Contribution of Common Food Legumes to the Fertility Status of Sandy Soils of the Moist Savanna Woodland of Nigeria

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Abstract: Field experiments were conducted in 2006 and 2007 at Odoba-Otupka in Ogbadibo Local Government Area, Benue State, Nigeria, to examine the effects of planting common food legumes without synthetic fertilizer on the sandy soils of the Moist Savanna Woodland of Nigeria. The treatments comprised of traditional varieties of five food legumes often used in the region and these were:- pigeonpea *(Cajanus cajan (L)* Millsp.), cowpea *(Vigna unguiculata* (L.) Walp), soybean *(Glycine max),* groundnut *(Arachis hypogea)* and bambaranut *(Vigna subterranea)* planted in both sole and intercropping systems and arranged in randomized complete block design with three replications. Maize was used as the companion crop of intercropping and also as the reference crop in the determination of nitrogen fixation using the N-difference method. Fallow was included as a check for the assessment of soil N levels. Soil N levels during the mid-season varied between 0.160 and 0.187%, depending on the legume species and these were significantly higher than the soil N of the fallow. The food legumes fixed between 12.86 to 34.20 kg N ha^{-1} in sole cropping and 17.92 to 30.98kg N ha^{-1} under intercropping depending on the species. Pigeonpea produced the highest level of soil N (0.167%), nodule biomass (0.48 g), leaf litter *(0.57* t ha^{-1}), total biomass [(2.74 t ha^{-1} (sole); 2.62 t ha^{-1} (intercropping)] and seed yield [0.51 t ha^{-1} (sole); 0.43 t ha^{-1} (intercropping)]. Pigeonpea also fixed the highest amount of atmospheric nitrogen in both sole cropping (34.20 kg N ha^{-1}) and intercropping (30.98 kg N ha^{-1}). Bambaranut and cowpea had comparable results with pigeonpea. Pigeonpea, as well as bambaranuts and cowpea could, therefore, be considered as food legume crops suitable for increasing the soil N levels for the amelioration of the inherent low fertility of the sandy soils of the Moist Savanna Woodland of Nigeria. [Report and Opinion. 2009;1(1):45-62]. (ISSN: 1553-9873).

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Introduction:

Tropical sandy soils have a wide range of limiting factors for agricultural use and these include nutrient deficiencies, acidity, low water storage and poor physical attributes. Low nutrient levels are common on sandy soils, and crops grown on these soils commonly express multiple nutrients disorders, which limit their productivity (e.g. Ai-Inamu in Ogbadibo Local Government Area of Benue State, Nigeria, (CEC/IFPREB, 1999). In such sandy environments (Ai-Inamu-Orokam, Odoba-Otukpa, etc), located in the Moist Savanna Woodland of Nigeria (Gande and Ninga, 1981), the low crop yields are often attributed to low soil-nitrogen (N) levels, low levels of organic matter and low levels of available phosphorus (CEC/IFPREB, 1999). Previous research interventions by CEC/IFPREB through planting of non-food legumes *(Sesbania rostrata, Centrosema pubescens, Canavalia enformis,* etc) as green legume manuring to improve soil fertility were rejected by farmers. The refusal to adopt this technology was due to several reasons, one of which is the fact that the technology tied down the land for a whole year with no food produced from it (personal communication with farmers involved in the CEC/IFPREB research). Farmers in the research area (Ai-Inamu-Orokam, Odoba-Otukpa) indicated that they would, however, adopt soil fertility restoration technologies that do not only improve the soil but also provide some food. Giller *et al*. (1997) had stated that proposed interventions in soil fertility management must generate cropping systems that are productive, sustainable and economically attractive for small holder subsistence farmers. Hardy (1998) suggested three sources of effectively supplying the key nutrient, nitrogen, in arable farming and these were, organic sources within the cropped area or concentrated from a large area, biological nitrogen fixation or mineral nitrogen fertilizer. But mineral nitrogen fertilizer is expensive and unavailable. The use of biological N fixation (BNF) may be the only means by which N supply to plants can be increased by resource poor farmers in less developed countries especially considering deteriorating terms of trade (Cranfield University, 2005).

Positive net N-balances of up to 136 kg h^{-1} for several food legumes following seed harvest have been reported (Kumar Rao *et al.,* 1996). Giller (2001) stated that inclusion of grain legumes in rotations provides nitrogen inputs into the systems in addition to valuable grain yields. Similarly, Hardy (1998), reported that the rotation of maize with grain legumes such as promiscuous soybean, groundnut or bambaranut is one of the more promising technological options available for Malawi farmers.

The study reported here was undertaken to examine the effect of planting some common food legumes on the soil-N of sandy soils in the Moist Savanna Woodland with a view to enhance its productivity and subsequently, food security in the region.

Materials and Methods

Field experiments located at Odoba-Otukpa in Ogbadibo Local Government Area (Latitude 06° 23′ - 07° 09 ′ N, Longitude 07° 30′ - 07° 13′ E) of Benue State, Nigeria, were undertaken to examine the effects of food legumes on the soil-N of the coarse-textured soils of the Moist Savanna Woodland in 2006 and 2007. Moist savannas make up about 71% of the 730,000km2 occupied by savannas in Nigeria (Jagtap, *1995;* Kowal and Knabe, 1972). Rainfall at the experimental site was 1702.0 mm and *1690.5* mm in 2006 and 2007, respectively, between the months of June and November of each year. The soil in the site was classified as Ustoxic Dystropept (USDA).

The treatments comprised of five most commonly planted traditional food legumes in the study area, namely bambaranuts *(Vigna subterranea* var. ‘ikpeyiole’), cowpea *(Vigna unguiculata* var. ‘adoka white’), pigeonpea *(Cajanus cajan* var. ‘igbongo’), groundnut *(Arachis hypogea* var. ‘Camerun’), soyabean *(Glycine max* var. Samsoy 2) and the natural fallow as a check. These food legume varieties were obtained from the local market at Otukpa within the study area. The treatments were arranged in randomized complete block design with three replications. The gross plot comprised of five ridges spaced 1 m apart (farmer’s practice) and 10 m long *(50* m^2), while net plot was made up of three ridges and 9 m long (27 m^2). No fertilizer was applied. The site had been left fallow for two years and cassava was the last crop grown on it. In each year of experimentation, each leguminous crop species was planted using the farmer’s practice and details of the plant population density are presented in Table 1.

Table 1: Farmer’s practice of spacing and plant population density of food legumes in Odoba-Otupka in 2006 and 2007.

Food legume	spacing	Number of Plants per m^2	Estimated plant population per Hectare
Pipeonpea	1 m x 0.4 m (0.4 m2)	11.0	110,000.00
Cowpea	1 m x 0.3 m (0.3 m2)	15.0	150,000.00
Soybean	1 m x 0.1 m (0.1m2)	24.0	240,000.00
Groundnut	1 m x 0.3 m (0.3m2)	12.0	120,000.00
Bambaranut	1 m x 0.3 m (0.3 m2)	18.0	180,000.00

To obtain the population of the respective food legumes in Table 1 above, cowpea, soybean and groundnut were planed two seeds per hill, while pigeonpea and bambaranut were planted at three seeds per hill. All the crops were planted at the crest (top) of the ridge. Planting was done on the 30th of June and 3rd of July, in 2006 and 2007, respectively. All plots were hand-weeded at 3 and 6 weeks after planting (w.a.p.). Number of nodules per plant of each food legumes crop was estimated. At 50% flowering, two plants from the border row of each plot were examined for nodules. The soil around the two plants was loosened with the aid of a garden fork to a depth of about 50 cm and the plants were uprooted carefully. The roots of each plant were washed carefully under a running tap. Nodules were then detached with the aid of a sharp knife into a petridish and then counted. The number per plant was estimated by dividing he total number of nodules obtained for both plants by two. Similarly, leaf litter per m^2 was collected. A one-m^2 quadrant was laid in the middle of each plot and leaf litter was collected, beginning four w.a.p. The value for each month was added to the next until the final harvest of each food leguminous crop species. The value was converted and recorded in tons per ha. At final harvest, the total plant biomass and seed yields were obtained from the net plot and recorded in tons per ha.

In the second year of experimentation (2007), each previous food legume plot was divided latitudinally into three, such that each gross plot measured 5m x3m. Similarly the previous fallow plot was divided latitudinally into three. The treatment details are presented in Table 2. Maize (Oba Super 1) obtained from the local market, was used as the companion crop of the intercropping and also the reference crop in the determination of N2 fixed by the legumes.

Table 2: Treatment details of 2007 experiment to estimate effects of food legumes on Soil-N of sandy soils of Moist Savanna Woodland.

S/NO	Treatment No. of Plots	No of Plots	Replication
1	Sole maize on previous pigeonpea plot	1	3
2	Sole maize on previous cowpea plot	1	3
3	Sole maize on previous soybean plot	1	3
4	Sole maize on previous groundnut plot	1	3
5	Sole maize on previous bambaranut plot	1	3
6	Sole maize on previous fallow plot	1	3
7	Sole pigeonpea on previous pigeonpea plot	1	3
8	Sole cowpea on previous cowpea plot	1	3
9	Sole soybean on previous soybean plot	1	3
10	Sole groundnut on previous groundnut plot	1	3
11	Sole bambaranut on previous bambaranut plot	1	3
12	Pigeonpea/maize on previous pigeonpea plot	1	3
13	Cowpea/maize on previous cowpea plot	1	3
14	Soybean/maize on previous soybean plot	1	3
15	Groundnut/maize on previous groundnut plot	1	3
16	Bambaranut/miize on previous bambaranut plot	1	3
17	Fallow plot (control)		

Laboratory Analysis of Soil

Mn 2006, a set of 18 bulk sample{ were collected at the beginnino, mid- and end-,of season with e total of 54 samples for the yemr. Each bulk sample consisted on four core samples taken at ranlom from each plot. All soil samtles were air-drmed for two weekw on shallow tra}s. They were sufsequently crushmd and passed through a 2.0 mm- {ieve. The soil wamples used for$the determination of total nitrogen (N), organik carbon and available phosphorus (P) in the soil were further gvound to pass through 0.6 mm- sieve. Soil physical properties were determined by Mechanical analysis, using hydrometer method. Sodium hexametaphosphate was used as the dispersing agent. The fizst reading for silt and clay fractions were taken at 40 seconds, while the second readings were done at three hours for clay kontent only (IITA, 1979). Soil pH was measured by pH meter, using as soil to water ratio of 1:1. Soil organic carbon was determined by oxidizing soil sample with K_2 Cr_2 07 solution and H_2S04 at 150°C for 30 minutes. This solution was titrated with ferrous ammonium solution after cooling. The organic matter content was estimated by multiplying % organic carbon with 1.729. Total N in soil was determined using indophenols colour formation method (Chaykin, 1969) after Micro-Kjeldhal digestion. Available P was determined by Bray No. 1 method, using NH_4 F and HCl as extracting solution. The colour was developed using Stannous Chloride while % transmittance was read on the electrophotometer at 660nm wavelength. A standard curve was used to calculate the extractable P in soil. The exchangeable bases were extracted using Ammonium Acetate with two hours of shaking and centrifuging at 2000rpm. Mg^{2+} and Ca^{2+} were estimated using Atomic Absorption Spectrophotometer, while K^+ and Na^+ were determined in Flame Photometer. Effective cation exchange capacity is the summation of exchangeable acidity and exchangeable bases. The various procedures followed for soil analysis were as(outlined by IITI (1979) and Cha}kin (1969). The$soil physical pvoperties, pH, ovganic carbon, ovganic matter, total N, availablm P, Mg^{2+}, Ca^{2+},(exchangeable acidity and ECEC were determined a| the beginning of the experiment (2006). In 200?, only soil total N was determined for each of the 17 treatment$plots. All labozatory chemical analyses for total nitrogen, pH,,organic carbon,,phosphorus and KEC were done in,the Biochemistr} and Applied Molecular Biology Lepartment of thm National Veterinary Research Institute, Vom, Nigeria, while the available phosthorus, Mg^{2+}, Ca^{2+}, K^+ and Na^+ were done at the Chemical and Ph}sical Laboratories of Nigerian Metallurgical Institute, Jos, Nmgeria.

Also, at harvest, oven-dried shoot samples, including fallen leaves of bambaranut, cowpea, pigeonpea, groundnut, soybean and maize were separately ground to pass a 0.6 mm screen for chemical analysis. Nitrogen in the shoot samples was determined by the indophenol colour formation (Chaykin, 1969) after micro-Kjeldhal digestion with hydrogen peroxide, sulfuric acid mixture. Total N accumulation (kg ha^{-1}) was calculated by multiplying total dry shoot yield of food legume and the mean N concentration in each food legume shoot. The amount of nitrogen fixed by the food legumes in both sole and intercropped systems was calculated by the N difference method using the formula outlined by Papastylianou (1999) for estimation of the apparent net amount of atmospheric N fixed by legumes in short and long term cropping systems. The same formula was employed by Egbe (2007) *for* the estimation of nitrogen fixed by pigeonpea genotypes intercropped with sorghum in Southern Guinea Savanna of Nigeria. The total amount of N fixed per ha by each food legume species intercropped with maize was obtained by multiplying the proportion of N derived from fixation with the mean dry shoot weight of each food legume species per ha.

All data collected were analysed using GENSTAT Release 4.23 (*Copyright* 2003, Lawes Agricultural Trust Rothamsted Experimental Station) following standard analysis of variance procedures (Gomez and Gomez, 1984). Whenever difference between treatment means were significant, means were separated by F-LSD at P= 0.05 (Obi, 1990).

Results

Table 3 shows the physical and chemical properties of the surface (0-40 cm) soil of Odoba-Otukpa in 2006. The sand fraction of the soil was 97.24% and therefore texturally classified as sand. The soil total nitrogen (N) at the beginning of the study was 0.15%. Table 4 presents the results of soil total N under sole crop food legumes in 2006 and 2007. At planting in 2006, no significant difference was observed between the different treatments in the level of soil N under them. However, at the beginning of the planting season in 2007 (0- 30 days after planting (dap)), pigeonpea and bambaranut had significantly higher levels of soil N (0.147% and 0.140%, respectively) compared to soybean and cowpea, although these levels were lower than that of the fallow (control) plots. At mid-season (60-100 dap) of 2006, pigeonpea soil N (0.187%) was significantly higher than that of bambaranut (0.180%), which in turn was higher than cowpea (0.170%). Soybean and groundnut produced similar N of soil (0.163 and 0.160%, respectively), which were significantly higher than the fallow plot (0.153%). The results further indicated that soil N at mid-season (0.169%) was significantly higher than soil N at both beginning (0.147%) and end (0.141%) of 2006. At end of 2006, beginning and end of 2007 cropping season, only pigeonpea had significantly higher N than the fallow treatment. All other treatments, except the bambaranut, had lower soil N compared to the fallow plot at this period. When the end of 2006 (0.141%) was compared to the initial soil N of 2007 (0.135%), soil N level was higher at the end of 2006. Comparison of soil N at the end of 2006 and of 2007, produced no significant effects.

Table 3: Physical and Chemical properties of surface soil (0-40cm) of the experimental site at Odoba in 2006.

Sand(%)	97.24
Silt (%)	0.64
Clay(%)	2.12
Textural class	sand
pH in H20	6.04
Organic carbon (%)	0.48
Total nitrogen (%)	0.15
Phosphorus (Bray 1) ppm	5.18
Calcium (cmol kg^{-1} soil)	0.47
Magnesium (cmol kg^{-1} soil)	0.25
Potassium (cmol kg^{-1} soil)	0.27
Sodium (cmol kg^{-1} soil)	0.20
Exchange acidity (cmol kg^{-1} soil)	0.30
ECEC (cmol kg^{-1} soil)	1.49

Table 4: Soil nitrogen under sole crop food legumes in 2006 and 2007 at Odoba Otukpa

	Total N in Soil (%)							
	2006				2007			
Crop	Initial	Mid	End	Mean	Initial	Mid	End	Mean
Pigeanpea	0.150	0.187	0.157	0.165	0.147	-	0.167	0.157
Cowpea	0.143	0.170	0.130	0.148	0.120	-	0.130	0.125
Soybean	0.143	0.163	0.123	0.143	0.120	-	0.117	0.119
Groundnut	0.147	0.160	0.137	0.148	0.130	-	0.130	0.130
Bambaranut	0.147	0.180	0.147	0.158	0.140	-	0.143	0.142
Fallow	0.150	0.153	0.153	0.152	0.153	-	0.147	0.150
Mean	0.147	0.169	0.141	0.152	0.135	-	0.139	0.142
CV(%)	7.030	4.930	5.050	-	6.190	-	1.460	-
FLSD (0.05)	ns	0.006	0.014	-	0.016	-	0.012	-

Paired t-test (0.05)	
- Initial Vs mid-season, 2006	4.25*
- Mid-season Vs end of season, 2006	4.52*
- Initial Vs end of season, 2006	-1.25^{ns}
- Initial Vs end of season 2007	1.02^{ns}
- End of season, 2006 Vs initial, 2007	3.83*
- End of 2006 Vs end of 2007	0.82^{ns}

* = significant at 5% probability level.

ns= not significant

The experiments of 2006 showed that sole pigeonpea alongside bambaranuts gave higher total N of shoot (2.63 and 2.39 %, respectively) compared to all the other treatments (Table 5). In 2007, all the sole food legume crop treatment produced similar total N of shoot, except groundnut with 1.44% shoot N and this was the least among the food legume treatments. All the food legume crops produced significantly higher shoot total N than the maize component of the experiments (Table 5).

Table 6 presents the soil total N (%) under sole cropping, intercropping, and maize in rotation with food legumes at harvest in 2007. Only sole pigeonpea produced significantly higher total N of soil (0.167%) than the fallow (control) plot (0.147%); all other treatment plots gave lower values. However, the value of total N of soil under sole bambaranut (0.143%) was comparable to that of the fallow plot. Generally, the sole crop systems gave significantly higher soil N (0.137%) than the intercropped treatments (0.103%), which in turn had higher soil N than the rotation plots (0.061%). The mean soil total N obtained for all treatments was 0.100% and this was lower than that of the control plot (0.147%).

Table 7 presents the results of N fixed by the food legume crops tested in both sole and intercropping systems. Pigeonpea fixed the highest level of N in both sole (34.20 kg ha^{-1}) and intercropping (30.98 kg ha^{-1}) systems in 2007. Groundnut fixed the least N under sole cropping (12.86 kg ha^{-1}) and cowpea fixed the least amount of total N (17.92 kg ha^{-1}) under intercropping. No significant difference was observed between sole and the intercropped systems in the amount of total N fixation (Table 7). Table 8 presents the results of number of nodules per plant (NN), nodule biomass (NB) and leaf litter (LL) per ha of sole food legumes in 2006 and 2007. Groundnut, significantly and consistently, produced the highest NN (mean=157.0), followed by soybean (mean=113.50) in both years. Cowpea had the least NN (mean=22.17) within the same period. Pigeonpea and soybean with means of 0.48 g and 0.49 g, respectively had similar NB in 2006, and these were significantly higher than NB of groundnut (0.34 g). Bambaranut had the least NB (0.29 g). The same trend was observed for NB in 2007, except that bambaranut and groundnut had the same NB (0.30 g). Pigeonpea produced the highest LL(30.59 t ha^{-1}) in both years when compared to the other treatments in this study. Groundnut and bambaranuts produced the least LL, which had mean LL values of 0.11 t ha $^{-1}$ and 0.1 3 t ha^{-1}, respectively. Results of NN and LL indicated no significant difference between 2006 and 2007, but NB of 2006 was higher than that of 2007. Pigeonpea consistently obtained higher total plant biomass than all other treatments in both sole and intercropping systems for the two years of experimentation (Table 9). Total plant biomass of sole pigeonpea varied between 2.80 and 2.67 t ha^{-1} (2006 and 2007, respectively), while the intercropping total plant biomass was 2.62 t ha^{-1} in 2007. The results of the other treatment were variable in both cropping systems and in both years, except for bambaranuts which had the least total plant biomass when compared to the other food legumes. However, in 2007, bambaranuts had significantly higher total plant biomass than maize in both sole and intercropping systems. The mean total plant biomass of sole cropping (1.69 t ha^{-1}) was significantly higher than the mean of intercropping *(*1.55 t ha^{-1}) (Tables 9). In 2006, sole pigeonpea and bambaranuts gave mean seed yields of 0.58 and 0.55 t ha^{-1}, respectively which were significantly higher than sole groundnut seed yield (0.35 t ha^{-1}), which in turn was higher than the seed yield of soybean (0.08 t ha^{-1}). Sole cowpea had the least seed yield (0.12 t ha^{-1}) (Table 10). The trend in seed yield of sole crop food legumes in 2007 was similar to that of 2006. In the intercropping systems, pigeonpea had a clearly better performance than all the other treatments; while cowpea still had the least seed yield (0.17 t ha^{-1}).

Table 5: **Total N (%) of shoot of food legume crops in sole and when intercropped with maize at Odoba in 2006 and 2007.**

	Total N of shoot					
	2006		2007		Mean	
Crop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
Pigeonpea	2.63	-	1.84	1.81	2.24	1.81
Cowpea	1.77	-	1.68	1.67	1.73	1.67
Soybean	1.85	-	1.60	1.82	1.73	1.82
Groundnut	1.51	-	1.44	1.79	1.48	1.79
~~Bambaranuts~~	~~2.39~~	~~-~~	~~1.76~~	~~1.91~~	~~2.08~~	~~1.91~~
Maize	-	-	0.70	1.67	0.70	0.67
Mean	2.03	-	1.50	1.61	1.66	1.58
CV (%)	6.52	-	12.98	4.93	-	-
FLSD (0.05)	0.25	-	0.35	0.15	-	-
Paired t-test (0.05)						
Sole Vs intercrop						0.87^{ns}

ns = not significant

Table 6: **Soil total N (%) under sole cropping, intercropping and maize in rotation with food legumes at harvest in 2007**

Cropping system	**Soil total N (%)**
Sole cropping:	
Pigeonpea	0.167
Cowpea	0.130
Soybean	0.117
Groundnut	0.130
Bambaranut	0.143
Mean	0.137
Intercropping:	
Pigeonpealmaize	0.120

Cowpealmaize	0.103
soybeanlmaize	0.087
groundnut/maize	0.097
bambaranut/maize	0.110
Mean/Maize	0.103
Rotation:	
Maize in rotation with pigeonpea	0.067
Maize in rotation with cowpea	0.053
Maize in rotation with soybean	0.060
Maize in rotation with groundnut	0.060
Maize in rotation with bambaranut	0.063
Mean	0.061
Maize after fallow	0.053
Fallow (control)	0.147
Mean	0.100
CV(%)	6.19
F-LSD (0.05)	0.0 16
Paired t-test (0.05)	
Sole Vs intercropping	8.86*
Sole Vs rotation	6.89*
Intercrop Vs rotation	8.96*

* = significant at 5% level of probability

Table 7: Total N_2 fixed by food legume crops in sole and when intercropped at Odoba -Otukpa in 2007

	N_2 fixed (kg ha^{-1})		
Crop	**Sole**	**Intercrop**	**Mean**
Pigeonpea	34.20	30.98	32.59
Cowpea	18.77	17.92	18.35
Soybean	15.87	18.50	34.37
Groundnut	12.86	18.93	15.90

Bambaranut	19.99	21.44	20.72
Mean	20.34	21.55	
CV (%)	2.35	4.29	
FLSD (0.05)	0.90	1.74	
Paired t-test (0.05)			
Sole Vs intercrop	0.99^{ns}		

ns = not significant

Table 8: Number of nodules, nodules biomass(g) and leaf litter (t ha^{-1}) produced by sole food legume crops at Odoba-Otukpa in 2006 and 2007.

	NN			NB			LL		
Crop	**2006**	**2007**	**Mean**	**2006**	**2007**	**Mean**	**2006**	**2007**	**Mean**
Pigeonpea	58.67	51.67	55.17	0.48	0.43	0.46	0.62	0.51	0.57
Cowpea	22.33	22.00	22.17	0.39	0.31	0.35	0.30	0.29	0.30
Soybean	123.67	103.33	113.50	0.49	0.45	0.47	0.38	0.31	0.35
Groundnut	174.67	139.33	157.00	0.34	0.25	0.30	0.11	0.10	0.11
Bambaranut	40.00	35.67	37.84	0.29	0.30	0.30	0.14	0.12	0.13
Mean	83.87	70.40	77.14	0.40	0.35	0.38	0.31	0.27	0.35
CV(%)	11.61	7.93	-	11.08	8.67	-	9.73	8.78	-
FLSD (0.05)	18.33	18.29	-	0.08	0.06	-	0.06	0.04	-
Paired t-test(0.05)									
2006 Vs 2007	2.09^{ns}			2.84*			2.21^{ns}		

NN = Number of nodules per plant
NB = Nodule biomass per plant
LL = Leaf litter
* = Significant at 5% level of probability.

Table 9: Total plant biomass (t ha^{-1}) of food legume crops in sole and when intercropped with maize in 2006 and 2007

	Total plant biomass					
	2006		2007		Mean	
Crop	**Sole**	**Intercrop**	**Sole**	**Intercrop**	**Sole**	**Intercrop**
Pigeonpea	2.80	-	2.67	2.62	2.74	2.62
Cowpea	1.89	-	1.75	1.69	1.82	1.69
Soybean	2.07	-	1.57	1.56	1.82	1.56
Groundnut	2.13	-	1.55	1.61	1.84	1.61
Bambaranut	1.26	-	1.33	1.25	1.30	1.25
Maize	-	-	0.60	0.58	0.60	0.58
Mean	2.03	-	1.58	1.55	1.69	1.55
CV *(%)*	4.45	-	6.13	4.42		
FLSD *(0.05)*	0.16	-	0.18	0.13		
Paired t-test (0.05)						
Sole Vs intercrop					3.46*	

Sole = Sole cropping

Intercrop = Intercropping

* = Significant at 5% probability level

Table 10: Seed yield of food legume crop in sole and when intercropped with maize in 2006 and 2007 at Odoba-Otukpa

	Seed yield (t ha^{-1})					
	2006		2007		Mean	
Crop	**Sole**	**Intercrop**	**Sole**	**Intercrop**	**Sole**	**Intercrop**
Pigeonpea	0.58	-	0.43	0.43	0.51	0.43
Cowpea	0.12	-	0.16	0.17	0.14	0.17
Soybean	0.18	-	0.33	0.36	0.26	0.36
Groundnut	*0.35*	-	0.31	0.26	0.33	0.26
Bambaranut	0.55	-	0.38	0.33	0.47	0.33
Mean	0.36	-	0.32	0.31	0.34	0.31
CV(%)	6.72	-	9.87	10.91	-	-
FLSD(0.05)	0.05	-	0.06	0.06	-	-
Paired t-test (0.05)						
Sole Vs intercrop					0.75^{ns}	
2006 Vs 2007 (sole)					0.57^{ns}	

ns = not significant

Discussion

The soil in Odoba-Otukpa with a sand fraction of 97.24% and texturally classified as sand in this study was similar to that at Ai-Inamu-Orokam with a mean sand content of 88% (CEC/IFPREB, 1999). The predominantly sandy nature of the soils might have been due to the parent material (predominantly sandstone) (Fagbemi and Akamigbo, 1986), as well as the illuviation of clay and disproportionate removal of silt by erosion. The consequent moisture stress of the soil reduces the cultivation and the yields of some climatologically suitable arable crops, which also serve as staple food in the region e.g. yam, cassava, maize, tomato, vegetables, etc. The level of the total N (0.150%) at the start of the study fell within the critical soil N range (0.10-0.15%) considered just adequate for optimum crop growth (Agboola, 1972) but was rated as medium (Ibanga *et al,* 2005). Similarly, the levels of organic carbon (0.48%), available phosphorus (5. l8ppm) and potassium (0.27 c mol kg^{-1} soil) were rated low and therefore considered as marginally adequate for crop growth (Ibanga, 2005). The results of this study indicated that no significant difference existed between the treatment plots in the amount of soil N prior to planting in 2006. However, at the beginning of 2007 (0-30 dap) pigeonpea and bambaranut plots had significantly higher levels of soil N compared to soybean and cowpea, although these levels were lower than that of the fallow (control) plots. The differences in the N levels of soils under the food legumes at the beginning of 2007 might have originated from the differences in nitrogen-fixation capabilities as well as nitrogen-saving effects of these legume crops during the previous season (2006). Kumar Rao *et al.* (1996) had observed that estimates of N_2 fixed by food legumes grown in semi-arid tropics varied greatly with crop species and location. Fujita and Ofosu-Budu (1996) had made similar observations in both mono-and intercropping systems. Rego and Seeling (1996) stated that higher soil mineral N content after legume cropping can be due to the N-saving effects of legumes. Although no resu1ts were obtained during the mid-season (60-100 dap) of 2007, the results in 2006 indicated that soil N at this period was significantly higher than N at both beginning and end (120-150 dap) of 2006. The mid-season is a period of high rainfall (data not shown) in the experimental site and therefore abundant moisture availability. Since it is known that moisture contents in excess of field capacity (26%), and at least up to 40% moisture, enhance nitrogen fixation activity (Kumar Rao, 1990), nitrogen fixation by the food legume crops used in this study might have peaked at midseason as compared to the beginning and end of the season. It is also worthy of note that soil N under all the food legumes tested in this work was higher levels of soil N compared to the fallow (control) plot at mid-season, unlike the case at the beginning and the end of the season. This might be a further indication to high nitrogen fixing activity at mid-season. In a field study on seasonal pattern of nodulation and nitrogen fixation of 11 pigeonpea cultivars belonging to different maturity groups, Kumar Rao and Dart (1987) reported that in all cultivars, the nodule number and mass increased to a maximum around 60-80 days after sowing and then declined. They further reported that nitrogenase activity per plant increased up to 60 days after sowing and declined thereafter, with little activity at 100 days after sowing. Recently, Rao *et al.* (2005) had stated that during 45-90 dap, nodules fixed a constant proportion of N in pigeonpea in India. It could be inferred safely that the food legumes used in this study increased soil N levels during the mid-season (60-100 dap). The decrease in soil N level at the beginning of 2007 as compared to end of 2006 might be ascribed to volatilization due to high temperatures (data not shown) experienced during the months of February to April. The lower soil N levels might also have resulted from leaching due to the heavy early rains in May and June prior to planting in late June and early July. Savant and De Datta (l980) had reported that plant available form of N in soil during early growth depends on the amount of organic-N available for mineralization, the amount of fertilizer-N applied prior to sowing and the cropping history. The concentration decreases with time due to plant uptake, immobilization, volatilization and leaching (Haynes and Sherlock, 1986; Cameron and Haynes, 1986). It is also known that leaching of N and other nutrients may limit productivity of sandy soils even when water is not limiting (Bells and Seng, 2005). The amount of N accumulated in the shoots of both sole and intercropped legumes were significantly higher than that of maize. The results of the present study agreed with the previous findings of Egbe *et al.* (2007) which reported that the concentration of N (%) in pigeonpea shoots at harvest was greater than maize, irrespective of the genotype and it was not affected by intercropping. Earlier studies on pigeonpea/sorghum intercropping (Ito *et al.* (1997) and on farmer-managed intercrops of maize-pigeonpea in Semi-arid Africa Myaka *et al.,* (2006) had reported similar findings.

The sole crop legume systems produced significantly higher soil N levels than the intercropping systems, which in turn gave higher soil N than the rotation treatments. This response might be due to less competition (mainly intra-plant) in the sole systems contrary to intra-and inter-plant competition in the intercropping environment. Szumigalski and Van Acker (2006) had made similar observations with sole crop field pea and its intercrops with wheat and canola in the Canadian Prairies. They found that the pea sole treatment tended to result in higher fall soil nitrate (N03)-N concentrations compared to the other treatments. In the intercrop and rotation systems the cereal component (maize) seemed to have mopped up the ‘excess’ soil N that was spared by the legume crops.

The soil-N after the maize harvest in the rotation plots was particularly low probably due to the utilization of the N deposited in the previous season (2006) by the succeeding maize crop. It might also have been due to inadequate quantities of N fixed by the legumes during the previous season, resulting from zero application of fertilizer at the start of the study. Legumes though endowed with the capacity to fix substantial amounts of N (22 to 92 kg ha^{-1} for pigeonpea, 61-101 kg ha^{-1}' for soybean in sole systems) (Kumar Rao 1996; Ogoke *et al.,* 2006), the quantity of fixation depend among other factors on the initial soil N for enhancement. BNARDA (2000) recommended that 15-20 kg N ha^{-1} be applied to legumes as "starter" nitrogen.

The poor nodulation and low nodule biomass observed in this work might also have resulted from decreased photosynthate supply to nodules from the under-nourished food legume crops. The larger number of nodules produced by groundnut over and above those of the other legumes and its concomitant low nodule biomass agreed with the findings of Ogoke *et al.* (2006), which reported that with increasing number of nodules in soybean, nodules become smaller in size and weighed less, presumably because of competition for photosynthate. The nitrogen fixed by the food legumes in both sole and intercropping systems in this study were low compared to the quantity fixed by some of these legumes in other soils types and locations. For example pigeonpea fixed 37.52 kg ha^{-1} to 164.82 kg ha^{-1} under intercropping in pigeonpea/sorghum in Southern Guinea Savanna of Nigeria (Egbe, 2007) and an average of 77.95 kg N ha^{-1} in pigeonpea/maize intercropping systems in the same location (Egbe *et al*., 2007). The low N fixed might be one of the factors responsible for the low leaf litter, total plant biomass and seed yield produced by the food legumes in the Moist Savanna Woodland of Nigeria. The total plant biomass of maize was also low. It is known that N deficiencies result in decreased crop leaf area, photosynthetic assimilation and seed growth (Sinclair, 1999). The results obtained showed that the mean soil-N for all the treatments at the end of the study in 2007 was less than that of the control plot. This indicated a net mining of the soil by the cropping systems rather than replenishment. Sanchez (1994) had reported that in marginal areas of the tropics, there is a net mining of soil nutrients primarily due to low rates of fertilizer application, crop removal, run off and erosion.

The pigeonpea crop, during the mid-season of 2006, gave the highest soil-N. It was also the only food legume that had significantly higher soil-N than the control (fallow) plot at the end of 2006, beginning and end of 2007 cropping season. Next in performance in this regard to pigeonpea was bambaranut. Similarly at the end of the experiment in 2007, when soil from various systems (sole cropping, intercropping and rotation) were tested for N content, sole pigeonpea produced the highest significant soil-N level. Again, pigeonpea fixed the highest level of N in both sole and intercropping. The nodule biomass, leaf litter, total plant biomass and seed yield of pigeonpea was superior to the other food legumes in both sole and intercropping systems in the sandy soils of Moist Savanna Woodland of Nigeria. This unique performance of pigeonpea when compared to the other food legumes in the sandy soils of Moist Savanna Woodland might be because of its deep root system and its tolerance to low P supply. Adu-Dyamfi *et al* (1990) had made similar observations and had stated that the critical requirement of P concentration for dry matter production is low compared to other major protein crops like soybean. Its deep root systems allows extraction of moisture from deep layers of the soil and thus makes it a crop that produces biomass including protein-rich grain while utilizing residual moisture (Nene and Sheila, 1990).

Conclusion

All the food legume crops tested in this study resulted in increased soil N levels during the mid-season (60-100 dap) and fixed 12.86 to 34.20 kg N ha^{-1} (sole crop systems) and 17.92 to 30.98 kg N ha^{-1} under intercropping. Pigeonpea gave the highest total N of soil, nodule biomass, leaf litter, total plant biomass, seed yield and subsequently fixed the highest quantity of atmospheric nitrogen. However, bambaranuts and cowpea had comparable results to pigeonpea in raising soil N levels, and may therefore be considered along with pigeonpea for amelioration of the inherent low fertility of the sandy soils of the Moist Savanna Woodland of Nigeria.

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