Agricultural Science
Volume 1, Issue 4 (2013), 15-28
ISSN 2291-4471 E-ISSN 2291-448X
Published by Science and Education Centre of North America

Nodulation, Nitrogen Yield and Fixation by Bambara Groundnut (*Vigna Subterranea* (L.)Verdc.) Landraces Intercropped with Cowpea and Maize in Southern Guinea Savanna of Nigeria

Moses Onyilo Egbe[1*], Godwin Adu Alhassan[1], and Michael Ijoyah[1]

[1]Department of Crop Production, University of Agriculture, Makurdi

*Corresponding author: Moses Onyilo Egbe, Department of Crop Production, University of Agriculture, Makurdi, Nigeria. Tel: +2348068698638; E-mail: onyiloegbe@yahoo.co.uk

Abstract: Two separate field experiments were undertaken during the rainy seasons (August – December) of 2010 and 2011 at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi, Nigeria. The objective of the study was to evaluate some landraces of bambara groundnut intercropped separately with cowpea and maize at varying planting densities for nodulation, nitrogen (N) yield and fixation. Each experiment was a 2 x 3 x 3 split-split plot set out in a randomized complete block design with three replications. Intercropping decreased the number and weight of nodules; nitrogen derived from the atmosphere and fixed in both bambara groundnut/maize and bambara groundnut/cowpea intercropping systems. No significant differences were noticed between the landraces in N content of shoot and roots, but ‘Okirikiri’ had significantly higher N content (3.11 %) of pod with seed than the other two landraces. ‘Okirikiri’ and ‘Adikpo’ landraces fixed more N than ‘Karo’. N fixed increased with decline in bambara groundnut planting density. Mean percentage of plant N derived from atmosphere varied from 49.80 in the bambara groundnut/maize systems to 56.80 in the bambara groundnut/cowpea intercrops, while N fixed was 11.27 kg/ha and 34.90 kg/ha in the respective intercrop systems. The expectation of enormous contribution of nitrogen fixation to bambrara groundnut yields and its residual effects on soil medium for ensuing crops may be an illusion with the use of the landraces tested in this work, except, probably when inoculated with the appropriate rhizobia?

Keywords: bambara groundnuts, intercropping, nodulation, nitrogen fixation

1. Introduction

Nitrogen (N) is an essential component of amino acids (building blocks of proteins) and nucleic acids. Consequently, it is not possible to synthesize the necessary proteins, enzymes, DNA and RNA required in virtually all plant cells for their essential development without N. The key role of the legume component is its contribution to the N-economy of the system. To what extent legumes contribute to the N-economy of intercropping systems is not completely understood. It is common knowledge that some nodulated legumes are capable of fixing atmospheric N2, and therefore will reduce competition for N when cereals are included in an intercropping system (Fujita, Ofosu-Budu, & Ogata, 1992). Symbiotic nitrogen fixation has been estimated to contribute approximately half of the amount of nitrogen (N) applied in inorganic N fertilizers (Smil, 2005) and it may represent an ecological alternative to inorganic N fertilization in several areas in the world. Nitrogen deficiencies result in decreased crop leaf area, photosynthetic assimilation and seed growth (Sinclair, 1990). Much of the variation in leaf photosynthetic capacity for different cultivars, age of leaves and growth conditions can be attributed directly to differences in leaf N content (Sinclair & Horie, 1989).

Bambara groundnut (*Vigna Subterranea* (L.) Verdc.) is an indigenous African crop that has been cultivated for ages. Nigeria is believed to be one of the centres of origin of this crop, and possesses extensive bambara groundnut genetic resources (Tanimu & Aliyu, 1997). In Southern Guinea Savanna region of Nigeria, some of the popular landraces include, “Karo”, “Okirikiri”, “Adikpo”, “Kparuru”, “Ikpeyiole” and “Carol”. In Nigeria, these landraces of bambara groundnut and some others are grown by subsistence farmers in small patches of land. It is regarded as women’s crop in most cultures and frequently intercropped or mixed with cowpea, maize and sorghum (Mkandiwire & Sibuga, 2002; DFID, 2002). Although current country-wide production figure is unavailable, Benue State, located in Southern Guinea Savanna of Nigeria, produced 14,180.00 metric tonnes of bambara groundnut in 2010 from 12,222 ha of land with a mean grain yield of 1.16 t/ha (BNARDA, 2010). Planting density of bambara groundnut is often low (< 100,000 plants ha^{-1}) in farmers’ fields (Egbe, Kalu, & Idoga, 2009) and especially when the crop is not grown in rows, resulting in low yields.

Legume-cereal intercropping is a method to obtain greater and more stable crop yields, improve the plant resource utilization (water, light, nutrients), increase the input of leguminous symbiotic nitrogen fixation to the cropping system and reduce negative impacts on the environment (Frye & Blevins, 1989). Many studies of cereal/legume intercropping have shown that the quantity of N fixed by the legume depends on such factors as the morphology, density, and competitive ability of the legume (Ofori & Stern, 1987), the effectiveness of the rhizobia symbiosis and the system of intercropping (Rerkasem, Rerkasem, Peoples, Herridge, & Bergersationen, 1988). Intercropping of grain legumes generally results in the legume deriving a greater proportion of its N from N fixation than when grown alone, but legume dry matter production and N accumulation are usually reduced because of competition from the companion crop (Giller, Ormeshe, & Awah,1991). Giller *et al*. (1991) also observed that as biomass and yields of sole-cropped grain legumes under smallholder conditions in Africa are often small (< 500 kg ha^{-1} of grain), the amounts of N_2 fixed are barely significant. Yakubu, Kwari & Sanadabe (2010) had reported that bambara groundnuts fixed up to 28.42 kgN/ha in the Nigerian Sudano-Sahelian zone of Nigeria. Bambara groundnut nodulates with cowpea-type bradyrhizobia (Dakora & Muofhe, 1997) and has the ability to cross-nodulate with isolates from different tropical legumes, which indicates that bambara groundnut is less selective in its bacterial requirements. Bambara groundnut fixes atmospheric nitrogen through symbiosis with *Rhizobium* bacteria and therefore beneficial in rotation and intercropping (Karikari, Chaba, & Molosiwa, 1999). Dakora and Muofhe (1997) have indicated the potential for increasing yields in bambara groundnut through enhancement of symbiotic nitrogen fixation. Nodulated plants of bambara groundnuts depend largely on symbiotic N for their N nutrition, even when free NO3 is available (Dakora & Muofhe, 1997). The practice of legume/legume intercropping is common among smallholder farmers, but scientific studies are rare despite potential advantages for soil fertility restoration and increased options for plant protein sources for poor households.

Nitrogen fixation is expected to increase the yield of the bambara groundnut crop and also contribute nitrogen to the soil medium for ensuing crops in areas where the cost of artificial nitrogen fertilizer is prohibitive.

Scientific information on nodulation, nitrogen yield and fixation by bambara groundnuts intercropped with cowpea or maize are rare, if not completely absent in Southern Guinea Savanna of Nigeria. The study reported here sought to bridge this knowledge gap with a view to increase the productivity of bambara groundnut/maize and bambara groundnut/cowpea intercropping systems.

2. Materials and Methods

2.1 Location, Soil Sampling and Analysis

Two field separate experiments were undertaken during the rainy seasons (August – December) of 2010 and 2011 at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi [latitude 07^o 45'- 07^{o}50'N, longtitude 08^{o}45'- 08^{o}50'E, elevation 98 meters above sea level, masl] in Benue State, located in the Southern Guinea Savanna of Nigeria. The objective of the study was to evaluate some landraces of bambara groundnut intercropped separately with cowpea and maize at varying planting densities for nodulation, nitrogen yield and fixation. The experimental site received a total rainfall of 1115.3mm and 1211.4 mm in 2010 and 2011, respectively. The soil was of soil were collected from different parts of each experimental field from a depth of 0-30 cm and bulked into a composite sample and used for the determination of the physical and chemical properties of the soil (see Table 1) before planting. The soil samples were air-dried at room temperature for one week, ground (using mortar and pestle) to pass through a 0.3 mm screen for chemical analysis. Mechanical analysis was carried out by the hydrometer method described by Bouyoucos (1962). Soil pH was obtained using a 1:2.5 soil-water ratio. Total organic carbon was determined by the use of an improved chromic acid digestion and spectrophotometric method (Heanes, 1984) and organic matter was estimated by multiplying the organic carbon figure by 1.724. Available phosphorus was determined by using Bray1 procedure (Bray & Kurtz, 1944). Nitrogen in soil was estimated by phenols colour formation method (Chaykin, 1969) after micro-Kjeldahl digestion; exchangeable potassium and calcium were determined using the methods described by Juo (1979). Magnesium was assessed using the methodology developed by Tel and Rao (1982). Effective cation exchangeable capacity (ECEC) was obtained by the summation method.

Table 1. Physical and chemical properties of the surface soil (0-30 cm) at the experimental sites in Makurdi in 2010 and 2011

	Bambara groundnut / cowpea		Bamabara groundnut / maize	
Parameter	2010	2011	2010	2011
Sand (%)	70	67	76	69
Silt (%)	22	24	18	20
Clay (%)	8	9	6	11
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH (H_2O)	7.7	6.10	7.10	5.90
Organic carbon (g kg^{-1})	10.40	9.05	14.00	12.07
Total N (g kg^{-1})	0.70	1.23	0.88	1.40
Available P (cmol kg^{-1} soil)	15.75	6.13	14.88	8.75
Ca^{2+} (cmol kg^{-1} soil)	3.60	3.00	3.80	3.00
Mg^{2+} (cmol kg^{-1} soil)	1.80	0.80	2.10	0.90
K^+ (cmol kg^{-1} soil)	0.21	0.11	0.23	0.17
Na^+ (cmol kg^{-1} soil)	0.61	0.03	0.42	0.02
H^+Al (cmol kg^{-1}soil)	0.10	0.05	0.10	0.05
ECEC (cmol kg^{-1} soil)	7.40	4.70	8.10	5.20
SO4 (mg/kg)	8.45	8.53	5.13	12.67

2.2 Experiment 1: Bambara Groundnut / Cowpea Intercropping

The plot was manually cleared with machetes and ridged with hand hoes before laying the experiment as a 2 x 3 x 3 split-split plot set out in a randomized complete block design with three replications. The main plot treatments comprised of two cropping systems [sole cropping (bambara groundnut, cowpea *var.* IT97K-499-35) and intercropping (bambara groundnut + cowpea)], while the sub-plot treatment was made up of three bambara groundnut landraces ("Adikpo", "Okirikiri" and "Karo"). The sub-sub-plot treatments comprised of three planting densities of bambara groundnut (200,000 plantsha-1, designated as P1 and set out as 1 m x 0.05 m x 1 plant/stand; 100,000 plantsha-1, designated as P2 and set out as 1 m x 0.1 m x 1 plant/stand; 50,000 plantsha-1, designated as P3 and set out as 1 m x 0.2 m x I plant/stand). Maize, *var* QPM, obtained from the Seed Technology Centre of the University of Agriculture, Makurdi, was included as the non-nitrogen fixing crop. A fallow plot was included to monitor the nitrogen dynamics. The bambara groundnut landraces were obtained from the local markets in Ankpa ("Karo"), Otukpo ("Okirikri") and Makurdi ("Adikpo"). The cowpea variety used was IT97K-499-35 obtained from International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. It was planted in both sole and intercropping at 50,000 plants per ha, set out as 1 m x 0.2 m x 1 plant/stand. Intercropping was formed by planting bambara groundnut at the top of the ridge, while cowpea occupied the side of the same ridge in a 1:1 row arrangement at the respective planting densities mentioned above. Both sole bambara groundnut and sole cowpea occupied the top of the ridge. The gross plot was made up of four ridges, spaced 1 m apart and 3 m long (12 m^2), while the bordered area had two ridges 2 m long (4 m^2). Planting was done on the 5^{th} day of August in both 2010 and 2011. No fertilizer was applied, as often practiced by farmers who intercrop bambara groundnut with cowpea (Mulila-Mitti, 1997). The plots were weeded manually using hand hoes at 3 weeks after planting (WAP) and at 6WAP as recommended by BNARDA (2003). At first flower opening, plots with cowpea were sprayed with 30 milliliters of Decis®EC (25 g/l (2.8% w/w) deltamethrin) in 20 liters of water. This was done three times at fortnightly intervals as recommended by BNARDA (2003).

2.3 Experiment 2: Bambara Groundnut/Maize Intercropping

The land preparation practices, landraces of bambara groundnut, seed sources, experimental design and layout were the same as in Experiment 1.The main plot treatments comprised of two cropping systems [sole cropping (bambara groundnut, maize *var.* QPM) and intercropping (bambara groundnut + maize)]. The sub-plot and the sub-sub-plot treatments were similar to those used in Experiment 1. All other agronomic practices as used in Experiment 1 were employed, except that NPK: 15:15:15 fertilizer was applied as basal dressing at 300 kg/ha by broadcasting and the maize component was top-dressed with Urea at 100 kg/ha by side placement.

2.4 Data Collection and Estimation of Nitrogen Yield and Fixation by the Intercropping Systems

At 50% flowering, five bambara groundnut plants were dug out from each of the sole and intercropping plots for nodule count, nodule dry weight, dry root and shoot weight, tap root length, number of lateral roots and the length of the longest lateral root. The process involved initially breaking the soils around the plants to a depth of 50 cm with a hand hoe making sure their roots were not disturbed. The plants were then pulled out gently and put in polyethylene bags. These were taken to the Crop Science Laboratory of the University of Agriculture, Makurdi and washed with water to remove soil particles on the roots. The nodules on the roots and those that broke off in the course of washing were picked and counted. These were put in envelopes and oven-dried at 70^{o}C for 72 hours after which they were weighed on a sensitive electronic balance. The roots were severed with a sharp knife from each plant, bagged separately, oven-dried at 70^{o}C for 72 hours and weighed to obtain the dry root weight; average root weight per plant was calculated. The same procedure was used to obtain average shoot weight per plant. The soil samples were air-dried and ground to pass through a 0.3 mm screen for chemical analysis. Nitrogen in soil was estimated by phenols colour formation method (Chaykin, 1969) after micro-Kjeldhal digestion. Similarly, oven-dried shoot samples of sole and intercropped bambara groundnut, cowpea and maize (non-fixing control) were separately ground to pass through a 0.6 mm screen for chemical analysis. Nitrogen yield in the leaves, stem, root, shoot and pod with seed of both sole and intercropped bambara groundnuts samples as well as maize shoot was determined as outlined by Chaykin (1969) after micro-Kjeldhal digestion. All the laboratory chemical analyses for N and P were done in the Soil Science Laboratory of Ahmadu Bello University, Zaria, Nigeria. The formula of Papastylianou (1999) for the estimation of the apparent net amount of atmospheric N_2 fixed by legumes in short- and long-term cropping systems was used to estimate N fixation.

$\mathbf{N_2} = (L-M) + (fi - fm)$

Where N_2 = amount of nitrogen fixed by systems;

L = N harvested in a N_2-fixing legume;

M = the amount of N in a non-fixing crop grown under the same condition as the legume;

fi = soil N after the legume;

fm = soil N under the non-N_2-fixing crop.

This equation assumes that the legume crop and the non-legume crop absorbed the same amount of soil N. The soil N value (fi-fm) in the equation could be positive, zero or negative, depending on whether the legume system removed less, equal or more soil N than the non-legume grown in monoculture. The amount of total N fixed per ha by bambara groundnut for each treatment plot was obtained by multiplying the proportion of N derived from N fixation by the dry shoot weight of bambara groundnut in that treatment plot.

The formula of Rennie (1984) for calculating the percentage of plant N derived from the atmosphere was used to estimate the percentage N derived from the atmosphere by bambara groundnut landraces.

%Ndfa = (N_2/Whole plant N) x 100)

Where % Ndfa is the percentage of plant N derived from atmosphere and whole plant N is the N harvested in bambara groundnut plant (stem + leaves + pod with seed).

Data collected were analyzed using GENSTAT Release 11.1 (PC / Windows) (2008. VSN International Ltd., London) and the least significant difference (LSD) test at 5% probability level was used to compare the treatment means. Student's t-test was used to compare N uptake in different plant parts.

3. Results

Year effects were not significant and consequently results from pooled data are presented here. The rainfalls received at the experimental site for both years (1115.3 mm and 1211.4 mm in 2010 and 2011, respectively) were considered adequate for crop growth and development.

3.1 Number and Weight of Nodules of Bambara Groundnuts Intercropped with Cowpea and Maize

Intercropping decreased the number and weight of nodules in both bambara groundnut/cowpea and bambara groundnut/maize intercropping systems in Makurdi (Table 2). Bambara groundnut intercropped with cowpea produced more nodules than when intercropped with maize, but there was no difference in the weight of the nodules between the two systems (Table 2). When intercropped separately with cowpea and maize, 'Adikpo' landrace, produced significantly higher number and weight of nodules than the other two landraces (Table 3). Under intercropping with maize, 'Okirikiri' had significantly higher number of nodules than 'Karo', but when intercropped with cowpea, it had less (Table 3).There was no significant difference between 'Karo' and 'Okirikiri' in the weight of nodules produced by bambara groundnut landraces when intercropped with maize, but 'Karo' had significantly heavier nodules than 'Okirikiri' under intercropping with cowpea (Table 3). There was no significant difference between bambara groundnut/cowpea and bambara groundnut/maize intercropping systems in the number and weight of nodules produced (Table 3). The number and weight of nodules decreased with decline in planting density of bambara groundnut in both bambara groundnut/cowpea and bambara groundnut/maize intercropping systems in Makurdi (Table 4).

Table 2. Number of nodules and weight (mg) per plant of bambara groundnut as affected by intercropping separately with cowpea and maize in Makurdi

Cropping systems	Bambara groundnut/cowpea (Expt. 1)		Bambara groundnut/maize (Expt. 2)	
	Number of nodules	Weight of nodules	Number of nodules	Weight of nodules
Sole	36.56	266.74	35.11	268.30
Intercrop	17.56	199.15	15.93	199.33
Mean	27.06	232.94	25.52	233.81
FLSD (0.05)	3.25	3.05	2.11	5.25
Paired t-test (0.05)				
Number of nodules in Expt.1 vs. Expt.2	17.11*			
Weight of nodules in Expt.1 vs. Expt.2	1.26ns			

*: significant; ns: not significant at 5% level of probability

Table 3. Number of nodules and weight (mg) per plant of bambara groundnut as influenced by landraces in Makurdi

Landraces	Bambara groundnut/cowpea intercrop (Expt. 1)		Bambara groundnut/maize (Expt. 2)	
	Number of nodules	Weight of nodules	Number of nodules	Weight of nodules
Karo	26.11	228.22	21.50	221.89
Okirikiri	22.33	213.50	23.78	224.89
Adikpo	32.72	257.11	31.28	254.67
Mean	27.06	232.94	25.52	233.81
FLSD (0.05)	0.91	1.89	1.93	3.98
Paired t-test (0.05)				
Number of nudules in Expt.1 vs. Expt.2	0.88ns			
Weight of nodules in Expt.1 vs. Expt.2	-0.16ns			

*: significant; ns: not significant at 5% level of probability

Table 4. Effect of planting density on the number and weight (g) of nodules per plant of bambara groundnut intercropped with cowpea and maize in Makurdi

Planting density	Bambara groundnut / cowpea intercrop (Expt. 1)		Bambara groundnut / maize (Expt. 2)	
	Number of nodules	Weight of nodules	Number of nodules	Weight of nodules
P1	31.39	252.72	28.83	249.50
P2	27.56	233.39	24.89	233.72
P3	22.22	212.72	22.83	218.22
Mean	27.06	232.94	25.52	233.81
FLSD (0.05)	1.53	2.26	1.20	3.17
Paired t-test (0.05)	1.43ns			
Number of nudules in Expt.1 vs. Expt.2	1.43ns			
Weight of nodules in Expt.1 vs. Expt.2	-0.96ns			

*: significant; ns: not significant

3.2 Nitrogen Yields of Shoot, Root and Pod with Seed of Bambara Groundnuts Intercropped with Cowpea and Maize

There was no significant difference between sole cropping and intercropping in nitrogen yields of both shoot and roots of bambara groundnut intercropped with maize in Makurdi, but intercropping (3.19%) gave significantly higher values of N yield in pod with seed than the sole crop (2.96%) treatment (Table 5). The N yields of shoots of the bambara groundnut landraces (Table 6) were not significantly different from one another, but the roots and pod with seeds of 'Okirikiri' had significantly higher levels of N than those of 'Karo' and 'Adikpo' landraces. While the roots (2.05 %) of 'Karo' gave significantly higher N yields than 'Adikpo' (1.94 %), the N yields of pod with seed (3.06 %) of 'Adikpo' was higher than that of 'Karo' (2.94 %) (Table 6). The N content of shoot, root and pod with seed of bambara groundnut intercropped with maize increased with decrease in planting density (Table 7). Under intercropping with cowpea, no significant differences were observed between sole and intercropped treatments in N yields of shoot, root and pod with seed of bambara groundnut (Table8). Table 9 presents the influence of landraces on the nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with cowpea in Makurdi. While no significant differences were noticed between the landraces in N content of shoot and roots, 'Okirikiri' had significantly higher N content (3.11 %) of pod with seed than the other two landraces. The N content of pod with seed of 'Karo' and 'Adikpo' were similar (Table 9). Table 10 shows the effect of planting density on the nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with cowpea in Makurdi. The N yield of bambara groundnuts increased with decline in planting density. The N yields of shoots and roots at P2 and P3 were statistically at par, but in the pod with seed, the trend was different. N yield of pod with seed at P3 (3.12%) was significantly higher than at P2 (2.67 %), which in turn was higher than P1 (2.52 %). The nitrogen yield of pod with seed of bambara groundnuts was consistently higher than that of shoot, which in turn was higher than root in both intercropping systems with maize and cowpea (Tables 5, 6,7,8,9 and 10). The differences were significant in most instances.

Table 5. Nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with maize in Makurdi

Cropping systems	Shoot nitrogen	Root nitrogen	Nitrogen in pod with seed	Mean
Sole	2.22	2.12	2.96	2.46
Intercropping	2.24	1.95	3.19	2.46
Mean	2.23	2.04	3.08	2.45
FLSD (0.05)	0.17ns	0.23ns	0.12*	
Paired t-test (0.05)				
Shoot vs root	-2.05ns			
Shoot vs pod	8.05ns			
Root vs pod	5.20ns			

*: significant; ns: not significant

Table 6. Influence of landrace on the nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with maize in Makurdi

Landraces	Shoot nitrogen	Root nitrogen	Nitrogen in pod with seed	Mean
Karo	2.19	2.05	2.94	2.39
Okirikiri	2.27	2.13	3.24	2.55
Adikpo	2.22	1.94	3.06	2.45
Mean	2.23	2.04	3.08	2.45
FLSD (0.05)	0.20ns	0.08	0.04	
Paired t-test (0.05)				
Shoot vs root	-4.00*			
Shoot vs pod	13.36*			
Root vs pod	13.86*			

*: significant; ns: not significant

Table 7. Effect of planting density on on the nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with maize in Makurdi

Planting density	Shoot nitrogen	Root nitrogen	Nitrogen in pod with seed	Mean
P1	1.91	1.80	2.89	2.20
P2	2.32	2.12	3.05	2.49
P3	2.45	2.19	3.30	2.65
Mean	2.23	2.04	3.08	2.45
FLSD (0.05)	0.13	0.10	0.08	
Paired t-test (0.05)				
Shoot vs root	-4.36*			
Shoot vs pod	11.82*			
Root vs pod	18.32*			

*: significant; ns: not significant

Table 8. Nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with cowpea in Makurdi

Cropping systems	Shoot nitrogen	Root nitrogen	Nitrogen in pod with seed	Mean
Sole	2.34	2.18	2.73	2.42
Intercropping	2.29	2.02	2.81	2.73
Mean	2.32	2.10	2.77	2.40
FLSD (0.05)	0.11ns	0.30ns	0.11ns	
Paired t-test (0.05)				
Shoot vs root	-3.91ns			
Shoot vs pod	7.00ns			
Root vs pod	5.58ns			

*: significant; ns: not significant

Table 9. Influence of landrace on the nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with cowpea in Makurdi

Landraces	Shoot nitrogen	Root nitrogen	Nitrogen in pod with seed	Mean
Karo	2.36	2.14	2.58	2.36
Okirikiri	2.33	2.03	3.11	2.49
Adikpo	2.27	2.12	2.62	2.34
Mean	2.32	2.10	2.77	2.39
FLSD (0.05)	0.14ns	0.17ns	0.17	
Paired t-test (0.05)				
Shoot vs root	-5.15*			
Shoot vs pod	0.12ns			
Root vs pod	3.30ns			

*: significant; ns: not significant

Table 10. Effect of planting density on on the nitrogen yields (%) of shoot, root and pods with seed of intercropped bambara groundnut with cowpea in Makurdi

Planting density	Shoot nitrogen	Root nitrogen	Nitrogen in pod with seed	Mean
P1	2.14	1.86	2.52	2.17
P2	2.38	2.20	2.67	2.42
P3	2.43	2.24	3.12	2.59
Mean	2.32	2.10	2.77	2.37
FLSD (0.05)	0.15	0.09	0.13	
Paired t-test (0.05)				
Shoot vs root	-6.81*			
Shoot vs pod	3.74ns			
Root vs pod	5.66*			

*: significant; ns: not significant

3.3 Nitrogen Fixed and N Derived from the Atmosphere by Bambara Groundnuts Intercropped with Cowpea and Maize

Bambara groundnut/cowpea intercrop systems fixed more N than bambara groundnut/ maize systems (Table 11). Mean percentage of plant N derived from atmosphere (% Ndfa) varied from 49.80 in the bambara groundnut/maize systems to 56.80 in the bambara groundnut/cowpea intercrops, while N fixed was 11.27 kg/ha and 34.90 kg/ha in the respective intercrop systems (Table 11). Intercropping depressed both percentage of plant N derived from atmosphere (% Ndfa) and fixed (kg/ha) by bambara groundnut intercropped with cowpea and maize in Makurdi, Benue State, Nigeria (Table 11). The depression in % Ndfa was not significant in both intercropping systems. Nitrogen fixed in sole cropping was significantly higher than under intercropping in both bambara groundnut/cowpea and bambara groundnut/maize intercrops. Sole cowpea fixed the highest amount of N (63.00 kg/ha), while bambara groundnut intercropped with maize fixed the lowest N (10.16 kg/ha). 'Okirirkiri' landrace had significantly higher % Ndfa (58.47) and fixed N (14.16 kg/ha) values than 'Adikpo' (57.12% and 13.05 kg/ha, respectively), which in turn gave higher figures than 'Karo' (53.90% and 12.20 kg/ha, respectively) (Table 12) under the bambara groundnut/ maize systems. No significant differences were observed between the landraces in both % Ndfa and N fixed in the bambara groundnut/cowpea intercrops (Table 12). Both % Ndfa and N fixed increased with decline in the planting density of bambara groundnuts from P1 to P3 in both bambara groundnut/cowpea and bambara groundnut/maize intercropping systems (Table 13). However, the differences were only significant in both intercropping systems in the amount of N fixed (Table 13).

Table 11. Percentage of plant N derived from atmosphere (%Ndfa) and fixed (kg/ha) by bambara groundnuts intercropped with cowpea and maize in Makurdi

Cropping systems	Bambara groundnut / cowpea intercrop (Expt. 1)		Bambara groundnut / maize (Expt. 2)	
	% Ndfa	N fixed	% Ndfa	N fixed
Sole bambara groundnut	53.50	12.10	50.00	12.37
Intercropped bambara groundnut	57.70	10.20	49.80	10.16
Sole cowpea	63.20	63.00	-	-
Intercropped cowpea	52.70	54.20	-	-
Mean	56.80	34.90	49.80	11.27
FLSD (0.05)	31.19ns	49.52	5.61ns	0.83
Paired t-test (0.05) (N fixed)				
Bambara groundnut / cowpea intercrop vs. Bambara groundnut / maize intercrop	15.04*			

* = significant; ns: not significant

Table 12. Percentage of plant N (% Ndfa) derived from atmosphere (% Ndfa) and fixed (kg/ha) by bambara groundnuts as influenced by landraces in maize and cowpea intercrops

Landraces	Bambara groundnut / cowpea intercrop (Expt. 1)		Bambara groundnut / maize (Expt. 2)	
	% Ndfa	N fixed	% Ndfa	N fixed
Karo	57.00	8.30	53.90	12.20
Okirikiri	57.10	22.50	58.47	14.16
Adikpo	53.20	12.46	57.12	13.05
Mean	55.80	14.40	56.51	13.14
FLSD (0.05)	15.87ns	19.61ns	2.25*	0.59*

* = significant; ns: not significant

Table 13. Percentage of plant N (% Ndfa) derived from atmosphere (% Ndfa) and fixed (kg/ha) by bambara groundnuts as affected by planting density

Planting density	Bambara groundnut / cowpea intercrop (Expt. 1)		Bambara groundnut / maize (Expt. 2)	
	% Ndfa	N fixed	% Ndfa	N fixed
P1	52.60	9.50	50.67	10.55
P2	57.20	11.68	56.27	12.48
P3	59.10	12.82	58.91	14.83
Mean	56.30	11.33	55.28	12.62
FLSD (0.05)	11.38ns	2.58*	0.58	1.87*

* = significant; ns: not significant

4. Discussion

Nodulation plays a critical role in N fixation by leguminous crops. Nodule growth and function require light-dependent photosynthates. The observed reduction in the number and weight of nodules of intercropped bambara groundnuts when compared to sole crop treatments might be as a result of shading from the more aggressive components of intercropping (maize and cowpea). This finding was in agreement with the results of earlier studies (Egbe & Egbo, 2011; Egbe, 2007; Nambiar *et al*., 1983) who observed decreased nodulation in intercropped cowpea, pigeonpea and groundnuts in their separate studies and attributed the reduction in nodulation to adverse effects of shading. The number of nodules in bambara groundnut/cowpea intercropping was significantly higher than in bambara groundnut/maize intercropping system, probably because a more conducive environment (moisture, temperature, etc.) for nodulation was created under the bambara groundnut/cowpea intercropping system. The cowpea (semi-spreading) component used in this study covered the ridges, thus reducing both moisture loss and soil temperature. Eaglesham and Ayanaba (1984) had indicated that moisture and temperature has a marked influence on legume-rhizobium symbioses. The varied response of the landraces of bambara groundnuts in the number and weight of nodules produced under both intercropping systems might be ascribed to differences in genetic composition. Significant differences in the number and biomass of nodules among crop varieties of the same species have been reported (Kaleem, 2000; Egbe, 2007; Egbe & Bar-Nyam, 2011). The decline in number and weight of nodules of bambara groundnuts in both intercropping systems with decline in planting density might be an indication that nodule number and weight depended more on the number of plants per unit area and may be little affected by competitive interactions. Rao (2002) in their study on biomass production and nutrient recycling through leaf litter from pigeonpea observed that the crucial factor determining biomass production was not spacing but planting density. The N content of roots and shoots of bambara groundnuts seemed not to have been affected by intercropping, but N content of pods with seeds of intercropped bambara groundnuts with maize was significantly higher than sole. A similar observation was recorded in intercropped pigeonpea at varying densities with sorghum in the Nigerian Southern Guinea Savanna ecology (Egbe & Bar-Nyam, 2011). The nitrogen yield of pod with seed of bambara groundnuts was consistently higher than that of shoot, which in turn was higher than root in both intercropping systems with maize and cowpea. Sinclair and Vadez (2002) stated that a large amount of the N is usually exported to the grain. No significant differences were noticed between the landraces in N content of shoot and roots, but 'Okirikiri' had significantly higher N content (3.11 %) of pod with seed than the other two landraces. This result suggests that selection for N content should be based on pod with seed rather than on root or shoot N. The results of % Ndfa in this study showed that bambara groundnuts obtained nearly 50% of its N requirement from the atmosphere and it was not affected by intercropping. Earlier studies had indicated that intercropping of grain legumes generally results in the legume deriving a greater proportion of its N from N fixation than when grown alone (Giller *et al*.,1991). Results of this study showed that N fixation in sole systems were higher than in intercropping. This is in agreement with the reports of Nambiar *et al*. (1983), which indicated that shading by tall cereal crops can reduce both yield and N fixation of shorter stature legumes. Mean quantities of N fixed by bambara groundnuts in both intercropping systems were small (11.27- 34.90 kg/ha). This result was in consonance with the observations of Giller *et al*. (1991), which reported that N fixed by bambara groundnuts was barely significant. The mean quantity of N fixed by the bambara groundnut/cowpea system (34.90 kg/ha) was significantly higher than that fixed by the bambara groundnut/maize system (11.27 kg/ha), probably because the number of nodules and weight were higher in bambara groundnut/cowpea system than in the bambara groundnut/maize system. Secondly, the cowpea component also fixed N unlike the maize component. 'Okirikiri' and 'Adikpo' landraces fixed more N than 'Karo' and N fixed increased with decline in bambara groundnut planting density. Many studies have shown that the quantity of N fixed by the legume depends on such factors as the genotype (Kumar Rao, Wani, & Lee, 1996), the morphology, density, and competitive ability of the legume (Ofori & Stern, 1987). The expectation of enormous contribution of nitrogen fixation to bambrara groundnut yields and its residual effects on soil medium for ensuing crops may be an illusion with the use of the landraces tested in this work, except, probably when inoculated with the appropriate rhizobia?

References

[1] BNARDA (Benue State Agricultural and Rural Development Authority) (2003). *Annual Report, 2003* (p. 25). BNARDA, Makurdi, Benue State, Nigeria.

[2] BNARDA (Benue State Agricultural and Rural Development Authority) (2010). *Agricultural Survey (APS) Report* (p. 23). BNARDA, Makurdi, Benue State, Nigeria.

[3] Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal*, *54*(4), 464-465.

[4] Bray, R. H., & Kurtz, L. T. (1944). Determination of total, organic and available forms of phosphorus in soils. *Soil Science, 59*(1), 39-46.

[5] Chaykin, S. (1969). Assay of nicotinamide deaminase: Determination of ammonium by the indolphenol reaction. *Annals of Biochemistry, 32*, 375-382.

[6] Dakora, F. D., & Muofhe, L. M. (1997). Nitrogen fixation and nitrogen nutrition in symbiotic bambara groundnut (Vigna subterranean (L.)Verdc.) and Kerting's bean (Macrotyloma geocarpum (Harms) Marech et Baud.). In J. Heller, F. Begemann, & J. Mushonga (Eds.), *Bambara Groundnut Vigna Subterranea (L.) Verdc: Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut (Vigna Subterranea (L.) Verdc.): 14-16 November 1995, Harare, Zimbabwe* (p. 72-77). Bioversity International.

[7] DFID (2002). *Marketing and processing of bambrara groundnuts (West Africa)*. DFID Programme: Crop Post Harvest, R Number: R7581.

[8] Eaglesham, A. R. J., & Ayanaba, A. (1984). Tropical stress ecology of Rhizobia, root nodulation and legume fixation. In N. S. Subba Rao (Ed.), *Current Development in Biological Nitrogen Fixation* (p. 1-35). Oxford and IBH, New Delhi.

[9] Egbe, O. M. (2007). Assessment of biological nitrogen fixing potentials of pigeonpea genotypes intercropped with sorghum in Southern Guinea Savanna of Nigeria. *Agro-Science, 6*(1), 33-45.

[10] Egbe, O. M., Kalu, B. A., & Idoga, S. (2009). Contribution of common food legumes to the fertility status of sandy soils of the Moist Savanna Woodland of Nigeria. *Report and Opinion Journal, 1*(1), 45-62.

[11] Egbe, O. M., & Bar-Nyam, M. N. (2011). Effects of sowing density of intercropped pigeonpea with sorghum on biomass yield and nitrogen fixation in Southern Guinea Savanna of Nigeria. *Journal of Production Agriculture and Technology*, *7*(1), 1-14.

[12] Egbe, O. M., & Egbo, C. U. (2011). Nodulation, nitrogen fixation and harvest index of extra-short and short-duration cowpea varieties intercropped with maize at Otobi, Benue State,Nigeria. *Journal of Animal and Plant Science, 10*(3), 1315-1324.

[13] Frye, W. W., & Blevins, R. L. (1989). Economically sustainable crop production with legume cover crops and conservation tillage. *Journal of Soil and Water Conservation, 44*(1), 57-60.

[14] Fujita, K., Ofosu-Budu, K. G., & Ogata, S. (1992). Biological nitrogen fixation in mixed legume-cereal cropping systems. *Plant and Soil,* 141(1-2), 155-175.

[15] Giller, K. E., Ormeshe, J., & Awah, F. M. (1991). Nitrogen transfer from *Phaseolus* bean to intercropped maize measured using ^{15}N-enrichment and ^{15}N-isotope dilution methods. *Soil Biology and Biochemistry, 23*(4), 339-346.

[16] Heanes, D. L. (1984). Determination of total organic C in soils by an improved chromic digestion and spectophotometric procedure. *Communications in Soil Science and Plant Analysis*, *15*(10), 1191-1213.

[17] Juo, A. S. R. (1979). *Selected methods for soil and plant analysis*. Manual series No.1. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

[18] Kaleem, F. (2000). Biological nitrogen fixation in a soybean / sorghum intercropping system. In N. Karanja, & H. P. Kahindi (Eds.), *Challenges and imperatives for biological nitrogen fixation researchand applications in Africa for the 21st century* (p. 50-62). Proceedings of the nineth congress of the African Association for Biological Nitrogen Fixation, 25-29th Sept. 2000, Nairobi, Kenya.

[19] Karikari, S. K., Chaba, O., & Molosiwa, B. (1999). Effects of intercropping bambara groundnuts on pearl millet,sorghum and maize in Botswana. *African Crop Science Journal, 7*(2), 143-152.

[20] Kumar Rao, J. V. D. K., Wani, S. P., & Lee, K. K. (1996). Biological nitrogen fixation through grain legumes in different cropping systems of the semi-arid tropics. In O. Ito, C. Johansen, J. J. Adu-Gyamfi, K. Katayama, J. V. D. K. Kumar Rao, & T. J. Rego (Eds.), *Roots and nitrogen in cropping systems of the semi-arid tropics*. Proceedings of the International Workshop: Dynamics of Roots and Nitrogen in Cropping Systems of the Semi-Arid Tropics, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India, 21-25 November 1994.

[21] Mkandiwire, F. L., & Sibuga, K. P. (2002). Yield response of bambara groundnut to plant population and seedbed type. *African Crop Science Journal*, *10*(1), 39-49.

[22] Mulila-Mitti, J. (1997). Towards increased food legume production. In J. Heller, F. Begemann, & J. Mushonga (Eds.), *Bambara Groundnut Vigna Subterranea (L.) Verdc: Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut (Vigna Subterranea (L.) Verdc.): 14-16 November 1995, Harare, Zimbabwe* (p. 89-92). Bioversity International.

[23] Nambiar, P. T. C., Rao, M. R., Reddy, M. S., Floyd, C. N., Dart, P. J., & Willey, R. W. (1983). Effect of intercropping on nodulation and N_2-fixation by groundnut. *Experimental Agriculture, 19*(1), 79-86.

[24] Ofori, F., & Stern, W. R. (1987). Cereal-legume intercropping systems. *Advances in Agronomy, 41*, 41-90.

[25] Papastylianou, I. (1999). Estimation of nitrogen fixed by legumes in long-term vs. short-term cropping systems. *Agronomy Journal*, *91*(2), 329-334.

[26] Rao, D. L. N. (2002). Nitrogen fixation by tree legumes. In S. Kannaiyan (Ed.), *Biotechnology of Biofertilizers* (p. 172-176).

[27] Rennie, R. J. (1984). Comparisonof N balance and ^{15}N isotope dilution to quantify N_2 fixation in field – grown legumes. *Agronomy Journal, 76*(5), 785-790.

[28] Rerkasem, B., Rerkasem, K., Peoples, M. B., Herridge, D. F., & Bergersationen, F. J. (1988). Measurement of N_2 fixation in maize (Zea mays L.) – ricebean [Vigna umbellata (Thumb.) Ohwi and Ohashi] intercrops. *Plant and Soil, 108*(1), 125-135.

[29] Sinclair, T. R. (1990). Nitrogen influence on the physiology of crop yield. In R. Rabbinge, J. Goudriaan, H. van Keulen, F. W. T. Penning de Vries, & H. H. van Laar (Eds.), *Theoretical Production Ecology: Reflection and Prospects* (p. 41-55). Pudoc Wageningen, The Netherlands.

[30] Sinclair, T. R., & Horie, T. (1989). Leaf nitrogen, photosynthesis and crop radiation use efficiency: A review. *Crop Science, 29*(1), 90-98.

[31] Sinclair, T. R., & Vadez, V. (2002). Physiological traits for crop yield improvement in low N and P environments. *Plant and Soil, 245*(1), 1-15.

[32] Smil, V. (2005). The next 50 years: unfolding trends. *Population and Development Review, 31*(4), 605-643.

[33] Tanimu, B., & Aliyu, L. (1997). Country Reports-Northern Nigeria. In J. Heller, F. Begemann, & J. Mushonga (Eds.), *Bambara Groundnut Vigna Subterranea (L.) Verdc: Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut (Vigna Subterranea (L.) Verdc.): 14-16 November 1995, Harare, Zimbabwe* (p. 45-49). Bioversity International.

[34] Tel, D., & Rao, P. (1982). *Automated and semi-automated methods for soil and plant analysis*. IITA Manual Series No. 7. International Institute of Tropical Agriculture, Ibadan, Nigeria.

[35] Yakubu, H., Kwari, J. D., & Sandabe, M. K. (2010). Effect of phosphorus fertilizer on nitrogen fixation by some grain legume varieties in Sudano – Sahelian Zone of North Eastern Nigeria. *Nigerian Journal of Basic and Applied Sciences, 18*(1), 44-49.

