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Variety and Phosphate Rock Effects on Yield and Yield Components of Cowpea [*Vigna unguiculata* (L.) Walp.]

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Abstract: Field experiments were conducted in 2004 and 2005 rainy seasons to determine the effects of Phosphate Rock (PR) levels and variety on growth and yield of cowpea varieties. Treatments consisted of factorial combinations of two varieties (Baadare and IAR 48) and three levels of phosphate rock (25, 50 and 75 kg ha^{-1}) along with a control (0 kg PR ha^{-1}) laid out in a randomized complete block design replicated three times. Results showed that, at 0 kg PR ha^{-1} (control) the two varieties had similar performance in all the parameters measured. But application of PR resulted in significant ($p<0.01$) response compared to control in most parameters studied. Application of 50 and 75 kg PR ha^{-1} resulted in significant increase in pods yield and number of pods $plant^{-1}$ in 2004 trial, while shelling percentage, grain and stover yields, 1000 grain weight, number of seeds $plant^{-1}$ and harvest index were not significantly influenced by PR levels. Significantly ($p<0.05$) higher pods yield, shelling percentage, grain and stover yields, 1000 grain wt. number of pods $plant^{-1}$ and number of seeds $plant^{-1}$ were observed with Baadare (local) than with IAR-48 (improved) but higher harvest index was observed with IAR 48. Therefore, from this study it was concluded that, application of 25 kg PR ha^{-1} was adequate for cowpea production and Baadara (local) variety was suitable for Sudan savanna zone.

Key words: Phosphate rock, cowpea (*Vigna unguiculata*), variety, Sudan savanna, Nigeria

INTRODUCTION

Cowpea is of major importance to the livelihood of millions of relatively poor people in less developed countries of the tropics. From production of this crop, rural families variously derive food, animal feed and cash together with spillover benefit to their farmlands. In fresh form, the young leaves, immature pods and peas are used as vegetables, while several snacks and main meal dishes are prepared from the grain. All the parts that are used as food are nutritious providing protein, vitamins and minerals. Cowpea grain on the average contains 23-25% protein and 50-67% starch (Quin, 1997).

Cowpea has the unique ability to fix nitrogen even in very poor soils (pH range 4.5-9.0, organic matter <0.2% and sand content of >85%) and therefore does not require nitrogenous fertilizers but phosphorous (P) or a compound of P and potassium are essential (Rao *et al*., 1999). Many soils in tropical and sub-tropical regions are low in both total and available P and as a result, P is normally the most limiting nutrient for the growth of leguminous crops in these regions (Chien and Menon, 1995; Rao *et al*., 1999) as reflected in the per hectare production of cowpea [0.434 t ha^{-1} in Nigeria, 0.157 t ha^{-1} in Niger, 0.470 t ha^{-1} in Burkina Fasso, 0.240 t ha^{-1} in Kenya, 1.00 t ha^{-1} in Uganda (FAOSTAT, 2005, htt://www.fao.org).

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Soil phosphorus can be replenished by addition of organic and inorganic fertilizers but the application of soluble P fertilizers alone in acid soils is uneconomical due to high P fixing abilities of the acid soils. P fixation limits crop production and inorganic fertilizers are expensive especially to a resource-poor farmer. Therefore, it becomes necessary to seek for an alternative P source and Phosphate Rock (PR) is one important potential alternative source of P to conventional water soluble P fertilizer. However, PRs are often sparingly soluble; thus, there is a need to search for varieties with an improved ability to mobilize P from the sparingly soluble soil-P pools.

In Nigeria, Sokoto is known for its PR deposits that could be used as a cheap source of P fertilizer. Sokoto PR is reported to contain 33.9% P_2O_5 which compares favorably with PR from other countries (IART, 1994). In the earlier studies at IART (1994) confirmed that, Sokoto PR can be used for direct application and that the efficiency of the materials as a P source is higher in acid soils and wetter areas of Nigeria. In the current study, we hypothesized that the choice of a proper cowpea variety and direct application of Sokoto PR could improve the performance of cowpea. Therefore, a study was carried out to select a cowpea variety that would respond to PR levels in the Sudan Savanna of Nigeria.

MATERIALS AND METHODS

Field experiments were conducted in 2004 and 2005 rainy seasons at Usmanu Danfodiyo University Dry Land Teaching and Research Farm, Sokoto (13°9N, 5°12'E, 300 m above sea level). Sokoto lies in the Sudan Savanna agro ecological zone of Nigeria with erratic and scanty rainfall (Singh, 1995) that lasts for about 4 months (mid June to September) and long dry period (October to May). The annual rainfall is highly variable over the years and averages around 700 mm. the temperature is also variable throughout the year and the relative humidity is generally low for the greater part of the year which is about 20-35% in January and increases to 60-80% in August (Rao, 1983). The annual rainfall in 2004 and 2005 cropping seasons were 293.6 and 668.5 mm, respectively (Fig. 1).

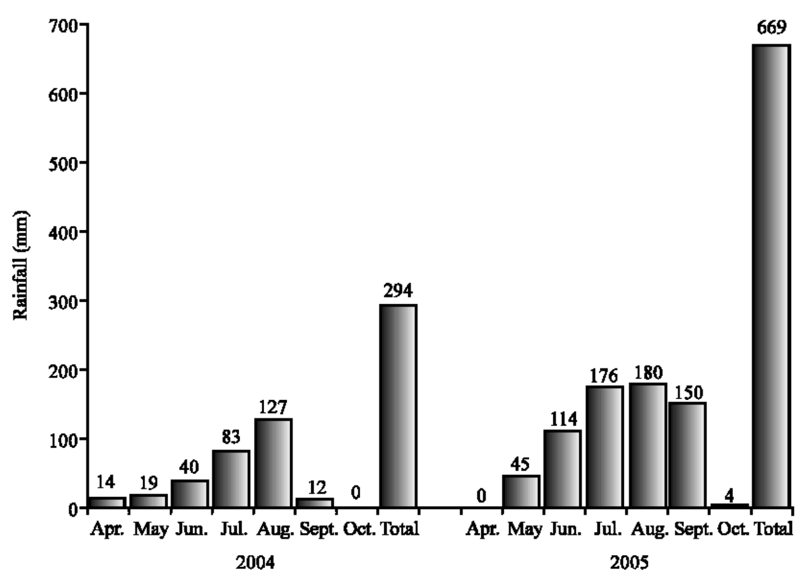

Fig. 1: Monthly and total annual rainfall at the experimental site in 2004 and 2005 cropping seasons. Source: Sokoto Energy Research Center, Usmanu Danfodiyo University, Sokoto

Table 1: Physico-chemical properties of the soil at the experimental site in 2004 and 2005 cropping seasons

Physico-chemical characteristics	2004	2005
Physical properties		
Sand (g kg^{-1})	930	940
Silt (g kg^{-1})	40	40
Clay (g kg^{-1})	15	20
Textural class	Sandy	Sandy
Chemical property (g kg^{-1})		
Organic carbon	6.80	7.60
Total nitrogen	3.00	4.20
Available P	0.40	1.00
Exchangeable K	2.20	2.00
CEC	3.10	3.50
Exchangeable bases (cmol kg^{-1})		
Na	0.11	0.11
Ca	0.35	0.48
Mg	1.02	1.90
pH (in water)	6.00	6.20
pH ($CaCl_2$)	5.80	5.90

Soil samples were randomly collected at 0-30 cm soil depth for physico-chemical analysis before the commencement of the experiment in 2004 and 2005 cropping seasons. The physico-chemical analysis of the soil of the study area showed that the soil was predominantly sandy. The soil reaction was slightly acidic with pH values of 6.0 and 6.2 for 2004 and 2005, respectively. Organic carbon and available P were very low. Total N and K content were low, the Cation Exchange Capacity (CEC) was low and the exchangeable bases (Na, Ca and Mg) were also low (Table 1).

Treatment consisted of factorial combinations of 3 levels of phosphate rock [25 (8.5 kg P_2O_5 ha^{-1}), 50 (17.0 kg P_2O_5 ha^{-1}) and 75 (25.5 kg P_2O_5 ha^{-1})] and 2 cowpea varieties (Baadare and IAR48) laid out in a randomized complete block design (RCBD) replicated three times.

Ground phosphate rock was sourced from Sokoto Phosphate Rock Beneficiation Plant located off Abdullahi Fodiyo Road, Sokoto. Certified seeds of cowpea variety (IAR48) were sourced from the Institute for Agricultural Research Zaria, while the seeds of local variety (Baadare) were obtained from Sokoto Agricultural and Rural Development Authority (SARDA), Sokoto. Sowing was done at an intra-row spacing of 40 cm and inter-row spacing of 75 cm. Three seeds were sown per hole at 3 cm depth, which were later thinned to one stand per hole at two weeks after planting (WAP). Ten kilogram nitrogen per hectare was applied as a starter dose and based on treatment, single dose application of ground rock mineral phosphate was done for the 3 prescribed fertilizer levels (25, 50 and 75 kg PR ha^{-1}) with 0 kg PR ha^{-1} (no fertilizer application) to serve as control plots for each of the two cowpea varieties.

Weeds were controlled manually by hoeing and hand-pulling and the plots were sprayed at 4 weeks interval to control insect infestations. Data were collected on number of pods per plant and seeds per pod, pod weight, shelling percentage, grain and stover yield, 1000 grain weight and harvest index.

Data obtained were subjected to analysis of variance (ANOVA) procedures using SAS® (2003) and significant difference in the treatment means were further analysed using Least Significant Difference (LSD) test. Group comparisons were carried out to study the combined effect of PR fertilizer versus control where no PR was applied.

RESULTS AND DISCUSSION

Pods per Plant and Seeds per Pod

When comparing the combined effects of rock phosphate levels (25, 50 and 75 kg PR ha^{-1}) with control level (0 kg PR ha^{-1}), results showed highly significant ($p<0.01$) response to applied rock phosphate fertilizer on pods per plant and seeds per pod in both 2004 and 2005 cropping seasons and

Table 2: Pods per plant and seeds per pod as influenced by phosphate rock level and variety in 2004 and 2005 cropping seasons and the two seasons combined

	Pods plant^{-1}			Seeds pod^{-1}		
Treatments	2004	2005	Combined	2004	2005	Combined
Rock phosphate (PR kg ha^{-1})						
0 (Control)						
Baadare	5.20	8.13	6.67	4.67	7.73	6.20
IAR 48	4.87	9.93	7.40	5.67	7.53	6.66
SE (Variety)	0.570	0.951	0.554	1.037	0.551	0.587
Mean (Variety)	4.54	9.03	7.04	5.17	7.63	6.43
Rock phosphate levels						
25	6.68^{b}	12.41	9.54	7.99	10.78	9.38
50	7.37^{a}	12.24	9.80	7.69	10.58	9.13
75	7.29^{a}	12.29	9.79	7.38	10.84	9.11
SE	0.237	0.39	0.228	0.425	0.209	0.237
Significance	s	ns	ns	ns	ns	ns
Response to phosphate rock fertilizer						
0 vs. 25, 50 and 75	0.0001s	0.0001s	0.0001s	0.0024s	0.0001s	0.0001s
Variety (V)						
Baadare	7.59^{a}	12.36	9.97	8.30^{a}	10.85	9.57^{a}
IAR 48	6.64^{b}	12.27	9.46	7.07^{b}	10.61	8.84^{b}
SE	0.194	0.318	0.186	0.347	0.170	0.193
Significance	s	ns	ns	s	ns	s
Interaction						
PR×V	ns	ns	ns	ns	ns	ns

Within a treatment group, means in a column followed by same letter(s) in superscript are not significantly different at 5% level using LSD, s = Significant at 5% level, ns = Not significant

in the two years combined (Table 2). This response to rock phosphate fertilizer applied could be as a result of low phosphorus content of the soil at the experimental site (Table 1). This is consistent with the findings of Chien and Menon (1995), Rao *et al*. (1999) who observed that, many soils in tropical and subtropical regions are low in both total and available phosphorus and thus becomes a limiting factor for cow production (Sanchez *et al*., 1997).

Phosphate rock levels significantly ($p<0.05$) influenced number of pods per plant only in 2004 trial but was non significant in 2005 trial and the two years combined. Also, differences in phosphate rock levels (25, 50 and 75 kg PR ha^{-1}) were not significant in terms of seeds per pod in both 2004 and 2005 cropping seasons and in the two seasons combined (Table 2). The high number of pods per plant (7.37) was observed at 50 and 75 kg PR ha^{-1} in 2004 trial. But, in 2005 trial, there was no significant influence of PR levels. This agrees with findings of Linquist (1996) and Jama *et al*. (1997). No differences in the numbers of pods per plant in 2005 trial and in the two seasons combined and seeds per pod in 2004 and 2005 trials and in two years combined might be due to poor solubility of PR at higher levels or probably due to P fixation in the soil.

Variety had highly significant ($p<0.01$) effects on number of pods per plant and number of seeds per pod in 2004 trial and number of seeds per pod in the two years combined. Baadare (local) had higher number of pods per plant and seeds per pod and in 2004 trial and seeds per pod in the 2 years combined than IAR 48 (improved) (Table 2). The higher numbers of pods per plant and seeds per pod recorded by Baadare (local cowpea) could be attributed to the genetic make-up of the variety which enabled it to adapt to water deficit condition (Fig. 1) in 2004 cropping season. Gibbon and Pain (1985) noted that about 8 to 20 seeds can be found per pod. But, Ogunbodede and Fatunla (1985) observed that, the numbers of pods per plant and seeds per pod are moderately to highly heritable. Although not significantly different but, the mean numbers of pods per plant (12.36 and 12.27) and seeds per pod (10.85 and 10.61) for Baadare (local) and IAR 48 (improved) varieties, respectively were found to be higher in 2005 trial than the mean numbers recorded on the same parameters in 2004 trial

Table 3: Pods weight and shelling percentage as influenced by phosphate rock levels and variety in 2004 and 2005 cropping seasons and the two seasons combined

	Pod weight ($kg\ ha^{-1}$)			Shelling (%)		
Treatments	2004	2005	Combined	2004	2005	Combined
Phosphate rock (PR $kg\ ha^{-1}$)						
0 (Control)						
Baadare	1579	1965	1772	73.0	74.4	73.7
IAR 48	1318	1718	1518	76.5	72.0	74.2
SE (Variety)	91.2	196.1	108.1	2.21	1.96	1.47
Mean (Variety)	1449	1841	1645	74.7	73.2	74.0
Phosphate rock levels						
25	2048[b]	2774	2412	74.4	76.7	75.5
50	2166[a]	2752	2460	73.3	76.4	74.9
75	2196[a]	2766	2481	72.2	77.2	74.7
SE	37.8	82.0	45.2	0.92	0.77	0.60
Significance	s	ns	ns	ns	ns	ns
Response to phosphate rock						
0 vs 25, 50 and 75 $kg\ ha^{-1}$	0.0001s	0.0001s	0.0001s	0.3768ns	0.0174s	0.0001s
Variety (V)						
Baadare	2202[a]	2834	2518[a]	75.6[a]	77.1	76.4[a]
IAR-48	2073[b]	2694	2384[b]	70.9[b]	76.5	73.7[b]
SE	30.9	66.9	36.9	0.75	0.63	0.49
Significance	s	ns	s	s	ns	s
Interaction						
PR×V	ns	ns	ns	ns	ns	ns

Within a treatment group, means in a column followed by same letter(s) in superscript are not significantly different at 5% level using LSD, s = Significant at 5% level, ns = Not significant, Comb. = 2004 and 2005 combined

(Table 2). This could be attributed to higher rainfall in 2005 cropping season (Fig. 1). This agrees with Ziska *et al*. (1985) who stated that, yield of cowpea is strongly dependent upon the water supply during the reproductive stage of growth.

Pod Weight and Shelling Percentage

Results at 0 kg PR ha^{-1} (no PR fertilizer applied) showed that the performances of the 2 varieties were similar in pod weight and shelling percentage. When combined effects of PR levels (25, 50 and 75 kg PR ha^{-1}) were compared with 0 kg PR ha^{-1} (control level). Results indicated significant ($p<0.01$) response to applied rock phosphate fertilizer on pod weight in 2004 and 2005 trials and the two years combined (Table 3). Shelling percentage in 2004 trial had no significant effect of PR fertilizer. Good response to PR fertilizer could be related to lower phosphorus and calcium status of the soil at the experimental site (Table 1). The low phosphorus content of the soil is not only in the Sudan Savanna but all over the tropics (Singh *et al*., 2000).

Rock phosphate levels significantly ($p<0.05$) influenced pod yield in 2004 trial while in 2004 and in the combined analysis there was no significant effect of PR levels. Shelling percentage was not significantly influenced by PR levels in both 2004 and 2005 trials and in the two years combined (Table 3). In 2004 trial, plots subjected to 75 kg PR ha^{-1} recorded higher pod yield (2196 kg PR ha^{-1}) though not different from of 50 kg PR ha^{-1} (2166 kg ha^{-1}). This indicated that even low level of P was adequate for cowpea production. This conforms with the findings of Peter (1970), IAR and T (1994), Jama *et al*. (1997) that reported increased crop yield with relatively small rates (10-25 kg P_2O_5 ha^{-1}). Crop yields can further be increased with higher P rates (100 kg P_2O_5 ha^{-1}) which can be financially attractive.

Variety significantly ($p<0.01$) influenced pod yield and shelling percentage only in 2004 trial and in the two years combined analysis. In 2005 trial, pods yield and shelling percentage were not significantly influenced by variety (Table 3). In both 2004 and 2 years combined, significantly ($p<0.05$) higher pod weight and shelling percentage was recorded with Baadare (local variety) than the

Table 4: Grain and stover yields as influenced by rock phosphate levels and variety in 2004 and 2005 cropping seasons and the two seasons combined

	Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
Treatments	2004	2005	Comb.	2004	2005	Comb.
Phosphate rock (PR kg ha^{-1})						
0 (Control)						
Baadare	1138	1461	1299	2696	1570	2133
IAR 48	1010	1242	1126	2673	1841	2257
SE (Variety)	62.8	162.1	86.9	285.3	115.3	153.9
Mean (Variety)	1074	1352	1213	1705	1206	1455
Phosphate rock levels						
25	1528	2127	1827	1726	1260	1493
50	1583	2105	1845	1803	1284	1544
75	1584	2147	1866	1987	1322	1654
SE	25.0	67.8	20.0	115.4	44.9	77.3
Significance	ns	ns	ns	ns	ns	ns
Response to phosphate rock fertilizer						
0 vs 25, 50 and 75	0.0001s	0.0001s	0.0001s	0.0003s	0.0001s	0.0001s
Variety (V)						
Baadare	1662^{a}	2188	1925^{a}	2307^{a}	1339	1823^{a}
IAR 48	1469^{b}	2064	1767^{b}	1370^{b}	1238	1304^{b}
SE	20.4	55.3	24.7	94.2	36.7	295.7
Significance	s	ns	s	s	ns	s
Interaction						
PR × V	ns	ns	ns	ns	ns	ns

Within a treatment group, means in a column followed by similar letter(s) in superscript are not significantly different at 5% level using LSD, s = Significant at 5% level, ns = Not significant, level, Comb. = 2004 and 2005 combined

improved IAR-48. Better performance of the Baadre (local variety) could be due to it adaptation in the study area. It probably had well developed rooting system that was efficient in taking up P from the soils. The differential response by the varieties to P application has been observed by Okeleke and Okelana (1997). The pod weight recorded in this study with PR (1.1 to 1.2 t ha^{-1}) was however higher than that recorded by Natarajan and Naik (1992) (0.32 t ha^{-1}).

Grain and Stover Yields

Results showed that, at 0 kg PR ha^{-1} (no fertilizer application), the two varieties had similar grain and stover yields in both 2004 and 2005 trials and in the 2 years combined (Table 4). In a group comparison where combined effect of 25, 50 and 75 kg PR ha^{-1} was compared with 0 kg PR ha^{-1} (no PR application), significantly ($p<0.01$) higher grain and stover yield was obtained with PR fertilizer than no fertilizer (0 kg PR ha^{-1}) in both 2004 and 2005 cropping seasons and the two seasons combined (Table 4). This could be due to ability of the cowpea roots through excretion of organic acids to solubilize PR (Krasilnikoff *et al*., 2002). This was further enhanced by slightly acidic nature of the soil at the experimental site (Table 1) as reported by Hammond *et al*. (1986). Acid soils are more conducive to PR dissolution than Ca^{++} rich alkaline soils (Hammond *et al*., 1986).

Results showed no significant effects of PR fertilizer levels on grain and stover yield of cowpea in both 2004 and 2005 cropping seasons and in the two seasons combined (Table 4). The non-significant effects of PR fertilizer levels on grain and stover yields could be attributed to fixation of P from the higher rates of RP fertilizer. Similar finding has been reported by Hammond *et al*. (1986) who stated that direct application of rock phosphate fertilizer is not normally recommended for low rainfall areas due to erratic agronomic effectiveness under conditions of low soil water content.

Variety significantly ($p<0.05$) influenced grain and stover yields in 2004 trial and in the two years combined (Table 4). Significantly ($p<0.01$) higher grain and stover yields were recorded by Baadare (local variety) than by IAR 48 (improved variety) during the 2004 trial and in the two seasons combined. Better performance shown by the local variety (Baadare) in terms of grain and stover yields could be due to its ability to effectively dissolve PR through the excretion of organic acids in the rhizosphere. Also, this variety is more adapted to the environmental conditions than IAR-48. Similar findings have been reported by Peter (1970) and Ziska *et al*. (1985).

1000 Grain Weight and Harvest Index (HI)

Results from the control plots showed that, at 0 kg PR ha^{-1}, the two cowpea varieties performed similarly in terms of 1000 grain weight and harvest index in both 2004 and 2005 trials and in the 2 years combined. In a group comparison where the combined effects of rock phosphate levels (25, 50 and 75 kg PR ha^{-1}) were compared with control (0 kg PR ha^{-1}), results indicated highly significant ($p<0.01$) response to applied rock phosphate fertilizer on 1000 grain weight and harvest index in both 2004 and 2005 trials and in the 2 years combined (Table 5). This response was due to low P content of the soil at the experimental site and P is known to enhance N fixation and physiological processes in plants (Fixen and Groven, 1990).

One thousand grain weight and harvest index were not significantly influenced by rock phosphate levels in both 2004 and 2005 trials and in the two seasons combined (Table 5). This could be related to P fixation or leaching in the soil of the excess P released from the higher rates of PR. However, Brouwer and Powell (1995) stated that, losses of P by leaching are very rare except in very sandy soils such as those of the Sahel.

Variety significantly ($p<0.01$) influenced 1000 grain weight and harvest index in 2004 trial and in the 2 years combined. Significantly ($p<0.01$) heavier 1000 grain weight (198.6 g in 2004 and 220.1 g in combined) were recorded by Baadare (local) than IAR 48 (improved) (162.6 g in 2004 and 198.4 g in combined). IAR-48 recorded significantly ($p<0.01$) higher harvest index (43% in 2004 and 47.8% in combined) than Baadare (local) (37.9% in 2004 and 45.5% in combined) in 2004 trial and in the two years combined (Table 5).

Table 5: One thousand grain weight and harvest index as influenced by rock phosphate levels and variety in 2004 and 2005 cropping seasons

	1000 grain wt. (g)			Harvest Index (%)		
Treatments	2004	2005	Comb.	2004	2005	Comb.
Phosphate rock (PR kg ha^{-1})						
0 (Control)						
Baadare	116.7	158.3	137.5	27.7	41.1	34.4
IAR 48	130.0	155.0	142.5	25.3	34.7	30.0
SE (Variety)	15.13	13.83	10.25	2.51	2.08	1.63
Mean (Variety)	123.3	156.7	140.0	26.5	37.9	32.2
Phosphate rock levels						
25	185.8	239.7	212.8	39.3	53.5	46.4
50	172.4	237.8	205.1	41.1	52.0	46.5
75	183.6	236.2	209.8	41.0	53.0	47.0
SE	6.41	5.77	4.31	1.08	0.84	0.68
Significance	ns	ns	ns	ns	ns	Ns
Response to phosphate rock fertilizer						
0 vs 25, 50 and 75	0.0001s	0.0001s	0.0001s	0.0001s	0.0001s	0.0001s
Variety (V)						
Baadare	198.6[a]	241.5	220.1[a]	37.9[b]	53.0	45.5[a]
IAR 48	162.6[b]	234.3	198.4[b]	43.0[a]	52.7	47.8[b]
SE	5.23	4.71	3.52	0.881	0.68	0.56
Significance	s	ns	s	s	ns	s
Interaction						
PR×V	ns	ns	ns	ns	ns	ns

Within a treatment group, means in a column followed by similar letter(s) in superscript are not significantly different at 5% level using LSD, s = significant at 5% level, ns = not significant, Comb. = 2004 and 2005 combined

The heavier grains produced by Baadare (local) in the trials could be related to its adaptation to water limited environment coupled with its very sensitive stomatal closure in response to soil drying which enabled it survive dry condition and more efficiently used water for physiological processes than the IAR 48 (improved variety). This is in line with Petrie and Hall (1992) and Ismail and Hall (1993).

The higher harvest index recorded by IAR-48 could be attributed to its' genetic make-up which enabled it to photosynthesize efficiently and store the excess photosynthates in the storage organs than Baadare (local). The magnitude of harvest index depends upon the extent of partitioning of dry matter to grain, leaves, stems, roots and nodules (Hall *et al*., 1994).

CONCLUSIONS

Based on the findings from this study, it was concluded that, there was significant response to applied PR and that application of 25 kg PR ha^{-1} was adequate for cowpea production. Baadare, a local variety was more adapted and efficient in solubilizing PR than IAR-48 under Sokoto semi-arid condition. Therefore, Baadre could be recommended for Sudan savanna zone if the source of P is phosphate rock.

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REFERENCES

Brouwer, J. and J.M. Powell, 1995. Soil Aspects of Nutrient Cycling in a Manure Application Experiment in Niger. In: Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa. Powell, J.M. *et al.* (Eds.), Vol. 11. Tech. Pap. Int. Livestock ctr for Africa, Addis Ababa Ethiopia, pp: 211-226.

Chien, S.H. and R.G. Menon, 1995. Factors affecting the agronomic effectiveness of phosphate rock for direct application. Fertilizer Res., 41: 227-234.

Fixen, P.E. and J.N. Groven, 1990. Testing Soils for Phosphorus. In: Soil Testing and Plant Analysis. Westerman, R.L. (Ed.), 3rd Edn., SSSA Book Series No. 3, Soil Science Society of America MADISON, WI., pp: 141-180.

Gibbon, D. and A. Pain, 1985. Intermediate Tropical Agriculture Series. Longman Group Ltd., pp: 111-112.

Hall, A.E., R.A. Richards, A.G. Condon, G.C. Wright and G.D. Farquhar, 1994. Carbon Isotope Discrimination and Plant Breeding. In: Plant Breeding Reviews. Janick, J. (Ed.), Vol. 12, John Wiley and Sons, NY., USA., pp: 81-113.

Hammond, L.L., S.H. Chien and A.U. Mokwunye, 1986. Agronomic evaluation of unacidulated and partially acidulated phosphate rocks indigenous to the tropics. Adv. Agron., 40: 89-140.

IART (Institute for Agricultural Research and Training), 1994. Boosting the Supply of Agricultural Raw Materials for Industrial Use. Final Report Submitted to Rmrdc on On-farm Trial of Agro Mineral and Fertilizer Sources Developed from Sokoto Rock Phosphate. In: RMRDC Publication, 97: 189-193.

Ismail, A.M. and A.E. Hall, 1993. Correlation between water-use efficiency and carbon Isotope discrimination in diverse Cowpea genotypes and Isogenic lines. Crop Sci., 32: 7-12.

Jama, B., R.A. Swinkels and R.J. Buresh, 1997. Agronomic and economic evaluation of organic and inorganic sources of phosphorus in western Kenya. Agron. J., 89: 597-604.

Krasilnikoff, G., T.S. gahoonia and N.E. Nielsen, 2002. Phosphorus Uptake from Sparingly Available Soil-P by Cowpea (*Vigna unguiculata*) Genotypes. pp: 239-250. In: Integrated Plant Nutrient Management in Sub-Saharan Africa: From Concept to Practice. Vanlauwe, B., J. Diels, N. Sanginga and R. Merckx (Eds.), CABI Publishing, CAB International, Wallingford, Oxon, UK., pp: 352.

Natarajan, M. and D.M. Naik, 1992. Competitive effects of short duration bush type cowpea when intercropped with cotton in Zimbabwe. Exp. Agric., 28: 409-416.

Ogunbodede, B.A. and T. Fatunla, 1985. Quantitative Studies of some Cowpea (*Vigna unguiculata* (L.) Walp.) traits. East Afr. Agric. For. J., 50: 89-100.

Okeleye, K.A. and M.A.O. Okelana, 1997. Effect of phosphorus fertilizer on nodulation, growth and yield of cowpea (*Vigna unguiculata*) varieties. Indian J. Agric. Sci., 67: 10-12.

Peter, M.A., 1970. West African Soils. Oxford University Press, London, pp: 156.

Petrie, C.L. and A.E. Hall, 1992. Water relations in Cowpea and Pearl Millet under soil water deficits: 11 water use and root distribution. Aust. J. Plant Physiol., 19: 591-600.

Quin, F.M., 1997. Introduction. In: Advances in Cowpea Research. Singh, B.B., D.R. Mohan Raji, K.E. Dashell and L.E.N. Jackai (Eds.), Co Publication of International Institute of Tropical Agricultural (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS) IITA Ibadan, Nigeria, pp: 9-15.

Rao, N.N.P., 1983. Preliminary results of the study on Agro climatology of Sokoto State. A Seminar Paper, University of Sokoto.

Rao, I.M., D.K. Friesen and W.J. Host, 1999. Opportunities for germplsm selection to influence phosphorus acquisition from low-phosphorus soils. Agrofor. Forum, 9: 13-17.

Sanchez, P.A., K.D. Shepherd, M.J. Soule, F.M. Place, R.J. Buresh, A.M.N. Izac, A.U. Mowunye, F.R. Kwesiga, C.J. Ndiritu and P.L. Woomer, 1997. Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital. In: Replenishing Soil Fertility in Africa. Buresh, R.J., P.A. Sanchez and F.G. Calhoun (Eds.), 1st Edn., ASA, SSSA, Madison, Wisconsin, pp: 1-46.

SAS (Statistical Analysis System), 2003. SAS Release 9.1 for Windows. SAS Institute Inc., Cary, NC, USA.

Singh, B.R., 1995. Soil Management strategies for the semi-arid ecosystem in Nigeria. The case of Sokoto and Kebbi states. Afr. Soils, 25: 317-320.

Singh, B.B., S.K. Asante, H. Ajeigbe and S.G. Mohammad, 2000. Geberal guide for cowpea cultivation and seed production SG 2000, Nigerian projects. International Institute of Tropical Agriculture (IITA) Kano Station Nigeria, pp: 5-6.

Ziska, L.H., A.E. Hall and R.M. Hoover, 1985. Irrigation management method for reducing water use of cowpea (*Vigna unguiculata* L.)Walp. and Lima beans (*Phaseolus lunatus* L.) While maintaining seed yield at maximum levels. Irrig. Sci., 6: 223-239.