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Phosphorus effects on growth and yield of groundnut varieties in the tropical savannas of northeast Nigeria

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Abstract

Groundnut production in northeast Nigeria is constrained by low level of soil phosphorus. This study evaluated four groundnut varieties for their response to P fertilization in two Nigerian agro-ecological zones (Sudan and Northern Guinea savanna) during 2005 and 2006. The experimental design was split plot with 0, 20, and 40 kg P ha^{-1} in the main plots and groundnut varieties ('Samnut 22', 'local Wadabura', 'Samnut 21', and 'Samnut 23') in the subplots. Pod yield increased linearly with increasing P rates in both years. Mean pod yield was higher by 49.3% at 20 kg and by 57.8% at 40 kg P ha^{-1} compared with unfertilized plots. 'Samnut 23' gave more grain yield than other varieties at both locations in 2005 and in Damboa during 2006. It is also an early maturing variety, and can thus be recommended to the farmers in Sudan savanna, which experiences short rainy seasons. However, for farmers interested in fodder production for livestock in addition to grain, the local variety, 'Samnut 21', and 'Samnut 22' are more appropriate.

Keywords: Agro-ecological zones, Early maturing, Grain yield, Fodder.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important cash and food grain legume crop grown for its edible oil- and protein-rich kernels in Sudan savanna (SS) and Northern Guinea savanna (NGS) of Nigeria. Groundnut cultivation in Northern Nigeria is expected to increase. As a leguminous crop, it does not require high amounts of nitrogenous fertilizers, hence most farmers in these ecological zones prefer to grow groundnut on poor soils without fertilizers. Groundnut is also an easily marketed cash crop that increases farmers' income, and is sometimes grown as a sole crop in rotation with cereals to reduce infestation by the parasitic weed, *Striga hermonthica*.

Phosphorus (P) deficiency is the most frequent nutrient stress for growth and development of grain legumes including groundnut (Kamara et al., 2008) in the Nigerian savannas. Mean soil P levels were 1.50 and 2.51 mg kg^{-1} in bush fields and compound fields in SS and 3.68 and 4.70 mg kg^{-1} in bush field and compound fields in SS and NGS, respectively (Kwari, 2005). As with other legumes, added phosphates may have beneficial effects on growth, nodulation, and nitrogen fixation of groundnut. Crop species and varieties, however, differ in their tolerance to low soil P and in their ability to utilise weakly soluble P sources under different climatic, soil, and management conditions. The Project, Promoting Sustainable Agriculture in Borno State (PROSAB), has introduced and disseminated three improved varieties of groundnut for farmers' use through the International Institute of Tropical Agriculture, Ibadan. These varieties can be grown in

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rotation with cereals to reduce *Striga* infestation and improve soil fertility. The response to P application of these varieties, however, is not known. Thus the three improved groundnut varieties were evaluated for their response to application of P in the SS and NGS alongside a local variety.

Materials and Methods

Field experiments were conducted in 2005 and 2006 in Wandali in the NGS (10°34.380' N and 11°58.649' E) and Damboa in the SS (11°10.739' N and 12°47.145' E). The soils in both locations were Alfisols formed on basement complex in Wandali and on argillaceous sediments in Damboa (Kwari et al., 1999). Separate but adjacent plots within each site were used each year to avoid the residual effects of applied fertilizers. At the beginning of the trials, composite soil samples (0 to 15 cm) were collected from each experimental site with an auger. Each composite sample contained 15 subsamples taken along three transects across the field and mixed together. The soil samples were air-dried and crushed using a pestle and mortar and passed through a 2 mm sieve and stored in sealed polythene bags for analysis. The soil samples were analyzed for texture, pH, organic carbon (dichromate oxidation), and total N (Kjeldhal method). Exchangeable K, available P, zinc (Zn), and copper (Cu) were extracted with Mehlich-3 solution. K was determined flame-photometrically and P using a spectrophotometer. Zn and Cu were determined using an atomic absorption spectrophotometer. Available sulphur was extracted with 0.01 M monocalcium phosphate and determined by the turbidimetric method. The characteristics of soils at the two sites are summarized in Table 1. The soil in Wandali had more organic matter than Damboa. However, P, zinc (Zn) and copper (Cu) are major limiting factors at both locations.

Table 1. Soil properties of two experimental locations in Borno State, northeast Nigeria.

Soil Properties	Damboa	Wandali
Sand (%)	33.7	66.2
Silt (%)	45.0	12.5
Clay (%)	21.3	21.3
Textural Class	L	SCL
pH 1:2.5 (H_20)	5.93	6.11
Organic C (%)	0.82	1.07
Total N (g kg^{-1})	0.70	0.84
Available P (mg kg^{-1})	2.1	2.8
Exchangeable K (meq 100 g^{-1})	0.36	0.36
Available S (mg kg^{-1})	9.56	7.01
Available Zn (mg kg^{-1})	0.066	0.141
Available Cu (mg kg^{-1})	0.034	0.048

The experimental design was split plot with 0, 20, and 40 kg P ha^{-1} in the main plots and groundnut varieties (‘Samnut 22’, ‘local Wadabura’, ‘Samnut 21’, and ‘Samnut 23’) in the subplots (4 ×5 m). The experimental site was cleared, tilled with a disc harrow, and ridges were prepared using work-bulls mounted with mouldboard ploughs. In Damboa, plots were sown on 6 July 2005 and 29 June 2006. In Wandali, sowing was on 29 June 2005 and 20 June 2006. At both locations two seeds per hill were planted with 25 cm between hills and 75 cm between rows to give a total plant population of about 106, 666 plants ha^{-1}. Each plot received a basal application of 30 kg K ha^{-1} as muriate of potash. All fertilizers were applied at planting by drilling. Paraquat (1:1 dimethly-4, 4'-bipyridinium dichloride) was applied at the rate of 276 g a.i L^{-1} immediately after planting to control weeds. Each subplot was weeded three times. Data were collected on days to 50% flowering, days to physiological maturity, dry matter accumulation (fodder yield), and number of pods $plant^{-1}$. Pod yield was determined from two central rows. In Damboa, pods were harvested on 13 October 2005 and 10 October 2006. In Wandali, harvest was on 24 October 2005 and 6 October 2006.

All data were subjected to ANOVA using PROC MIXED statements (SAS, 2000). Block was treated as random effect while P levels and groundnut varieties were treated as fixed effects in determining the expected mean square and appropriate F test in the analysis of variance. LSD at 5% probability level was calculated and used for comparing treatment means. Pearson’s correlation coefficients were calculated between days to 50% flowering and maturity using PROC CORR of SAS (SAS, 2000).

Results

At both locations, days to 50% flowering was influenced by year and variety (p <0.0001). Year × variety interaction was, however, significant (p = 0.0272) only at Damboa. P fertilization had no significant effect on days to 50% flowering. At both locations, 50% flowering was earlier in 2006 than in 2005 (Table 2). At Damboa, all varieties reached 50% flowering 8 to 10 days earlier in 2006 than in 2005. 'Samnut 23' reached 50% flowering two days before the other improved varieties in Damboa, as expected, and 2 to 3 days before them in Wandali.

Year and variety (p<0.001) but not P application influenced days to maturity. All varieties at both locations reached maturity later in 2006 than in 2005 (Table 2). The local variety had a maturity period similar to that of 'Samnut 21' at both locations in 2005. 'Samnut 23', however, matured much earlier than the other varieties in both years (Table 2). Averaged across years, 'Samnut 23' matured 19 days earlier than the local variety and 'Samnut 21', and 23 days before 'Samnut 21' at Damboa. In Wandali, 'Samnut 23' matured 18 to 19 days before the other varieties. There was a significant inverse correlation between days to 50% flowering and maturity period at Damboa (r = –0.26; p = 0.0281) and at Wandali (r = –0.34; p = 0.0035).

Number of pods plant^{-1} and 100-kernel weight were influenced by year and variety (p = 0.001) at both locations. Number of pods plant^{-1} responded significantly (p = 0.0130) to P application in Damboa but not in Wandali (p = 0.3058). At Damboa, the number of pods plant^{-1} increased linearly with P application (16, 19, and 20 pods plant^{-1} at 0, 20, and 40 P kg ha^{-1} respectively). At both locations, the mean number of pods was significantly higher in 2005 (20.7 and 27.7 pods plant^{-1} at Damboa and Wandali respectively) than in 2006 (15.5 and 14.0 pods plant^{-1} at Damboa and Wandali respectively). The local variety with a longer growth cycle had a significantly lower number of pods (14 to 17 pods plant^{-1}) than the improved varieties (18 to 23 pods plant^{-1}) at both locations. 'Samnut 23' with a shorter growth cycle produced significantly more pods than 'Samnut 21'; and 'Samnut 22' in Damboa. At Wandali, however, the average (23 pods plant^{-1}) was similar for all improved varieties.

Year, P application, and variety had significant effects on pod yield (p <0.001). The interaction between year and P application (p = 0.004) in Damboa and between year and variety (p = 0.0197) in Wandali were also significant. In 2005, pod yield was higher in Wandali than in Damboa but not in 2006 (Table 3). In Damboa, pod yield was significantly higher in 2006 than in 2005 at all P rates (Table 3). In both years, pod yield increased linearly with increasing P rates re-confirming P as the major nutrient limiting groundnut production. The difference in pod yield between 20 kg and 40 kg P ha^{-1}

Table 2. Varietal differences on days to 50% flowering and groundnut maturity in 2005 and 2006 at Damboa and Wandali, northeast Borno State, Nigeria.

	Days to 50% flowering						Days to maturity					
	Damboa			Wandali			Damboa			Wandali		
Variety	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
Local	48.8	41.1	44.9	50.6	43.4	47.0	116.4	125.1	120.8	113.2	126.8	120.0
'Samnut 21'	46.8	36.7	41.7	50.3	42.6	46.5	122.8	125.1	124.0	115.0	126.9	120.9
'Samnut 22'	45.7	35.7	40.7	48.9	41.9	45.4	115.7	125.4	120.6	112.1	127.1	119.6
'Samnut 23'	44.6	34.6	39.6	47.0	39.8	43.4	89.9	112.8	101.4	90.8	111.7	101.2
Mean	46.4	37.0		49.2	41.9		111.2	122.1		107.8	123.1	
L.S.D year (Y)	0.69			1.74			0.81			1.91		
L.S.D variety (V)	0.87			1.01			1.28			2.58		
L.S.D (Y x V)	1.27			1.41			1.82			3.65		

was significant in 2005 but not in 2006. Averaged across years, pod yield was higher by 49.3% at 20 kg and 57.8% at 40 kg P ha^{-1} over no fertilization. In Wandali, pod yield was higher in 2005 than in 2006. Although there was a linear response in pod yield to P fertilization, a significant difference in pod yield was noted only between 40 kg P ha^{-1} and no fertilization at this location. In Damboa, pod yield was generally higher in 2006 than in 2005 (Table 4). At this location, 'Samnut 23' significantly out-yielded 'Samnut 21', 'Samnut 22' and the local variety. In Wandali, 'Samnut 23' yielded significantly higher than the other varieties in 2005 but in 2006 its yield was lower than that of 'Samnut 22' though the difference was not significant (Table 3). Averaged across years, 'Samnut 23' yielded 17.8% more than 'Samnut 21' and 26.6% more than the unfertilized treatment.

At both locations, P application and variety influenced fodder yield. At Damboa, year by variety interaction was significant (p = 0.0415). Fodder yield of 'Samnut 23' was significantly lower than that of the other varieties in both years at this location (Table 4). The local variety had a fodder yield similar to that of 'Samnut 22' but produced significantly more than 'Samnut 21'. A similar trend was observed in Wandali (Table 4). Phosphorus application at 40 kg ha^{-1} significantly depressed fodder yield by 19.3% at Damboa and by 20% at Wandali compared to 20 kg P ha^{-1}.

Discussion

The results showed significant response of grain yield and yield components to P application confirming the importance of P for groundnut production in the Nigerian savannas. According to Kwari (2005), the soil P levels in the trial sites were far below the critical values recommended for groundnut. There were no P × V interactions suggesting that the varieties responded

Table 3. Effect of phosphorus on pod yield in Damboa and Wandali, northeast Borno State, Nigeria.

	Damboa			Wandali		
Phosphorus level (kg ha^{-1})	2005	2006	Mean	2005 (pod yield, kg ha^{-1})	2006	Mean
0	1062	1568	1315	1918	1717	1818
20	1114	2340	1727	2057	1852	1955
40	1460	2474	1967	2140	2093	2116
Mean	1212	2127		2038	1887	
L.S.D year (Y)		160.6			154.7	
L.S.D phosphorus (P)		196.7			189.4	
L.S.D (P x V)		309.1			253.6	

Table 4. Effect of variety on pod and fodder yields in Damboa and Wandali, northeast Borno State, Nigeria.

	Pod yield (kg ha^{-1})						Fodder yield (kg ha^{-1})					
	Damboa			Wandali			Damboa			Wandali		
Variety	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
Local	958	2028	1493	1838	1586	1789	4359	3292	3826	3207	4285	3746
'Samnut 21'	1148	2043	1595	1843	1592	1862	2769	2756	2763	2676	2926	2801
'Samnut 22'	1251	1986	1618	1673	1921	2006	4012	3033	3523	2966	3925	3445
'Samnut 23'	1492	2453	1972	2320	1769	2006	1897	2328	2112	2242	2323	2282
Mean	1212	2127		2038	1887		3260	2852		2773	3365	
L.S.D year (Y)	160.6			154.7			447.6			394.3		
L.S.D variety (V)	227.2			218.8			633.1			557.6		
L.S.D (Y x V)	273.3			266.9			776.4			689.1		

similarly to P application. There were, however, location-specific differences in the magnitude of varietal response to P. Inter-annual differences in groundnut performance were also prominent. While flowering was delayed in 2005 because of water deficit during the growing season (Table 5), days to maturity was shorter in 2005. Despite this, pods per plant and pod yield were higher in 2005 than in 2006 at both locations. The relatively lower rainfall in July 2005 apparently had no negative effects on pod yield. The long growing season in 2006 resulted in longer growth period which delayed maturity. Previous studies (Sivakumar and Sarma, 1986) also reported higher yield owing to a mild drought stress during the pre-flowering phase, which promoted peg and pod productivity.

Location by year interactions in terms of pod yield was probably due to differences in soil temperature during the cropping season. A more favourable soil temperature regime due to the relatively less rainfall received in September 2005 in Wandali may partly explain the higher pod yields at that location. Temperature has a profound effect on the partitioning of dry matter in groundnut (Ong, 1984). Damboa in the SS zone has a characteristically higher temperature regime and greater light intensity than those at Wandali (NGS), which explain the higher pod yield obtained at Damboa in 2006. The optimum temperature for vegetative growth (photosynthesis and dry matter production) for groundnut is about 30°C; and higher the temperature than this, shorter will be the growth period.

Table 5. Rainfall data in Damboa and Wandali during 2005–2006, northeast Borno State, Nigeria.

	2005		2006	
	Wandali	Damboa	Wandali	Damboa
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	67	6.5	46.2	30
May	240	30.75	82.5	64
June	110.6	0	229.5	160.5
July	94	87.5	283.9	193.5
August	276	426.3	254.6	240.5
September	157	129.5	330	205.5
October	94	35.5	49.2	0
November	0	0	0	0
December	0	0	0	0
Total	1038.6	716.05	1275.9	894

Grain yield responded to P at both locations (Table 3). Carsky (2003) reported that P is a major limiting nutrient for legumes in the West African Savanna and significant responses of cowpea (*Vigna unguiculata*) and soybean (*Glycine max*) to applied P are probable. Phosphorus application at 40 kg ha^{-1}, however, significantly depressed the fodder yield (Table 4). This may be because more dry matter was translocated to the pods at 40 kg P ha^{-1} at the expense of fodder production, implying better partitioning of photosynthates between the vegetative and reproductive components at this level of P application. This is confirmed by the higher pod yields of the groundnut varieties at this P level at both locations (Table 3).

There were significant differences among varieties for days to flowering, maturity, number of pods per plant, pod, and fodder yield in both locations. At both locations, the local variety with a longer growth cycle had a significantly lower pods plant^{-1} than improved varieties but produced more fodder. ‘Samnut 23’ with a shorter growth cycle produced significantly more pods than ‘Samnut 21’ and 22 in Damboa where the rainfall duration was shorter. Among the improved varieties there was no significant difference in the mean number of pods at Wandali.

The groundnut variety ‘Samnut 23’ consistently produced higher pod yield than the other varieties. Because of shorter growth cycle, ‘Samnut 23’ completed its growth and produced pods before the rains in the savanna ceased. This makes it an attractive variety for this eco-zone. However, ‘Samnut 21’ and ‘Samnut 22’, which produced appreciable pod yield as well as enough fodder for livestock are appropriate for the Nigerian savannas where livestock fodder is in high demand particularly during the dry season.

Conclusions

This study found that groundnut responded consistently to P application, which confirms the importance of P for groundnut production in the Nigerian savannas. 'Samnut 23' matured earlier than the other varieties. The early maturing 'Samnut 23' also produced higher yields than the other varieties. Other late maturing varieties, however, produced higher fodder yields than 'Samnut 23'. The early-maturing 'Samnut 23' variety is recommended for farmers in the Sudan savanna zone with shorter rainy seasons. However, for farmers interested in fodder for their livestock in addition to grain, the local, 'Samnut 21', and 'Samnut 22' varieties are recommended.

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References

Carsky, R.J. 2003. Response of cowpea and soybean to P and K on terre de barre soils in southern Benin. Agric. Ecosyst. Environ., 100: 241–249.

Kamara, A.Y., Kwari, J.D., Ekeleme, F., Omoigui, L., and Abaidoo, R. 2008. Effect of phosphorus application and soybean cultivar on grain and dry matter yield of subsequent maize in the tropical savanna of north-eastern Nigeria. Afr. J. Biotech., 7: 2593–2599.

Kwari, J.D. 2005. Soil fertility status in some communities in southern, Borno. Final Report to PROSAB Project, Maiduguri, IITA, Nigeria, pp 21.

Kwari, J.D., Nwaka, G.I.C., and Mordi, R.I. 1999. Studies on selected soil fertility parameters in soils of North-eastern Nigeria. I. Phosphate sorption. J. Arid Agric., 9: 61–70.

Ong, C.K. 1984. The influence of temperature and water deficits on the partitioning of dry matter in groundnut (*Arachis hypogaea* L.). J. Exp. Bot., 154: 746–753.

SAS 2000. *SAS/STAT® User's Guide,* Version 8, vols 1–3. SAS Institute Inc. Cary, NC, USA.

Sivakumar, M.V.K., and Sarma, P.S. 1986. Studies on water relations of groundnut. *In*: *Agrometeorology of Groundnut.* Proceedings of an International Symposium, 21–26 August 1985, ICRISAT Sahelien Center, Niamey, Niger. Patancheru, A.P. 502 324, India, pp 83–98.