

Growth and yield response of Bambara groundnut (*Vigna subterranea* (L.) Verdc) to varying densities and Phosphate fertilizer rates in Calabar, South Eastern Nigeria

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ABSTRACT

The low sufficiency of animal protein sources has elevated the need for alternative protein sources. Despite its food security potential, bambara groundnut (*Vigna subterranea* (L.) Verdc) has remained an orphaned or neglected underutilized crop. The need to increase national output will necessitate its introduction into areas with no history of the crop. Two year field experiments were conducted at the Teaching and Research Farm of the University of Calabar, Nigeria to evaluate the effects of three planting densities (30 x 30, 30 x 40 and 30 x 50 cm) corresponding to 111,111; 83,333 and 69,400 plants ha^{-1} and four levels of P_2O_5 (0, 45, 60 and 75 kg ha^{-1}) on the yield performance of bambara nut, using a 3 x 4 factorial experiment. Treatments were dispersed using randomized complete block design with three replications. Results showed that the vegetative attributes were not significantly affected by the treatments. However, total dry matter, dry pod yield and the seed yield ha^{-1} significantly increased at 83,333 plants ha^{-1} than at other densities and resulted in the best seed yield of Bambara nut. The effects of P_2O_5 however, may have been masked due to high P fixing ability of acid soils.
Keywords: Neglected crops, Bambara nuts, Planting density, P_2O_5, yield performance

1.0 Introduction

Bambara ground nut (*Vigna subterranea* (L.) Verdc) is a drought resistant, neglected underutilized species, third after groundnut in importance. According to Swanvelder (1998), its food security potential is highly undermined. The Bambara plant makes little demand on soil nutrients, thus is useful for climate change adaptable agriculture. Bamabara groundnut increases photosynthetic capacity, through Rhizobium or Bradyrhizobium mediated biochemical sequences in the host plants roots causing nodulation and the fixing of nitrogen required by the plant. Access to the nitrogen allows the plants to produce leaves fortified with nitrogen that can be recycled throughout the plant which in turn yields nitrogen-rich seeds (Hubbell and Kidder, 2009). Through these symbiotic relationships, it fixes atmospheric nitrogen to the soil, thereby benefitting crop rotations and intercropping systems (Egbe *et al*., 2009 and Alhassan *et al*., 2012).

Bambara groundnut has been reported to fix up to 28.42 kg N ha^{-1} in the Sudano-Sahelian zone of Nigeria (Yakubu *et al.*, 2010). However phosphorus is the most important limiting nutrient element that has to be applied to the crop (Toungos *et al.*, 2009). Bambara nuts contain 63 % carbohydrates, 19 % protein and 6.5 % oil (Goli, 1997). Kari-Kari *et al*. (1997) characterized its micro nutrient content per 100 mg as Ca (95.5 - 99.0 mg), Fe (5.1 - 9.0 mg), K (11.45 – 14.36 mg) and Na (2.9 – 10.6 mg). Its high protein content confers advantage in alleviating nutritional disorders in both humans and animals (Massawe *et al*., 2002). Imbalances in calorific intake, excess consumption of carbohydrates from roots and tubers, as well as low protein supplementation predispose humans to malnutrition and cardiovascular diseases, kidney failure, typhoid fever, kwashiorkor, konzo and tropic ataxial neuropathy (Ciglenecki, *et al*., 2011).

The absence of cheap animal protein and the emphasis on composite flours incorporating cassava could worsen food values without adequate proteinisation of foods. Much at risk are children fed large portions of noodles and other fermented cassava products not properly accompanied with vegetables and proteins. Protein fortification of foods may be cheaply achieved through supplementation with vegetables and legumes including bamabara ground nut (BBG). Jonah (2012) reported that immature BBG seeds could be boiled soft in salt water and eaten as a snack or used in the production of milk and other fermented products. Adequate mineral supply either as organic or inorganic fertilizer to the crop will produce desirable yields (Nweke and Emeh, 2013). Nitrogen based fertilizers stimulate nodulation, while P enhances growth and seed yield (Toungos, *et al*., 2010). P is also responsible for the formation of phosphoric acid containing compounds which aid carbohydrate synthesis and fat metabolism in plants (Onasanya *et al*., 2007).

Sowing densities impact on Bambara yields (Sticksel, *et al*., 2001), influencing growth habit. A major constraint in BBG production is paucity of information on sowing densities and fertilization regimes. According to Egbe *et al*. (2009), sowing density is often low in farmer's fields with attendant low yields. Alhassan *et al*. (2012) reported that density varies between locations in both eastern and western Africa. In Tanzania, farmers adopt 30 x 30 cm, while in West Africa, 60 x 30 cm density is adopted (Mkandiwire and Sibuga, 2002). Jakusko and Belel (2009) reported highest seed yields per plant on application of 60 kg ha^{-1} P_2O_5 in Yola, North East Nigeria. There is need for scientifically generated evidence to guide future production and make informed recommendation to farmers regarding bambara production especially for locations in south eastern Nigeria. The present study was therefore conducted to evaluate the yield performance of BBG under varying plant densities and P_2O_5 fertilizer rates in Calabar, within the south eastern rainforest agro-ecological zone of Nigeria.

2.0 Materials and methods

Two year field experiments were conducted at the Teaching and Research Farm of the University of Calabar, Calabar (4.5 - 5.2 ^{0} N, 8.0 – 8.3 ^{0} E, 39 m above sea level) within the south eastern rainforest of Nigeria from October, 2013 to January 2014 and October, 2014 to January 2015. After manual clearing, the plot was partitioned into units of 1.2 x 2.4 m each, separated by 0.5 m pathways while the replications were separated by 1 m pathways. Net plots measured 1.2 x 1.0 m. Common weeds at the site were *Pennisetum purpureum, Sida acuta,Cyperus rotundus, Chromolena spp., Eleusine indica and Calapogonium mucunoides.* Soil was sampled at 0 – 20 cm depth and analysed for physico – chemical properties (Table 1). Meteorological data of the study area during the experiment is given in Table 2. Treatments were combined in a 3 x 4 factorial disposition having three sowing densities (111,111; 83,333 and 69,400 plants ha^{-1}) and four rates of single super phosphate fertilizer (0, 45, 60 and 75 kg ha^{-1}). These were dispersed using randomized complete block design having three replications.

A local land race of BBG described as 'creamy white' sourced from farmers field was treated with 'Dress force' (a.i.: Imida + Cloprid + Metalaxyl –M + Tebuconazole) at 10 g per 2 kg weight of seeds before sowing at two seeds per hill. Following the spacing regime of 30 x 30, 30 x 40 and 30 x 50 cm, the planting densities of 111,111; 83,333 and 69,400 plants ha-1 respectively were obtained. Urea (20 kg ha-1) was applied as a starter dose and the stated P2O5 rates were applied at sowing to stimulate initial growth. Six middle plants in the net plots were sampled every two weeks for plant height, number of leaves, branching, canopy diameter, days to 50 % flowering, total dry matter. Yield data included harvest index, dry pod yield and the seed yield (t ha-1). The incidence and severity of disease observed among the plants were recorded and yield reduction occasioned by disease severity was also assessed. Mature plants were harvested at three months when about 90 % of foliage had dropped. Pods were detached and sundried for 21 days before shelling while the seeds were oven dried for 72 hours at 60 0C. Data was analyzed using Genstat Discovery Edition 4 software package and significant means compared using LSD test at 5 % significance.

Table one: Physical and chemical properties of soil at the experimental site

Chemical composition	2013	2014
pH	5.10	4.8
Organic matter	3.98	0.99
Total N	0.14	0.08
Avail P (mg/kg)	28.95	34.89
Exchangeable bases composition		
Ca (cmol/kg^{-1})	4.1	3.4
Mg (cmol/kg^{-1})	1.3	2.0
Na (cmol/kg^{-1})	0.11	0.07
K (cmol/kg^{-1})	0.13	0.09
Exchangeable acidity Al^{3+} (cmol/kg^1)	0.94	0.64
ECEC (cmol/kg^{-1})	6.4	6.68
Base saturation	84.2	83
Micro nutrients		
Mn (Mg/kg)	84.4	82.5
Cu (Mg/kg)	33.0	32.1
Zn (Mg/kg)	82.0	81.2
Fe (Mg/kg)	141.3	121.0
Particle size analysis		
Sand (%)	81.0	82.0
Silt (%)	7.0	6.0
Clay (%)	12.0	12
Soil textural class	Sandy loam	Sandy loam

Table 2: Meteorological observations of Calabar for 2013 and 2014

Month	**Monthly mean temp (^{0}C)**				**Total rainfall (mm)**		**Humidity (%)**		**Sunshine (Hrs)**	
	Maximum		**Minimum**							
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
August	27.5	28.3	22.9	21.9	18.6	12.5	91.0	90.0	1.1	1.1
September	28.8	29.0	23.3	22.1	19.1	15.7	91.0	90.0	1.8	2.4
October	29.9	30.1	22.5	22.1	11.8	8.1	88.0	87.0	3.3	3.0
November	20.6	30.8	22.3	22.4	11.0	7.0	87.0	87.0	3.5	4.5
December	31.3	32.0	22.1	22.3	3.1	0.2	82.0	79.0	5.4	3.4
January	33.0	33.1	20.9	20.9	0.8	0.0	82.0	65.0	5.8	5.1
February	33.1	33.3	23.7	23.7	1.9	0.0	84.0	83.0	4.9	3.8
Total	**204.2**	**216.6**	**157.7**	**155.4**	**66.3**	**43.5**	**605.0**	**581**	**25.8**	**23.3**
Mean	**29.17**	**30.94**	**22.53**	**22.20**	**9.47**	**6.21**	**86.43**	**83.0**	**3.69**	**3.34**

Source: Nigeria meteorological Agency (NIMET), Margaret Ekpo International Airport, Calabar

3.0 Results

3.1 Sowing density effects

The effects of density ha^{-1} and P_2O_5 on vegetative attributes of BBG are presented in Table 3. Only plant height in both years responded to sowing density ha^{-1}. Plants sown at 111,111 and 83,333 stands ha^{-1} were statistically similar in height, but significantly ($P < 0.05$) taller than those sown at 69,400 stands ha^{-1}. Phenology indices such as number of days to 50 % flowering, total dry matter and harvest index responded positively to sowing density, except for mean harvest index and days to 50 % flowering in 2013 (Table 4). Number of days to 50 % flowering was not significant in 2013, but decreased significantly ($P < 0.05$) as sowing density decreased in 2014. Decrease in sowing density from 111,111 to 69,400 stands ha^{-1} resulted in significant ($P < 0.05$) increase in total dry matter, except in 2013 when the total dry matter at 111,111 and 83,333 stands ha^{-1} was statistically similar ($P>0.05$). The mean total dry matter indicated an inverse relationship to stand density ha^{-1}, increasing significantly as stand density decreased. Harvest index of 111,111 and 69,400 stands ha^{-1} was statistically similar but significantly higher than that at 83,333 stands ha^{-1} in 2013. In 2014 however, harvests from 111,111 and 83,333 stands ha^{-1} plots were statistically similar and significantly higher than harvest index from 69,400 stands ha^{-1} plots. The combined harvest index was however not significant (Table 4).

Table 3: Effects of P_2O_5 and plant density on growth attributes of bambara ground nut

Density ha^{-1}	Plant height (cm)		No. of leaves		No. of branches		Canopy diameter (cm)	
	2013	2014	2013	2014	2013	2014	2013	2014
111,111	27.00	27.00	77.29	96.40	10.92	12.32	82.73	96.30
83,333	26.83	27.61	85.15	86.10	11.42	12.83	88.21	96.90
69,400	22.52	23.80	87.46	87.20	12.40	13.81	84.67	93.00
LSD	2.95	3.07	NS	NS	NS	NS	NS	NS
P_2O_5 kg ha^{-1}								
0	25.78	26.52	77.78	83.60	11.36	11.53	83.19	89.90
45	27.33	26.07	88.06	94.60	11.89	12.77	91.11	98.50
60	26.67	25.91	86.72	95.90	11.75	13.42	88.42	96.10
75	26.03	26.88	80.64	98.00	11.31	13.56	88.44	96.90
LSD	NS	NS	NS	NS	NS	NS	NS	NS
Interaction								
LSD	NS	NS	NS	NS	NS	NS	NS	NS

NS indicates means that are non- significant.

Table 4: Effects of P_2O_5 and plant density on phenology indices

Density ha^{-1}	Days to 50 % flowering		Total Dry Matter (t ha^{-1})		Mean dry matter (t ha^{-1})	Harvest Index (HI)		Mean HI
	2013	2014	2013	2014		2013	2014	
111,111	40.83	45.58	4.19	2.46	3.36	69.59	67.32	66.46
83,333	41.25	45.00	4.65	3.17	4.11	65.86	66.16	66.01
69,400	41.25	44.67	6.61	5.15	5.88	68.83	64.14	66.49
LSD	NS	0.55	1.47	0.68	1.08	3.19	2.14	NS
P_2O_5 kg ha^{-1}								
0	41.67	45.00	5.27	3.47	4.37	65.87	66.17	66.02
45	40.56	45.22	4.53	4.09	4.31	68.35	67.95	68.15
60	40.56	44.67	5.67	3.80	4.74	70.90	71.02	70.96
75	41.67	45.44	5.13	3.94	4.54	67.24	68.92	68.08
LSD	NS	NS	NS	NS	NS	NS	NS	NS
Interaction								
LSD	NS	NS	NS	NS	NS	NS	NS	NS

NS indicates means that are non-significant.

The dry pod yield (DPY), seed yield (t ha^{-1}) and their mean values were significantly affected by stand density ha^{-1} (Table 5). In 2013, DPY at 83,333 stands ha^{-1} was statistically similar to DPY at 111,111 and 69,400 stands $ha^{-}1$, whereas the DPY at 111,111 stands ha^{-1} was significantly ($P < 0.05$) higher than at 69,400 stands ha^{-1}. Dry pod yield in 2014, combined pod yield, seed yield in 2013 and combined seed yield at 111,111 and 83,333 stands ha^{-1} were statistically similar ($P > 0.05$) but significantly ($P < 0.05$) higher than values at 69,400 stands ha^{-1}. In 2014 however, seed yield increased significantly as stand density ha^{-1} increased from 69,400 to 111,111 stands ha^{-1}. The combined pod and seed yield increase was of the order 111,111> 83,333 > 69,400 stands ha^{-1} (Table 5).

Table 5: Effects of P_2O_5 and plant density on yield attributes of Bambara nuts

Density ha^{-1}	Dry pod yield (t ha^{-1})		Combined pod yield (t ha^{-1})	Seed yield (t ha^{-1})		Combined seed yield (t ha^{-1})
111,111	3.66	1.64	2.65	2.55	0.80	1.68
83,333	3.36	1.07	2.22	2.30	0.47	1.39
69,400	2.15	0.73	1.44	1.45	0.20	0.82
LSD	1.27	0.55	0.89	0.89	0.15	0.52
P_2O_5 kg ha^{-1}						
0	3.44	1.38	2.41	2.30	0.26	1.28
45	3.22	1.02	2.12	2.26	0.40	1.33
60	2.74	1.84	2.29	1.89	0.41	0.65
75	2.84	1.94	2.39	1.97	0.43	1.2
LSD	NS	NS	NS	NS	NS	NS
Interaction						
LSD	NS	NS	NS	NS		NS

NS indicates means that are non- significant.

Severe incidence of viral leaf curl disease was observed in 2014 season. Symptoms were leaf curl among new leaves, severe discoloration and blight of older leaves in later stages of plant growth. The severity of leaf curl disease and the corresponding yield reduction are presented in Table 6. At 8 weeks after sowing (WAS), leaf curl severity was inversely related to stand density, statistically similar at 111,111 and 83,333 stands ha^{-1} but significantly higher than at 69,400 stands ha^{-1}. At 10 WAS, infection among the 83,333 and 69,400 stands ha^{-1} was statistically similar ($P > 0.05$) and significantly ($P < 0.05$) higher than that observed among plants in the 111,111 stands ha^{-1}. The percentage increase in leaf curl infection was 23.7 > 20.8 > 13.3 %, while percentage leaf curl severity was highest ($P < 0.05$) at 69,400 stands ha^{-1} compared to other densities (Table 6). This resulted in a yield reduction of 38.59, 35.43 and 20.72 % at 111,111; 83,333 and 69,400 stands ha^{-1} respectively.

Table 6: Incidence of viral leaf curl disease and percentage yield reduction

Density ha^{-1}	Leaf curl incidence (%) 8 WAS	10 WAS	% increase in leaf curl infection	Leaf curl severity (%)	% Yield reduction
111,111	33.1	53.9	20.8	38.59	68.63
83,333	43.2	66.9	23.7	35.43	79.56
69,400	50.9	64.2	13.3	20.72	86.21
LSD	11.65	8.85	2.8	3.16	8.31
P_2O_5 kg ha^{-1}					
0	41.0	60.6	19.6	32.34	88.70
45	37.8	56.9	19.1	33.57	82.30
60	49.6	64.5	14.9	23.10	78.31
75	41.2	64.8	23.6	36.42	78.17
LSD	NS	NS	NS	NS	NS
Interaction					
LSD	NS	NS	NS	NS	NS

NS indicates means that are non- significant.

3.2 Phosphate fertilizer effects

The effects of P_2O_5 fertilizer on the various plant growth and yield attributes of bambara ground nut were not significant. Similarly there were no significant interaction effects in the study.

3.3 Discussion

Increase in plant height in relation to plant density is attributable to density stimulated intra plant competition for available plant growth resources. Due to mutual shading within the canopy, ‘compensatory etiolation’ may occur as plants compete for available aerial resources. The direct proportionality of number of days to 50 % flowering to stand density is indicative of early maturity among low density plants. Lower density m^{-2} implies higher nutrient availability, increased photo activity, acceleration of growth leading to early flowering. Havlin *et al*. (2007) and Akmal *et al*. (2010) reported early tasselling and maturity in cereals associated with higher N supply thresholds. This directly potentiates the accumulation of assimilates and photosynthates, as plants have a longer period of growth in the field for photo-assimilates and sink accumulation, contributing to higher biomass and dry matter accumulation.

Highest combined pod and seed yield observed at the upper and middle population densities than at the lowest density are implicative of cumulative yield from larger number of plants contributing to total yield. Although sparse population conferred spatial advantage that led to higher total dry matter per plant, the overall pod and seed yields were however low. However discrete yield accumulated from higher populations and more numerous but smaller seeds, outweighed the yields of lower populations. Also the maximizing of effective leaf area due to close contact and reflection of light within the canopy leads to increased solar capture and photo efficiency which ultimately increased yields in denser planting. Chaniyara *et al*. (2001) reported increase in groundnut pod yields in response to narrow spacing and denser planting compared to wider rows. The findings in this present study also agree with Kouassi and Zorobi (2011) who recorded highest bambara nut yields at the highest planting density of 250,000 stands ha^{-1} in Cote d’ Ivoire.

Although Swanvelder (1998) reported that infections by pests and disease causing agents have not been observed yet, viral or other disease agents can be a real threat to bambara nut yields and as such farmers should not compromise crop protection. Drastic yield reductions as a result of viral leaf curl were recorded in the second season of this trial. With severe leaf curling, loss of chlorophyll pigment and blight of bambara plants, the yield reduction was significant. The yield loss among stand densities was of the order 69,400 > 111,111 > 83,333, corresponding to 38.59 > 35.43 > 20.72 % in the second year compared to the first year yields. Damage of the plants photosynthetic apparatus resulted to ineffective photosynthesis as well as poor photo assimilates storage to the sink as effective yield. It is not established if the pathogens were seed borne or over wintered in plant debris following the first years planting. For future security of bambara groundnut yields, plant protection and the use of disease resistant planting material must be emphasized. It is worthy to note however, that the meteorological conditions during the study period, may have accentuated the effects of infections so observed. In 2013, plants received relatively higher rainfall compared to lower rainfall in 2014 (Table 2). Moreover, higher temperatures and lower rainfall at the critical period of October and November in 2013 against 2014, which coincide with pod filling, may have led to higher transpiration loss of moisture and by implication moisture stress on the plants. A cursory examination of data may imply that there was a synergy between disease severity and adverse weather conditions that resulted in the yield decline reported in this study. Although Bambara groundnut is drought tolerant, damage to its photosynthetic apparatus may have reduced its resilience in the event of adverse weather conditions.

The non significant effects of P_2O_5 or interactions may have stemmed from the immobilization of external applied P as well as the high local P status in the soil of the experimental site (Table 1). Under high pH, available P is readily fixed and subsequent additions quickly immobilized out of the soil reaction. The application of lime might be a ready solution to the problem of P immobility in this environment.

4.0 Summary and conclusion

This study has demonstrated that Bambara groundnut responded to sowing density ha^{-1} but not to P_2O_5 fertilizer rates. The combined pod and seed yield were highest among the higher stand densities of 111,111 and 83,333 than 69,400. For effective yields, farmers should adopt the 30 x 30 cm spacing which gives a corresponding population of 111,111 stands ha^{-1}.

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