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Influence of phosphorus on the performance of cowpea (*Vigna unguiculata* (L) Walp.) varieties in the Sudan savanna of Nigeria

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ABSTRACT

Savanna regions of Nigeria are deficient in nitrogen and phosphorus, which retard the growth and yield of crops. Therefore, a study was conducted in the wet season of 2006 at the Dry Land Teaching and Research Farm of Usmanu Danfodiyo University, Sokoto to evaluate the effect of phosphorus on the growth and yield of two cowpea varieties sourced from Republic of Niger. Treatment consisted of four (4) rates of phosphorus (0, 20, 40, 60 kg·ha^{-1}) factorialy combined with (2) varieties of cowpea (KVX303096G and TN5-78) and laid out in a randomized complete block design (RCBD) replicated three (3) times. Results showed significant response to applied P on pods per plant, grain and stover yield and 100-seed weight with highest response to the application of 60 kg P ha^{-1}. From this study it can be concluded that KVX303096G and TN5-78 could both be sown under Sokoto condition to obtain reasonable yield of about 1 t·ha^{-1} of grain and 1.6 t·ha^{-1} of stover. Irrespective of the varieties, application of 60 kg P_2O_5 ha^{-1} could be recommended for higher yield of cowpea (1.4 t·ha^{-1}) relative to 0 kg P/ha that yielded 1.0 t·ha^{-1}.

Keywords: Cowpea [*Vigna Unguiculata* (L.) Walp.]; Phosphorus; Sudan Savanna; Nigeria

1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important grain legume in the dry savanna of the tropics covering 12.5 million hectares with annual production of about 3.3 million tones [1]. Nigeria is the world's largest producer with 2.1 million tones followed by Niger with 650,000 tones and Mali with 110,000 tones [2]. About 64% of the area under cowpea is grown in central and east Africa. Cowpea is mostly cultivated in mixture with others crops such as millet and sorghum mostly in Sahelian and Sudan region.

Cowpea is well adapted to poor fertility and low rainfall conditions. Cowpea grows best on fertile, loam soils with rainfall of 760 - 1520 mm during the growing period, and thrives best on dry areas of Northern part of Nigeria and transported to the Southern part of Nigeria [3]. Cowpea is an important crop because of its role in human and livestock nutrition. It reduces the shortage of food by making efficient use of water and nutrient. It is a source of protein and also less expensive than meat. Cowpea is of vital importance to the livelihood of several million of people in east and central Africa [4]. Cowpea is an important legume crop in the dry savannas of Africa, especially West Africa. Out of the 12.5 million hectare cultivated to cowpea worldwide, Singh *et al.* [5] estimated that eight million hectare are in West and Central Africa, distributed predominantly between Nigeria and Niger. In spite of the fact that grain yields are low, cowpea has continued to be a popular crop among farmers. This is because cowpea provides high protein food for people, especially children; it improves and sustains soil fertility, and provides high quality fodder for livestock [6,7]. Cowpea contributes to the improvement of soil fertility by the fixation of nitrogen (N) in the soil (60 - 70 kg·N·ha^{-1} to the subsequent crop) [8]. The result obtained from a research work carried by IITA [9] showed that cowpea fixed 240 kg·ha^{-1} of N. The crop provides a high proportion of its own requirement, besides leaving a fixed N deposit in the soil of up to 60 - 70 kg·ha^{-1}. In addition to its role-played in mixture with cereals, the crop is advantageous in terms of weed control, soil cover, protection from soil erosion and dispersal of insects [10].

Phosphorus (P) is among the most needed elements for crop production in many tropical soils. However, many tropical soils are P-deficient [11]. Phosphorus, although not required in large quantities, is critical to cowpea yield because of its multiple effects on nutrition [12]. All growing plants require P for growth and development in significantly large quantity. P deficiency is the most limiting soil fertility factor for cowpea production [10]. Phosphorus although not required in large quantities is critical to cowpea yield (particularly for improved photoperiod-insensitive cultivars) because of its multiples effects on nutrition. It not only increases seed yields but also nodulation. Others workers have reported that phosphorus application influences the content of others nutrients in leaves [13] and seed. The deficiency can be so acute in some soils of the savanna zone of western Africa that plant growth ceases as soon as the P stored in the seed is exhausted [14]. Because of its multiple effects on plant nutrition (not only on nodulation), a phosphorus fertilizer is recommended to increase yields (P_2O_5: 20 - 60 kg·ha^{-1}) [10]. Smyth and Cravo [15] working on Xanthic Hapludox near Manaus, Brazil reported that for cowpea critical levels for soil P was 60 kg·P·ha^{-1}.

Despite the importance of cowpea in human diet and feed for animals, the yield obtained by most farmers is very low. In Nigeria the average yield per hectare in the respective years were 0.75 t·ha^{-1} in 1990, 0.72 t·ha^{-1} in 1991, 0.51 t·ha^{-1} in 1992, 1993 and 1994, 0.49 t·ha^{-1} in 1995, 0.45 t·ha^{-1} in 1996, 0.48 t·ha^{-1} in 1997, 0.41 t·ha^{-1} in 1998, 0.42 t·ha^{-1} in 1999, 2000, 2001 and 2002; 0.43 t·ha^{-1} 2003 and 2004 [16]. Because of the rapid increase in population, there is a high demand for food and therefore, there is a need to augment the production of cowpea. N is not critical for legumes because legumes fix atmospheric N_2 through symbiotic association with strains of *Rhizobium* sp. Phosphorus is the second most important nutrient after N and could be used to increase production of cowpea as most soils in the tropics are P deficient. Phosphorus is known to increases the yield of cowpea by increased N_2 fixation through nodulation and utilization of N fertilizer [10]. Thus, this study was conducted to evaluate the effect of phosphorus fertilizer on yield of cowpea and select cowpea variety responsive to phosphorus application.

2. MATERIALS AND METHODS

The experiment was conducted in 2006 cropping season at the dry land farm of Usmanu Danfodiyo University, Sokoto. Sokoto is located on latitude 13˚01′ N and at longitude 05˚15′ E and lies at an altitude of 350 m above the sea level. It falls in Sudan Savanna agro-ecological zone. The rainfall starts mostly in June and ends in October with a mean annual rainfall of about 350 - 700 mm. The maximum and minimum temperature of Sokoto ranges from 40 to 15˚C, respectively [17]. The treatments consisted of factorial combinations of four (4) levels of phosphorous (0, 20, 40 and 60) and twovarieties of cowpea (KVX303096G and T5-78) (8 treatment combinations) laid out in a randomized complete block design (RCBD) replicated 3 times.

The seeds of cowpea varieties were obtained from the research institute of Niger Republic known as INRAN in Tahoua State and sown on the 18th of June, 2006. Two seeds were sown per hill at a depth of 3 - 4 cm and 75 cm apart at a plant-to-plant spacing of 50 cm within a row. Urea at the rate 15 kg·ha^{-1} was applied as a starter dose to all the plots while P_2O_5 was applied as per treatment (0, 20, 40, and 60 kg P_2O_5 ha^{-1}). Weeding was carried out twice manually at 5 and 8 weeks after sowing. The plots were sprayed with karate (*Lambda cyhorlothrim*) to take care of *Aphis craccivora*. Harvesting was done manually at physiological maturity when the pods had turned yellowish brown.

Data collected on yield parameters were subjected to analysis of variance (ANOVA) technique using Statistical Analysis System (SAS) [18]. Significant different between treatments were further analyzed using least significant different test (LSD) for mean separation.

3. RESULTS AND DISCUSSION

3.1. Physico-Chemical Properties of the Soil

The general chemical and physical properties of the surface soils (0 - 15 cm) used for the field experiments are presented in **Table 1**. Soils at the experimental site were largely Sandy and the soil pH (H_2O) was moderately acidic (6.5). The organic carbon (OC), total N and available P in the soil was very low while exchangeable K in the soil at the experimental site was low. The total annual rainfall at the experimental site was 604 mm with peak in August. The rain established in June and ceased in October coinciding with sowing and harvesting of cowpea, respectively (**Figure 1**).

Table 1. Physico-chemical characteristic of the soil at the experiment site.

Parameters	Value	Remarks
Texture	Sandy	
pH in water	6.50	Mod. acidic
pH in $CaCl_2$	6.19	
Total phosphorus (P) (mg·kg^{-1})	1.80	Very Low
Organic carbon (g·kg^{-1})	1.58	Very Low
Total nitrogen (N) (g·kg^{-1})	0.65	Very low
Exchangeable potassium (K) (cmol·kg^{-1})	0.65	Low

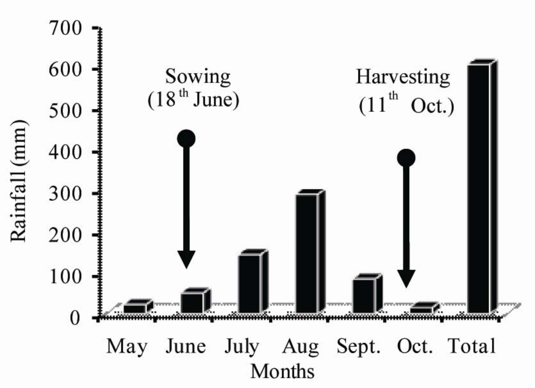

Figure 1. Monthly rainfall pattern and total annual rainfall at the Experimental site. (Source: Energy Research Center, Usmanu Danfodiyo University, Sokoto).

Table 2. Effect of variety and phosphorus on the number of pods per plant and seeds per pod.

Treatment	Pods per plant	Seeds per pod
Variety (V)		
KVX303096G	52 ± 6.8	9.7 ± 2.8
TN5-78	49 ± 8.4	10.8 ± 3.8
SE	2.1	0.51
Significance level	ns	ns
Phosphorus (P)		
0	43 ± 8.3^{b}	11.1 ± 1.8
20	50 ± 7.8^{ab}	9.9 ± 1.2
40	54 ± 3.4^{a}	10.3 ± 2.4
60	54 ± 3.2^{a}	9.7 ± 1.8
SE	2.9	0.73
Significance level	s	ns
Interaction		
V × P	ns	ns

3.2. Number of Pods per Plant and Seeds per Pod

There was no significant effect of the variety on the number of pods per plant. However, variety KVX303096 G recorded higher number of pods per plant (52) than the variety TN5-78 (49) **(Table 2).** Phosphorus had significant ($P < 0.05$) effect on the number of pods per plant. Significantly ($P < 0.05$) higher pods per plant were recorded in plots applied with 40 (54) and 60 (54) kg P ha^{-1} than 0 (43) and 20 (50) kg P ha^{-1} (**Table 2**). This could be due to higher level of *P* in those plots. Mokwunye and Bationo [19] have reported that, P is essential for photosynthesis, pod development and grain filling in leguminous crops. *P* is responsible for nodulation in cowpea. Thus higher nodulation resulted in higher nitrogen fixation and eventually the number of pods per plant. There was no significant effect of interaction of variety and phosphorus on pods per plant.

The results of the present study are higher than that recorded by Okeleye *et al.* [20] where the number of pods per plants obtained ranged from 7.3 to 30.8 by applying a rate of 20 and 30 kg P ha^{-1} using short and medium duration cowpea varieties.

Both the variety and phosphorus had no significant effect on the number of seeds per pod. Statistically similar seed number per pod was recorded in variety TN5-78 (10.8) and KVX303096G(9.7). Interaction between variety and phosphorus had no significant effect on the number of seeds per pod**.**

3.3. Grain and Stover Yield

There was significant effect of phosphorus on the stover yield of cowpea. Similar to the grain yield, significantly ($P < 0.05$) higher stover yield was recorded in plots supplied with 60 (2115 kg·ha^{-1}) than with 0 (1411 kg·ha^{-1}), 20 (1482 kg·ha^{-1}) and 40 kg P_2O_5 ha^{-1} (1571 kg·ha^{-1}). This could again be attributed to the availability of P that would have increased the intensity of nodulation and thus nitrogen fixation. Higher nitrogen fixation would result in higher yield of the crop. Interaction between phosphorus and variety had no significant effect on the stover yield of cowpea.

Variety had no significant effect on the grain yield of cowpea. Statistically similar grain yield was recorded in both KVX303096G (1120 kg·ha^{-1}) and TN5-78 (1074 kg·ha^{-1}) (**Table 3**). This indicated the similar performance of the two varieties under Sokoto agro-ecology.

There was significant ($P < 0.05$) response to applied P on the grain yield of cowpea. Significantly higher grain yield was recorded in plots applied to 60 (1353 kg·ha^{-1}) than 0 (1017 kg·ha^{-1}), 20 (1067 kg·ha^{-1}) and 40 kg P ha^{-1} (951 kg·ha^{-1}). Application of 20 and 40 kg P_2O_5 ha^{-1} was

Table 3. Effect of variety, phosphorus and their interaction on the grain and stover yield of cowpea.

P levels (kg·ha^{-1})	Variety		Mean phosphorus levels (Main effect P)
	KVX303096G	TN5-78	
	Grain yield (kg·ha^{-1})		
0	928 ± 239 b	1106 ± 188 ab	1017±216 b
20	1165 ± 179 ab	968 ± 218 b	1067±209 b
40	914 ± 82 b	988 ± 298 b	951±200 b
60	1472 ± 266 a	1235 ± 61 a	1353±216 a
Means Variety	1120 ± 294	1074 ± 211	
SE	$SE_{Variety}$ = 62.6; $SE_{phosphorus}$ = 88.6; $SE_{Variety \times Phosphorus}$ = 125.28		
	Stover yield (kg·ha^{-1})		
0	1314 ± 261	1509 ± 522	1411 ± 384 b
20	1753 ± 665	1546 ± 202	1649 ± 454 ab
40	1595 ± 416	1881 ± 539	1738 ± 458 ab
60	2072 ± 265	2158 ± 284	2115 ± 250 a
Means Variety	1684 ± 468	1773 ± 449	
SE	$SE_{Variety}$ = 100.1; $SE_{phosphorus}$ = 141.5; $SE_{Variety \times Phosphorus}$ = 259.9		

Values following ± are standard deviation of the means. Means in a column for Phosphorus and across row and column for variety x P interaction followed by same letter (s) are not significantly different at 5% level, ns = Not significant, *Significant at 5% level.

not different from those plots that were not applied with P (0 kg P ha^{-1}). This indicated that P became a limiting factor at later stage of plant growth. Higher yield recorded with 60 kg·ha^{-1} was attributed to higher availability of *P* that is responsible for effective nodulation in cowpea. Okeleye and Okelana [21] also observed significantly increased nodulation, grain yield, and total dry matter for cowpea varieties in response to P application.

Variety had no significant effect on the stover yield of cowpea as both varieties recorded 1600 kg·ha^{-1} of cowpea stover (**Table 3**).

There was significant effect of phosphorus on the stover yield of cowpea. Similar to the grain yield, significantly ($P < 0.05$) higher stover yield was recorded in plots supplied with 60 (2115 kg·ha^{-1}) than with 0 (1411 kg·ha^{-1}), 20 (1482 kg·ha^{-1}) and 40 kg P_2O_5 ha^{-1} (1571 kg·ha^{-1}). This could again be attributed to the availability of P that would have increased the intensity of nodulation and thus nitrogen fixation. Higher nitrogen fixation would result in higher yield of the crop. Interaction between phosphorus and variety had no significant effect on the stover yield of cowpea.

3.4. Harvest Index and 100-Seed Weight

Harvest index is the proportion of grain in the total aboveground biomass of the crop expressed in percentage and it ranged from 36% to 40%. This indicated that only 36% to 40% of the photosynthate was translocated to the grain. Variety did not have significant influence on the HI of the crop. KVX303096G recorded statistically ($P > 0.05$) similar HI with TN5-78 variety (**Table 4**). *P* also did not have significant influence on the HI of the crop implying that HI is a genetic trait and will only be influenced by variety differences. Effect of interaction between variety and phosphorus was not significant (**Table 4**).

There was no significant effect of variety on the hundred seeds weight (**Figure 2**). The two varieties recorded similar 100-seed weight of about 20.2 g. Effect of phosphorus on 100-seed weight was significant ($P < 0.05$)

Table 4. Effect of variety, phosphorus and their interaction on harvest index of cowpea.

P levels (kg·ha^{-1})	Harvest index (%) KVX303096G	Harvest index (%) TN5-78	Mean phosphorus levels
0	41.2 ± 1.8	43.0 ± 6.6	42 ± 4.4
20	40.9 ± 6.4	38.4 ± 6.9	40 ± 6.1
40	37.0 ± 5.7	35.2 ±13.7	36 ± 9.4
60	41.4 ± 1.4	36.6 ± 3.7	39 ± 3.7
Means Variety	40.0 ± 4.2	38.0 ± 7.9	
SE	$SE_{Variety}$ = 2.10; $SE_{phosphorus}$ = 2.97; $SE_{Variety \times Phosphorus}$ = 4.196		

Values following ± are standard deviation of the means.

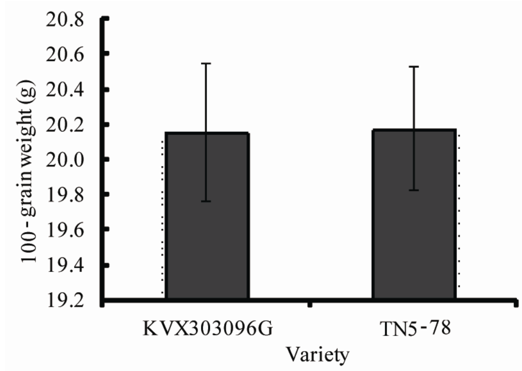

Figure 2. Main effect of variety on 100-seed weight of cowpea.

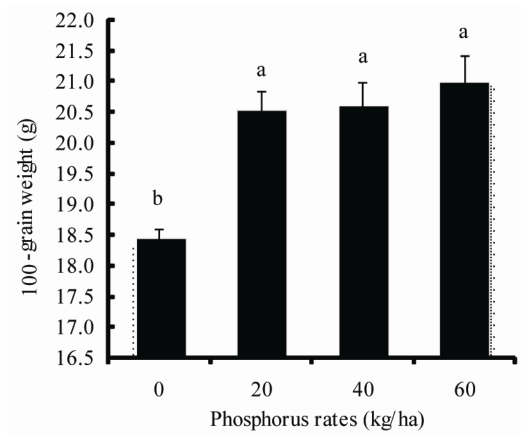

Figure 3. Main effect of phosphorus levels on 100-seed weight of cowpea. Bars with same letter (s) are not significantly different using LSD at 5% level.

Table 5. Interaction effect of variety x phosphorus on 100-grain weight of cowpea.

Phosphorus levels (kg·ha^{-1})	100-grain weight (g) KVX303096G	100-grain weight (g) TN5-78
0	18.32 ± 0.06 b	18.59 ± 0.54 b
20	20.51 ± 1.05 a	20.60 ± 0.23 a
40	21.50 ± 0.57 a	20.54 ± 0.93 a
60	20.30 ± 0.73 a	20.98 ± 1.31 a
SE	0.439	

Values following ± are standard deviation of the means. Means across rows and columns followed by same letter (s) are not significantly different using LSD at 5% level.

with 40 kg·ha^{-1} (54.17 g) and 60 kg·ha^{-1} (54.17 g) recording significantly higher 100-seed weight than 0 kg P ha^{-1} (42.83 g) (**Figure 3**). The interaction of variety and phosphorus on 100-grain weight of cowpea was significant (**Table 5**). For both variety KVX303096G and TN5-78, application of 20, 40 and 60 kg P ha^{-1} resulted in similar 100-grain weight (**Table 5**). For all levels of P including control, the two varieties were at par. These results coincide with the results recorded by Okeleye *et al*. [20] where the weight of 100 seed of cowpea ranged from 13.50 to 39.7 g by the application of 20 and 30 kg P ha^{-1}. Phosphorus intervenes in the formation of seed and improves seed quality [21].

4. CONCLUSIONS

From this study it can be concluded that KVX303096G and TN5-78 could both be sown under Sokoto condition to obtain reasonable yield of about 1 $t \cdot ha^{-1}$ of grain and 1.6 $t \cdot ha^{-1}$ of stover. Irrespective of the varieties, application of 60 kg P_2O_5 ha^{-1} could be recommended for higher yield of cowpea (1.4 $t \cdot ha^{-1}$) relative to 0 kg P_2O_5 ha^{-1} that yielded 1.0 $t \cdot ha^{-1}$. However, 60 kg P_2O_5 ha^{-1} may not be the optimum as further application of P may or may not increase the yield of cowpea. Therefore it is subject to investigation.

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