SCIREA Journal of Agriculture

http://www.scirea.org/journal/Agriculture

October 22, 2016

Volume 1, Issue1, October 2016

YIELD RESPONSE OF BAMBARA GROUNDNUT (*Voandzeia subterrenea* (L) Thours.) VARIETIES TO ORGANOMINERAL FERTILIZER IN THE COASTAL FOREST OF SOUTHEASTERN NIGERIA

Shiyam, JO; Nkor, NN; Binang, WB and Effa, EB

Department of Crop Science, Faculty of Agriculture, Forestry and Wildlife Resources Management University of Calabar, PMB 1115, Calabar, Nigeria

e-mail: j.shiyam@yahoo.com; GSM: +2348035529894

Abstract

A factorial field experiment was conducted in 2014 at the Teaching and Research Farm of the Department of Crop Science, University of Calabar located in the coastal rainforest zone of southeastern Nigeria on coordinates 05^0 32' and 04^0 27'N ; 07^0 15' and 09^0 28'E with an altitude of 37 m above sea level. The experimental factors were the different rates (0, 2.5, 5.0, 7.5 and 10.0 tonnes/ha) of John Ker Organomineral Fertilizer® (OMF) and three varieties of bambara groundnut (*Voandzeia subterrenea* (L) Thours) (Black, Cream and Tan) combined in a 3 x 5 factorial combined in a randomized complete block design (RCBD) in a factorial arrangement to give fifteen treatment combinations each replicated three times. Result obtained showed that

OMF significantly ($p \leq 0.05$) improved dry seed yield and yield components (number of pods/plant, number of seeds/plant, 100-seed weight) of bambara groundnut. The bambara groundnut varieties exhibited differential yield potential. The highest dry seed yield was obtained at 2.5 t OMF/ha in the Cream variety (1.95 t/ha) followed by the Black variety (1.75 t/ha) and lowest in the Tan variety (1.1 t/ha). The Cream variety out-yielded the Tan and Black varieties by 0.5 t/ha (25.64 %) and 0.2 t/ha (10.26 %) respectively, indicating its high adaptability and suitability in the forest agroecology.

Key words: Adaptation, organomineral fertilizer, bambara groundnut variety, yield components, moist forest

1.Introduction

Bambara groundnut (*Voandzeia subterrenea* (L) Thours. syn. *Vigna suterranea* (L)Verdc.) is a tropical pulse with underground pods and is the 3^{rd} most important food legume after groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* Walp.) in the semi-arid areas of sub-Sahara Africa. The name bambara groundnut reflects its area of origin in the Bambara tribe in the Sahelian region of West Africa (Hillocks *et al.,* 2012). The crop also known as 'Jugo beans' in South Africa, 'Ntoyo Cibemba' in Zambia and 'Nyimo beans' in Zimbabwe, while in Nigeria it is known as 'Gurjiya' or 'Kwaruru' in Hausa, 'Epa-wro' in Yoruba and 'Okpa' in Ibo (DoubleGist, 2013).

Bambara groundnut is one of the most neglected and under exploited/under-researched grain legumes commonly cultivated by smallholder women farmers and is derogatorily referred to as 'woman's crop' which reflects its low status among other food legumes in Nigeria (Bamishaiye *et* al, 2011; Hillocks *et al,*2012). It is hard crop highly adapted to marginal production environmental conditions in the sub-humid areas of many sub-Saharan Africa countries including Nigeria, Ghana, Cote d'Ivoire, Benin Republic, Mali, Chad, Kenya, Namibia, Angola, Tazania, Zimbabwe, Congo, and South Africa (Heller *et al,* 1997; Thottapilly and Rossel, 1977).

Nigeria is the world's largest producer of the crop, accounting for about 33,000 – 40,000 metric tonnes annually from an area of about 15,350 hectares (PROTA, 2006). Intensive cultivation of the crop is carried out mainly under smallholder intercropping system with sorghum, millet, maize, groundnut, yams, and cassava in the Guinea – Sudan Savanna zone of the country in Benue, Taraba, Adamawa, Bauchi, Nasarawa, Kaduna, Niger, and Kogi states including Ebonyi, Enugu and parts of Cross River State (Linnemann and Azam-Ali, 1993). It has high potential for food and nutritional security among the pro-poor households due to its highly nutritious seeds which contain 55.5 – 69.3 % carbohydrate, 5.3 – 7.8 % fat, metabolizable energy value of 362 – 414 kcal/100 g and 17 – 24 % high quality protein (Caroline, 2000; Dansi *et al*, 2012; Hillocks *et al*, 2012; Olanipekun *et al*, 2012), as well as high amounts of nutritional fibre, Calcium and Iron including such vitamins as thiamin, riboflavin, niacin, and carotene. (Abdulsalami and Sheriff, 2010).

Bambara nuts are utilized in various ways. Fresh mature seeds are boiled and eaten like groundnut while dry seeds can either be roasted or fried and consumed as snacks. Dry seeds may be milled into flour and made into a paste and fried in hot oil as 'akara'. Wheat can be substituted with up to 20 % bambara flour in bread making and can also be used as a composite flour in biscuits and cakes (Addo and Oyeleke 1986; Brough *et al*. 2005; Alozie *et al*. 2009). Seeds can be canned like green beans and limited amounts of high quality milk like soy milk can be processed from the seeds (Akande *et al,* 2009). However, bambara seeds are commonly used in the preparation of the popular 'Okpa' a highly cherished delicious and nutritious food especially in the eastern parts of Nigeria (Onyimonyi and Okeke, 2007; Adumanya *et al,* 2012).

The crop has numerous agronomic benefits particularly its high yielding potential, adaptation to marginal soils and high temperature environment where most food grains like maize, sorghum, rice and other leguminous crops cannot be grown successfully (Yamaguchi,1983; Baryeh, 2001; Massawe *et.al,*.2007). It also contributes high amount of Nitrogen ranging from 20 – 100 kg ha^{-1} to the soil at a level similar to other legumes (Ncube and Twomlow, 2007).

The need for more food sources to feed the ever increasing human population has led to increased demand for bambara seeds and this has generated unprecedented interest in the production of the crop which is fast gaining popularity in areas where it has not been intensively cultivated.

However several factors interplay to limit increased production of the crop among which is the declining soil fertility and productivity under continuous cropping systems occasioned by increasing scarcity of arable land. Increased farm productivity has been recognized as a major strategy to break the vicious cycle underlying food insecurity and rural poverty (Vanlauwe, 2015). Most soils in the humid tropics are naturally infertile and poor cropping and unsustainable management practices have led to a severe decline in their productive capacity (Weigelt and Alva, 2015). Soils in most areas of sub-Saharan Africa are normally highly acidic, poor in nutrient content and are characteristically low in organic matter content. Such soils can only support intensive cultivation of traditional food crops if managed strategically to improve their productivity. About two thirds of the tropical soils are highly acidic and represent the largest untapped arable land in Africa and more productive utilization of these soils is key to expanding agricultural productivity.

Though bambara groundnut can produce good yields on poor soils, its productivity can be greatly enhanced if cultivated on healthy and fertile soil guaranteed under organic production practices.

Organic farming emphasizes a shift from the use of expensive and hazardous synthetic fertilizers to organic nutrient sources to ensure sustainable production of safe and nutritious food as well as ecosystem health. Organic farming prohibits the use of energy intensive synthetic fertilizers and is suitable for pro-poor smallholder farmers as it promotes the use of cheap and affordable organic nutrient materials in soil health/fertility management and conservation for increased farm productivity (Muller *et al.*, 2012). Application of organic soil nutrients on impoverished soil is strategic in ensuring increased organic matter and nutrient contents of soil, enhanced aggregate formation and water retention capacity of soil as well as improved soil health/biological processes. Utilization of organic soil nutrient resources is a healthy soil management and farming practices that enhance soil life which is essential in organic farming (Cooperband, 2002).

Given the inherently poor status and low level of organic matter in tropical soils, organic fertilizer use must be promoted to reverse the current trends of low farm productivity and the environmental/health hazards and the high cost associated with commercial fertilizers which makes it unaffordable to resource-poor women farmers who are the main producers of bambara groundnut. Organic resources contain plant nutrients that are released gradually in the soil depending on their quality and their application at low levels commonly used by traditional farmers is not sufficient to guarantee optimum crop yields. A combination of organic and mineral inputs in organomineral fertilizer is strongly advocated as a sound soil fertility management principle because both inputs are needed in the long run to sustain soil fertility and crop production

Promotion of organic bambara groundnut production in Nigeria requires authentic agronomic information on the organic nutrient requirement of the crop. Such information is currently lacking particularly in the coastal rainforest area of the country which has potential for the cultivation of the crop. This trial was designed to determine the most suitable variety and the optimum rate of organo-mineral fertilizer for enhanced productivity of the crop in the area.

2.Materials and Methods

2.1 Location and description of the experimental site

The experiment was conducted in the 2014 cropping season on a piece of land that had been under vegetables, maize and cassava cultivation for three consecutive years at the Teaching and Research Farm of the Department of Crop Science, University of Calabar. The town is located in the coastal rainforest zone of southeastern Nigeria on coordinates 05^0 32’ and 04^0 27’N ; 07^0 15’ and 09^0 28’E. The area has annual rainfall of about 2500 mm with relative humidity ranging from 60-85 % and minimum and maximum temperature of about 23 and 33 ^{0}C, respectively.

The land had been under continuous cultivation of cassava, maize, *Telfaiaria*, Talinum and melon. The predominant weed species found at the site was *Panicum maximum* mixed with *Chromolaena odorata, Aspilia africana* and *Ageratum conyzoides* as well as some shrubs and broadleaf species.

2.2 Land preparation and soil sampling

Clearing of the vegetation and tilling of the land were done manually using a machete and spade. Prior to tilling, surface (0-30 cm depth) soil samples were randomly collected from the plot and bulked and taken to the laboratory for analysis of the physico-chemical properties. The bulk sample was air-dried in the laboratory and ground to pass through 2-mm sieve and used for the analysis according to the standard laboratory procedures described by IITA (1982).

2.3 Plot size, experimental treatments and design

Unit plot size was 2.0 m x 2.0 m (4 m^2) and separated either way by 1.0 m paths within the block while adjacent blocks were 2.0 m apart. The treatments were factorial combinations of three bambara groundnut varieties (Black, Tan and Cream varieties) and five levels of John Ker Organomineral fertilizer® (OMF) (0, 2.5, 5.0, 7.5 and 10.0 tonnes/ha) fitted in a randomized complete design with five replicates.

2.4 Treatment application and sowing of bambara groundnut

The *John Ker®* Organo-mineral fertilizer containing 2.8 % N, 1.2 % P, 2.2 % K, 14.5 % moisture and 40.0 % Total organic matter content was applied by incorporating the appropriate rate into the soil during seedbed preparation while sowing was done one week later on the 6th of September, 2014. Two seeds were sown per hole 3-5 cm deep at 30 cm inter- and 50 cm intra-row spacing and later thinned to one seedling per stand one week after emergence to give a plant population of 66,666 plants ha^{-1}.

2.5 Crop management

Weeding was done manually when necessary to reduce competition for growth factors and enhance crop growth. During weeding soil was gathered around the base of the plants to cover the developing pods. Cross bunds were also maintained regularly to check erosion. There was no threat either from pests or diseases except from the cattle which were kept off by fencing with Indian bamboos.

2.6 Data collection and analysis

Data collected on seed yield and yield components were number of pods per plant, number of seeds/plant, 100-seed weight, and dry seed yield/ha.

Data analysis was done by using analysis of variance (ANOVA) technique and test of significance was done using the Fisher's least significance difference (F-LSD) at 5 % level of probability.

3. Results and Discussion

3.1 Result of soil analysis

The soil at the experimental site was acidic and contained low plant nutrients and low effective cation exchange capacity (ECEC) with high base saturation. The soil also contained low amounts of clay and silt but had high sand fraction giving it a sandy textural class (Table 1). Such low fertility status soils with open structure are suitable for under-ground pod-bearing crops like bambara groundnut and groundnut. According to Anetor and Omueti (2014) such soils also require amelioration with integrated nutrient inputs especially organomineral fertilizers which contain concentrated plant nutrients such as Nitrogen, Phosphorus, Potassium, Sulphur and Zinc as well as sufficient amounts of high quality organic matter to improve and sustain their fertility for increased productivity of quality crops. Organomineral fertilizer with high organic matter profile also confers numerous agronomic benefits to poor sandy soils including increased cation exchange capacity, enhanced moisture retention capacity, high soil trace nutrients levels, improved structure, high buffering capacity against major swings in Ph, and increased soil biological activities (Cooperband, 2002).

3.2 Yield components and seed yield of bambara groundnut

3.2.1 Pod formation

Pod production on plant basis significantly ($p \leq 0.05$) increased by application of organomineral fertilizer but there was no pod yield difference among the different OMF rates applied though pod number increased with successive increase in the rates of fertilizer (Table 2). Irrespective of the OMF rate, pod yield increase per plant ranged from 20 – 26 % in all fertilized plots indicating positive response of the varieties to soil amendment with organomineral fertilizer irrespective of the rate applied to the crop. The similarity effect of the different OMF rates on pod formation could be indicative of the adequacy of the minimum OMF rate (2.5 t/ha) for bambara groundnut nutrition under the agroecological conditions of the study area and application of higher rates would amount to economic waste as it would not enhance higher pod formation.

3.2.2 Number of seeds per plant

The bambara groundnut varieties evaluated did not differ among themselves in seed production but OMF rates influenced the number of seeds per plant which was similar in all varieties except in the Cream variety irrespective of the rate applied but significantly ($p \leq 0.05$) higher in fertilized plots than in the control (Table 3). In the Cream variety, the number of seeds per plant was highest in plots treated with the highest OMF rate (10.0 t/ha), followed by plots amended with 2.5 – 7.5 t OMF /ha and lowest in control plots. The increase in the mean number of seeds produced per plant in the Black and Tan varieties due to fertilizer application ranged from 4.5 – 6.0 and 5.2 – 7.0 seeds respectively, whereas in the Cream variety the highest seed increase of 12.0 seeds per plant or 78.4 % was obtained at the highest OMF rate (10.0 t/ha), indicating its more likely suitability in the humid environment.

3.2.3 100-seed weight

Fertilizer rates and variety significantly affected the 100-seed weight in bambara groundnut with the Cream variety having the highest seed weight in plots fertilized with organomineral fertilizer at 2.5 t/ha (Table 4), representing an increase of 15.0 g or 15.38 % above the control. The rate of increase in seed weight reduced sharply as the OMF rate was increased above 2.5 t/ha and was 5.0 and 2.5 g at 5.0 and 7.5 t OMF/ha respectively. There was no increase in seed weight as OMF rate was further increased above 7.5 t/ha and at 10.0 t OMF/ha it was not different from that in the control.

The 100-seed weight of the Black variety also increased by applying fertilizer and was significantly highest at 2.5 t OMF /ha which also produced the highest seed weight increase of 10.5 g above the value obtained in control plots. All other OMF rates did not differ in seed weight which was also higher than in the value obtained in the control by 12.5 g.

The seed weight trend in the Black and Cream varieties was very different from the scenario obtained for the Tan variety in which the value in the control plants was significantly higher than values recorded in fertilized plants which had similar seed weights irrespective of the OMF rate applied.

The decrease in seed weight observed at OMF rates higher than 2.5 t/ha could be due to the high number of pods and seeds produced per plant at higher fertilizer rates (Tables 2 and 3) which probably affected the individual seed weight and hence the 100-seed weight. The influence of seed number on seed weight has been reported in kiwifruit (Lawess *et al*, 1990). Also, plants fertilized with OMF rates higher than 2.5 t/ha exhibited dense foliage which obviously required more energy resulting in assimilates distribution more in favour of vegetative growth than seed development/growth and storage.

The different bambara groundnut varieties varied in their mean seed weight which was significantly higher and similar in the Black and Cream varieties than in the Tan variety and there was no significant interaction between the OMF rates and bambara groundnut varieties.

3.2.4 Dry seed yield of bambara groundnut

Dry seed yield of bambara groundnut varieties varied at the different OMF rates and was significantly higher in all fertilized plots than in zero fertilizer treatments with the highest value in plots treated with 2.5 t OMF/ha across the varieties (Table 5). Application of OMF to bambara groundnut at 2.5 t/ha resulted in seed yield increase but above this rate yield suppression set in which was similar across the OMF rates in each variety. At 2.5 t OMF/ha, seed bambara seed yield increased by 0.64 t/ha or 57.66 % but reduced by 0.22 t/ha or 19.57 % in the Black variety at higher OMF rates. Similarly, at 2.5 t OMF/ha increased seed yield of 0.95 t/ha (95 %) was obtained in the Cream variety whereas yield reduction ranging from 0.40 – 0.52 t/ha or 20.51 – 26.67 % occurred by applying OMF rates above this level. Also increased seed yield of 0.42 t/ha corresponding to 40.78 % increase was obtained at 2.5 t OMF/ha, while seed yield suppression of about 0.25 t/ha or 17.24 % occurred at higher OMF rates. The best seed yield obtained by applying 2.5 t OMF/ha could be the optimum rate required for the crop in the study area.

The bambara groundnut varieties exhibited differential yield potential which was highest in the Cream variety followed by the Black variety and lowest in the Tan variety. The Cream variety out-yielded the Tan and Black varieties by 0.5 t/ha (25.64 %) and 0.2 t/ha (10.26 %) respectively, indicating its high adaptability and suitability in the forest agroecology. The high yield performance of the cream and white landraces has also been reported by Onwubiko *et al.* (2011). These varieties are more popular than the black and darker types and are highly preferred by farmers because of their early maturity, large seeds, high consumer demand and good market prices (Berchie *et al* 2010; Akpalu *et al* 2013).

However, all the varieties produced more than one and a half tonnes of dry seeds per hectare which is higher than the yield figure of 650 – 800 kg/ha commonly obtained under the traditional zero inputs mixed cropping systems in the savanna zone of sub-Saharan Africa (Mkandawire, 2007; Tanimu *et al*,1990; Heller *et al*, 2012). This is an indication that the crop is also adaptive to high rainfall conditions and can be cultivated extensively in such areas if adequate awareness is created.

3.3 Conclusion

Organomineral fertilizer was efficient in improving the seed yield of bambara groundnut which was highest at 2.5 t OMF/ha in all varieties, indicating the high potential of the moist forests for commercial cultivation of the crop at low levels of nutrient inputs.

Table 1. Physico-chemical properties of the surface (0-30 cm deep) soil at the experimental site.

Soil parameter	Value
p^H ($H^2 0$)	5.5
Organic Carbon (%)	1.3
Total Nitrogen (%)	0.08
Phosphorus (mg/kg)	28.27
Exch. Cations (cmol/kg):	
Ca	5.4
Mg	0.7
K	0.1
Na	0.09
Exch. Acidity (cmol/kg)	1.50
Effective cation exch. Capacity	3.50
Base saturation (%)	81
Physical properties (%):	
Clay	4.5
Silt	8.0
Sand	87.5
Textural class	Sandy soil

Table 2. Effect of different rates of organo-mineral fertilizer rates on the number of pods/plant of bambara groundnut (Voandzeia subterrenea (L) Thours) varieties in Calabar

OMF rate	Bambara groundnut variety			
(t/ha)	**Black**	**Tan**	**Cream**	**OMF mean**
0 (Control)	27.0	26.3	25.3	26.2
2.5	32.3	31.5	30.5	31.4
5.0	32.5	32.0	31.0	31.8
7.5	32.8	32.3	32.3	33.0
10.0	33.5	33.3	32.3	33.0
Variety mean	**31.6**	**31.1**	**30.1**	**-**

F-LSD(0.05) for fertilizer (F) means=2.1

F-LSD(0.05) for variety (V) means= NS

F-LSD (0.05) for (V X F) interaction means-NS

Table 3. Effect of organo-mineral fertilizer rates on number of bambara groundnut (Voandzeia subterrenea (L) Thours) seeds/plant

OMF rate	Bambara groundnut variety			
(t/ha)	Black	Tan	Cream	OMF mean
0 (control)	17.0	16.3	15.3	16.8
2.5	21.5	21.5	20.5	21.2
5.0	22.0	22.0	21.0	21.8
7.5	22.3	22.5	22.0	22.3
10.0	23.0	23.3	27.3	24.5
Variety mean	**21.2**	**21.10**	**21.2**	

F-LSD(0.05) for fertilizer (F) means=2.4

F-LSD(0.05) for variety (V) means= NS

FLSD (0.05) for (V X F) interaction means-NS

Table 4. Effect of different rates of organomineral fertilizer on 100-seed weight (g) of three varieties of bambara groundnut (Voandzeia subterrenea (L) Thours.) in Calabar.

OMF rate (t/ha)	100-SSeed weight (g)			
	Black	Cream	Tan	OMF Mean
0 (Control)	90.5	97.5	92.5	93.5
2.5	105.0	112.5	82.5	100.0
5.0	102.5	102.5	80.0	95.0
7.5	102.5	100.0	85.0	95.8
10.0	102.5	97.5	90.5	96.8
Variety mean	100.0	102.0	86.5	-

F-LSD (0.05) for fertilizer (F) means=6.2

F-LSD (0.05) for Variety (V)means=7.3

F-LSD (0.05) for (V x F) interaction means=ns

Table 5. Effect of different rates of organomineral fertilizer on dry seed yield of three varieties of bambara groundnut (Voandzeia subterrenea (L) Thours.) in Calabar.

OMF rate (t/ha)	Dry seed yield (t/ha)			
	Black	Cream	Tan	OMF mean
0 (Control)	1.11	1.00	1.03	1.05
2.5	1.75	1.95	1.45	1.72
5.0	1.53	1.43	1.23	1.40
7.5	1.53	1.53	1.23	1.43
10.0	1.53	1.55	1.20	1.43
Variety mean	1.49	1.49	1.23	-

F-LSD (0.05) for fertilizer (F) means=0.23

F-LSD (0.05) for Variety (V)means=0.18

F-LSD (0.05) for (V x F) interaction means=ns

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