growth and yield of leguminous crops and cereals. Its deficiency in tropical soils is considered one of the main constraints to food production in large areas of farmland of sub humid and semi arid Africa[1,2]. According to Adediran and Sobulo[3], P-fertilization is a vital factor in agricultural development in Africa.

The use of inorganic P sources has been limited by its acquisition and distribution to farmers as a result of high cost and poor distribution network[4]; hence the need to look for alternative or supplementary and cheaper sources. The direct use of sparingly soluble, ground Rock Phosphate (RP) as an alternative to the imported and expensive more soluble P fertilizers has been reported[5]. RP are known to be less effective than the super phosphates due to their limited solubility[6]. They provide a gradual release of plant available P and a residual effect for several years[7].

Throughout the world, wheat, rice and maize are produced in greater quantities than any other crop. Of these crops, maize has the highest average yield of 3.7 t ha^{-1}[8]. Maize is used for human consumption, animal feed and for industrial purpose[9]. Soybean is significant as a world crop due to its high protein content and high quality oil. It is a food crop of great potential in the improvement of diet of millions of people in developing countries[10].

Information on the Right Time of RP application and the best RP source for maize and soybean production are not substantial. Besides, not much research has been done on the residual effect of RP in soybean production. As such, the present study sought to determine the best time of RP application, the best RP source in maize and soybean production and evaluate the residual effect of RP on soybean production.

MATERIALS AND METHODS

Three field experiments were carried out at the Rockefeller experimental plot of the Teaching and Research Farm, University of Ibadan, Nigeria, with an Ibadan soil series[11] classified as a haplic luvisol/arenic

Corresponding Author: Ezekiel A. Akinrinde, Department of Agronomy, University of Ibadan, Ibadan, Nigeria
Tel: 00234-2-8033937476

haplustalf by the FAO/UNESCO classification[12]. The soil textural class was loamy sand and Ibadan lies in the northern limit of the lowland forest zone of western Nigeria on latitudes 7°43'N and longitudes 3°90'E, with an annual rainfall of about 1220 mm having a bimodal distribution[13].

The field plot (30×20 m = 600 m^2) was divided into three equal blocks (replicates) of 30× 6 m with inter-block spacing of 1 m. Each replicate was divided into 20 equal plots (6×1 m) with interplot spacing of 0.5 m, giving a total of 60 plots. The experiments were split-plot with Randomized Complete Block Design involving two factors:

- Four P application times (one week before planting, 1 WBP; at planting, AP; one week after planting, 1 WAP and 2 WAP) as sub plot factor
- Five P sources (ground rock phosphate of crystallizer, Cryst; Ogun rock phosphate, ORP; Sokoto rock phosphate, SRP; single super phosphate, SSP, as reference P fertilizer source and control, no phosphate addition) as main plot factor.

Besides the control (0 kg P_2O_5 ha^{-1}), an optimum P level of 50 kg P_2O_5 ha^{-1} was used. Before the commencement of each of the experiments, soil samples (five cores per plot) were collected for physico-chemical analysis.

Early maturing maize (*Zea mays* variety Acr. 89 DMR-ESRW) was used as test crop for the first experiment spanning between August and October 1999. Planting was done on the flat. Prior to planting, the first treatment of 1 WBP was applied. Thereafter, the other treatments of AP, 1 WAP and 2 WAP were respectively applied. Plant spacing was 60×30 cm with one plant per stand, giving a plant population of 55,555 plants ha^{-1}. Nitrogen was uniformly applied as urea (90 kg ha^{-1}) at 2 WAP and 60 kg ha^{-1} at 6 WAP. Potassium as muriate of potash was also applied at a rate of 60 kg ha^{-1} at 2 WAP.

The second and third experiments, carried out in 2000 and 2001, respectively made use of an early maturing non-inoculated promiscuous soybean [*Glycine max* (L) Merr.] variety TGX 1845 1D. The experimental design remained the same as in the first experiment but while in the second experiment there was P application, the third experiment was to test for the residual effect of the previously applied P. Nitrogen was uniformly applied (as urea) at a rate of 60 kg ha^{-1} at 2 WAP in both experiments. The soybean was planted at a spacing of 60×5 cm, giving a plant population of 333,333 plants ha^{-1}.

RESULTS AND DISCUSSION

The nutrient status of the soil prior to the first experiment (Table 1) showed that available P value was

Table 1: Pre-planting soil analysis of surface (0-15 cm) soil samples for the three experiments

Parameters	1st Experiment	2nd Experiment	3rd Experiment
Physical properties (g kg^{-1})			
Sand	859	859	858
Silt	64	64	63
Clay	77	77	77
Textural class	Loamy sand	Loamy sand	Loamy sand
Chemical properties	6.7	6.4	6.6
pH (H_20)	8.0	6.0	9.1
% Organic carbon	0.07	0.08	0.08
%Total nitrogen	17.14	13.51	15.17
Available P mg kg^{-1}	0.03	0.03	0.07
Exchangeable K cmol kg^{-1}	0.07	0.08	0.18
Exchangeable Mg cmol kg^{-1}	0.35	0.25	1.05
Exchangeable Ca cmol kg^{-1}	0.05	0.03	0.11
Exchangeable Na cmol kg^{-1}	0.09	0.13	0.18
Exchangeable CEC cmol kg^{-1}	0.59	057	1.59
% Base saturation	84.20	71.90	77.40

Table 2: Rainfall data (mm) during the three field experiments.

Months	1999	2000	2001
January	0.0	11.7	0.0
February	86.3	0.0	11.9
March	105.5	96.5	68.8
April	176.8	123.5	93.3
May	130.8	87.3	153.8
June	255.8	163.9	328.0
July	267.0	231.6	169.3
August	99.3	251.7	79.8
September	180.4	236.2	298.7
October	309.2	103.8	52.4
November	36.9	0.0	0.0
December	0.0	0.0	0.0

Source: International Institute of Tropical Agriculture (IITA) Weather Station, Ibadan, Nigeria

high compared with the critical value of 8-10 mg kg^{-1}[14]. From the first to the start of the second experiment available P and soil pH reduced. This could be attributed to the fact that it was about 13 months after the first experiment that the second experiment was carried out. Several processes (e.g., nutrient fixation) must have taken place in the soil that must have led to P unavailability. There were increases in available P, pH and exchangeable cations from the commencement of experiment 2 to experiment 3. These increases could be due to the liming effect of RP[15] and its ability to contribute to the increase in the soil available P[16].

The response of maize to different times of phosphorus application: The growth parameters (plant height, stem girth, number of leaves and leaf area) were highest when the P fertilizers were applied 2 WAP (Table 3-5).

Table 6 shows that the effect of the different times of P application on maize grain yield was variable. However, Cryst and ORP were most effective when applied 1WAP. On the contrary, SRP and SSP performed best when applied 2 WAP and AP, respectively. These fall in line with the recommendations of Adepetu[17]. He reported that P application AP and 2 WAP are the most favourable times of application.

Table 3: Effect of time of phosphorus fertilizer application on height (cm) of maize and soybean at successive growth periods

Time of fertilizer application	Maize plant height (cm) Weeks after planting			Soybean plant height (cm) Weeks after planting		
	4	5	6	3	4	5
Crystallizer						
1 WBP	35.70a*	58.88a	94.28a	14.63a	19.93a	23.97a
AP	36.62a	62.43a	96.47a	14.13a	17.67a	22.73a
1 WAP	35.95a	62.38a	96.87a	13.57a	17.77a	22.50a
2 WAP	37.86a	61.27a	98.90a	14.60a	19.07a	23.50a
Ogun rock phosphate						
1 WBP	35.55a	54.91b	86.36c	15.40a	19.73a	22.77ab
AP	35.65a	59.66ab	93.80b	14.17a	17.73b	22.33b
1 WAP	36.43a	60.68a	97.70b	13.97a	17.93b	21.87b
2 WAP	39.29a	63.06a	107.13a	14.27a	19.17ab	23.70a
Sokoto rock phosphate						
1 WBP	34.06b	50.37b	79.25b	15.17a	20.13a	23.67a
AP	33.99b	59.30a	93.60ab	13.67a	17.57b	21.73a
1 WAP	35.85ab	59.93a	105.30a	13.93a	17.23b	22.20a
2 WAP	38.10a	64.97a	103.30a	14.63a	18.63ab	22.90a
Single super phosphate						
1 WBP	36.96a	62.76a	100.98a	15.33a	19.63a	23.70a
AP	36.72a	63.98a	104.57a	13.77a	17.20b	21.20a
1 WAP	38.29a	67.37a	109.47a	14.20a	17.33b	21.90a
2 WAP	39.45a	66.76a	108.00a	15.40a	18.67ab	22.90a

* Means in the same column followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test);
WBP = Week before planting; AP = At planting; WAP = Week after planting

Table 4: The effect of time of phosphorus fertilizer application on number of leaves of maize and soybean at successive growth periods.

Time of P-fertilizer application	Maize leaves Weeks after planting			Soybean leaves Weeks after planting		
	4	5	6	3	4	5
Crystallizer						
1 WBP	7.07a*	9.53a	9.13c	10.77a	14.97a	22.57a
AP	7.57a	9.13a	9.27bc	9.77b	13.95ab	20.27b
1 WAP	7.77a	9.93a	9.80ab	9.47b	13.90ab	20.60ab
2 WAP	7.63a	9.73a	9.90a	9.17b	13.43b	19.27b
Ogun rock phosphate						
1 WBP	7.10b	9.27a	9.13a	11.13a	14.60a	21.40b
AP	7.23ab	9.43a	9.63a	9.53b	13.90a	20.50ab
1 WAP	7.57ab	9.80a	9.57a	9.83ab	13.93a	20.50ab
2 WAP	9.87a	9.90a	9.73a	9.10b	12.93b	18.50b
Sokoto rock phosphate						
1 WBP	6.97b	8.70b	8.87b	10.07a	14.57a	20.23a
AP	7.50a	9.67a	9.37ab	9.40a	14.03a	20.67a
1 WAP	7.63a	9.80a	10.00a	9.37b	13.97a	19.50a
2 WAP	7.57a	9.83a	9.53ab	9.33a	12.63b	19.23a
Single super phosphate						
1WBP	7.63a	9.13b	9.53a	10.97a	14.27a	21.33a
AP	7.43a	9.93ab	9.47a	9.83a	13.93ab	20.17a
1 WAP	7.57a	10.20a	10.30a	9.37b	14.40ab	20.57a
2 WAP	7.70a	9.90ab	9.37a	8.83b	12.93b	17.27b

* Means in the same column followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test);
WBP = Week before planting; AP = At planting; WAP = Week after planting

The effect of the different times of phosphorus application on soybean growth: From results of the effect of times of P application on the growth parameters (plant height, leaf area and number of leaves) of soybean (Table 3-5), it is evident that P application at 1 WBP was the most appropriate time irrespective of the P source. This is in accordance with the report by Sinclair *et al.*[18] and Wendt and Jones[19]. These reports recommended that P should be applied before planting so as to allow for solubilization to take place for easy plant uptake of the added P.

ORP, SRP and SSP led to highest soybean seed yield when applied 1 WAP (Table 6). Cryst, however, produced the highest seed yield when applied 1 WAP as recommended by Sinclair *et al.*[18].

The very low seed yield recorded is attributable to the fact that the crop was planted late in the season

Table 5: The effect of time of phosphorus fertilizer application on leaf area (cm^2) of maize and soybean at successive growth period

Time of P-fertilizer application	Maize leaves, Weeks after planting 4	5	6	Soybean leaves, Weeks after planting 3	4	5
Crystallizer						
1 WBP	241.14a*	380.40a	452.18a	24.91a	32.87a	40.13a
AP	240.14a	386.18a	494.36a	20.93a	33.00a	38.63a
1WAP	250.51a	368.11a	486.95a	20.77a	31.77a	38.47a
2WAP	263.39a	381.72a	481.08a	20.83a	32.23a	37.03a
Ogun rock phosphate						
1 WBP	220.05b	355.72a	425.14b	22.20a	32.93a	38.83a
AP	221.08b	389.75a	495.90a	20.02a	32.27a	37.30a
1 WAP	252.15ab	363.39a	509.68a	19.06a	33.93a	39.03a
2 WAP	279.17a	415.17a	537.86a	21.41a	30.23a	38.17a
Sokoto rock phosphate						
1 WBP	226.29b	317.88b	391.21b	19.48a	30.57a	37.40a
AP	236.90ab	380.41ab	461.29a	19.42a	31.73a	37.57a
1 WAP	253.27ab	355.89ab	490.00a	19.48a	30.50a	36.23a
2 WAP	266.90a	387.35a	496.02a	19.50a	29.00a	34.00a
Single super phosphate						
1 WBP	245.95a	425.46a	526.62a	23.20a	33.13a	39.23a
AP	239.77a	390.08a	516.68a	18.65a	31.65a	35.37ab
1 WAP	264.04a	409.89a	522.97a	19.63a	31.00a	38.10ab
2 WAP	260.34a	391.98a	534.61a	19.13a	28.57ab	32.70b

* Means in the same column followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test);
WBP = Week before planting; AP = At planting; WAP = Week after planting

Table 6: Grain yields of maize and soybean in response to phosphorus fertilizer sources applied at different times in the first and second cropping

Phosphorus Sources	Time of P-fertilizer application: Control	1 WBP	AP	1 WAP	2 WAP
Maize grain yield (kg ha^{-1})					
Crystallizer	1854.2a	2216.7a	1633.4a	2200.0a	1700.0a
Ogun rock phosphate	1854.2a	1666.7a	1950.0a	2250.0a	1716.7a
Sokoto rock phosphate	1854.2ab	1283.4b	1866.7ab	1800.0a	2250.0a
Single super phosphate	854.2a	2166.7a	2533.4a	2333.4a	2200.0a
Soybean seed yield (kg ha^{-1})					
Crystallizer	85.0a	187.2a	117.84a	128.3a	136.7a
Ogun rock phosphate	85.0a	182.2a	128.8a	182.8a	153.3a
Sokoto rock phosphate	85.0a	93.4ab	110.5ab	176.7a	137.2ab
Single super phosphate	85.0b	90.5b	94.5b	176.7a	140.5ab

*Values followed by the same letters are not significantly different at p=0.05 (Duncan's Multiple Range Test)
WBP = Week before planting; AP = At planting; WAP = Week after planting

(September) and the drought affected the reproductive stage (Table 2). Board and Harville[20] as well as Linkemer *et al.*[21] explained that water deficit leads to greatest decreases in soybean seed yield by reducing branch seed yield. It reduces branch growth[22].

The response of maize and soybean to different phosphorus sources: Table 7 shows the effect of the different P sources on maize and soybean production. SSP had the best effect on maize grain yield (2.31 t ha^{-1}), followed by Cryst (1.89 t ha^{-1}), ORP (1.94 t ha^{-1}) and SRP (1.80 t ha^{-1}). However, in soybean production, ORP performed best (Table 7). This performance by ORP was only significantly higher than the yield for the control. The good performance of ORP as a source of P for soybean production was due to its reported good reactivity in soils with pH greater than 6[23]. On the other hand, crystallizer's performance could be attributed to its having most of the micronutrients necessary for plant growth.

Table 7: Grain yields of maize and soybean in response to different phosphorus fertilizer sources in the first and second cropping, respectively

Phosphorus sources	Grain yield (kg ha^{-1}): Maize	Soybean
Control	1854.2b*	116.7b
Crystallizer	1937.5b	159.0ab
Ogun rock phosphate	1895.9b	166.7a
Sokoto rock phosphate	1800.0b	133.3ab
Single super phosphate	2308.4a	133.3ab

*Values followed by the same letters are not significantly different at p=0.05 (Duncan's Multiple Range Test)

The residual effect of phosphorus sources on soybean yield: The seed yield varied between 1116.7 and

Table 8: Residual effects of the phosphate fertilizer sources on the seed yield of soybean

Phosphorus sources	Soybean yield (kg ha^{-1})
Control	1116.7a*
Crystallizer	1333.4a
Ogun rock phosphate	1166.7a
Sokoto rock phosphate	1150.0a
Single super phosphate	1150.0a

*Values followed by the same letters are not significantly different at p=0.05 (Duncan's Multiple Range Test)

1333.3 kg ha^{-1} (Table 8). Cryst had the best residual seed yield of 1333.3 kg ha^{-1}, though it was not significantly higher than those of the other P sources. It was closely followed by ORP with 1166.7 kg ha^{-1}, while both SRP and SSP gave 1150.0 kg ha^{-1} each. The higher residual seed yield produced by Cryst could be attributed to its enhancement of soil nutrient balance since it acts as a useful source of some micronutrients e.g., Fe, Cu etc.[23].

Any of the RP sources (Cryst, ORP and SRP) could be used as a source of P for the growth of both maize and soybean. Likewise, any of the four times of applications (1 WBP, AP, 1 WAP and 2 WAP) is suitable for a good yield of maize or soybean. Considering the insignificance of the effect of the residual P of the RP sources, any of them could be relied upon to provide good residual effect on the yield of soybean.

ACKNOWLEDGMENT

The Senate Research Grant of University of Ibadan, Nigeria funded the research.

REFERENCES

1. Ssali, H., P. Ahn and A.U. Mokwunye, 1986. Fertility of Soils in Tropical Africa: A Historical Perspective. In: A.U. Mokwunye and P.L.G. Viek, (Ed.), Management of Nitrogen and Phosphorus Fertilizer in Sub-saharan Africa. Martinus Nijhoff, Dordrecht, pp: 59-82.
2. Bationo, A., E. Rhodes, E.M. A. Smaling and C. Visker, 1996. Technologies for Restoring Soil Fertility. In: Mokwunye, A.U. and P.L.G. Vlek, (Eds.), Restoring and Maintaining the Productivity of West African soils: Key to Sustainable Development. Misc. Fert. Stud. 14. Intl. Fert. Dev. Ctr., Africa, Lome, Togo., pp: 61-82.
3. Adediran, J.A. and R.A. Sobulo, 1995. The potentials and use of rock phosphate in sub-Saharan Africa. Nigeria as a case study. 3rd Conference Panafricaine des pedologues. OUA/CSTR Ibadan, Nigeria, pp: 295-305.
4. Schultz, J.J., 1986. Sulphuric acid-based partially acidulated phosphate rock. Its production cost and use. Tech. Bull. IFDC T31. Muscle shoal Alabama, pp: 1-12.
5. Obigbesan, G.O. and N.A. Udosen, 1995. Agronomic assessment of rock phosphate for direct use as a P source for crop production. Paper presented at the 3rd All African Soil Science Society Conference 19-26 August 1995, University of Ibadan Conference Centre.
6. Sample, E.C., R.J. Soper and G.J. Racz, 1978. Reaction of Phosphate Fertilizer in Soils. In: Khasawneh, F.E., (Ed.), the Role of Phosphorus in Agriculture. ASA. Madison, WI., pp: 263-310.
7. Sanchez, P.A., A.U. Mokwunye, F.R. Kwesiga, C.G. Ndiritu and P.L. Woomer, 1997. Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital. In: Buresh, R.J., (Ed.), Replenishing Soil Fertility in Africa. SSSA Spec. Publication, 51: 1-46.
9. Okoruwa, A.E., 1997. Utilization and processing of maize. IITA Research Guide 35. Training Program. IITA Ibadan, Nigeria, pp: 29.
8. Anonymous, 1991. Yearbook of production. FAO Rome, Italy, 45: 24-44.
10. Carrao, P.M.C. and J.M.M. Gontijo, 1994. In tropical soybean improvement and production. FAO Plant Production and Protection Series, 27: 44-57.
11. Smyth, J. and R.F. Montgomery, 1962. Soil and land use in central Western Nigeria. Government Press of Western Nigeria, Ibadan, pp: 1-66.
12. Soil Survey Staff, 1975. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Survey. USD A Handbook 436. US Government Printing Office, Washington, DC., pp: 45-66.
13. Anonymous, 1984. Fertilizer and plant nutrient guide. FAO Fertilizer and Plant Nutrition Bulletin, 9: 47-58.
14. Agboola, A.A., 1982. Organic manuring and green manuring in Tropical Agricultural Production Systems. In: Proceeding 12th International Congress of Soil Science. New Delhi, India, 8th-16th Feb., pp: 198.
15. Hong-Qing, H., L. Xue-Yuan, L. Jing-Fu, X. Feng-Lin, L. Jing and L. Fan, 1997. The Effect of Direct Application of Phosphate Rock on Increasing Crop Yield and Improving the Properties of Red Soils. Nutrient Cycling in Agro Ecosystems Kluwer Academic Publishers, 46: 235-239.
16. Akande, M.O., E.A. Aduayi, A. Olayinka and R.A. Sobulo, 1998. Efficiency of sokoto rock phosphate as a fertilizer source for maize production in Southwestern Nigeria. J. Plant Nutr., 20: 1339-1353.

17. Adepetu, J.A., 1981. Soil Phosphorus. In: Adepetu, J.A., A.A. Fagbemi and G.O. Obigbesan, (Eds.), Soil and Fertilizer Use Research in Southern Nigeria. Federal Ministry of Agric. Water Resources and Rural Development, Lagos Nigeria, pp: 1-17
18. Sinclair, A.G., P.G. Johnstone, L.C. Smith, M.B. O'Connor and L. Nyuyen, 1993. Agronomy, modeling and economics of reactive phosphate rock as a slow-release phosphate fertilizer for grassland. Fert. Res., 36: 229-238.
19. Wendt, J.W. and R.B. Jones, 1997. Evaluation of the Efficacy of Malawi Tundulu Phosphate Rock for Maize Production. Nutrient Cycling in Agro Ecosystem Kluwer Academic Publishers, 48: 161-170.
20. Board, J.E. and B.G. Harville, 1998. Late planted soybean yield response to reproductive source/sink stress. Crop Sci., 38: 763-771.
21. Linkemer, G., J.E. Board and M.E. Musgrave, 1998. Water logging effects on growth and yield components in late planted soybean. Crop Sci., 38: 1576-1584.
22. Frederick, J.R., C.R. Camp and P.J. Bauer, 2001. Drought-Stress effects on pattern of yield components in Braxton soybean. Agron. J., 76: 495-497.
23. Fayiga, A.O., 1998. Physico-chemical characterization and P-release by local rock phosphates under different moisture regimes M. Sc Project, University of Ibadan, Nigeria, pp: 98.