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RESEARCH ARTICLE

PRODUCTIVITY, NITROGEN FIXATION AND GRAIN YIELD OF LEGUMES INTERCROPPED WITH ROSELLE IN SOUTHERN AND NORTHERN GUINEA SAVANNAH OF NIGERIA

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ABSTRACT

A field experiment was conducted at the Teaching and Research Farm, University of Agriculture, Makurdi, and at the Demonstration Farm, Federal College of Education (Technical), Gombe during the 2012 cropping season to evaluate various grain legumes for productivity, N-fixation and grain yield. Three grain legumes intercropped with a reference roselle were grown in a randomised complete block design (RCBD) with three replications. No fertilizer was applied, as often practiced with farmers. The results showed that it was more productive to grow legume/ roselle crops together as depicted by yield advantages of 41%-55% and 44%-58% for Makurdi and Gombe, respectively. Intercropping depressed N-fixation and grain yields. Sole cowpea fixed the highest amount of N (50.07Kg/ha) and 50.73Kg/ha) for Makurdi and Gombe, respectively, while groundnut intercropped with roselle fixed the lowest amount of N (34.63Kg/ha and 34.97Kg/ha) for Makurdi and Gombe, respectively. The highest grain yields of 143.07Kg/ha and 143.73Kg/ha were obtained from sole cowpea for Makurdi and Gombe, respectively, while the lowest grain yield of 104.44Kg/ha and 104.97Kg/ha were obtained from groundnut intercropped with roselle for Makurdi and Gombe, respectively.

KEYWORDS: cowpea, groundnut, bambara groundnut, intercropping, productivity, nitrogen fixation, grain yield.

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INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) belongs to the family of Leguminosae and is primarily cultivated for its pulses for human and animal consumption. It was domesticated in West Africa and this might be related to the existence of maximum diversity of cultivated cowpea varieties in the area (Steele *et al.*, 1985). Worldwide, Nigeria is reported as the largest producer of cowpea in 2010 (FAOSTAT, 2010). At present cowpea is the second most important pulse crop in Africa, which produces over 95% of the world crop (Olufajo and Singh, 2000).

Groundnut (*Arachis hypogaea)* originated in South America and must have been introduced to West Africa by Portuguese traders and travellers and then to East Africa (Schilling, 2002). It is an annual legume and there is a wide variation in the types cultivated in particular localities. The global production in 1988 was 30.97million tonnes of unshelled nuts, of which India produced 8.3million tonnes and Nigeria 2.53million tonnes (FAO, 1998). Nigeria, once the largest exporter of the crop, is now an importer of groundnut.

Bambara groundnut (*Vigna subterranean* L.) is indigenous to tropical Africa and is primarily grown by subsistence farmers mostly women (Rachie, 1979). It is the 3rd most important grain legume after cowpea and groundnut (Mkandawire, 2007). It is widely grown in Nigeria, particularly Southern guinea savanna belt, where it is mostly grown as a mixed crop with cowpea, maize and groundnut (Thottappilly and Rossel, 1997).

Intercropping which is the simultaneous cultivation of two or more crops on the same piece of land is predominant practice in traditional farming systems of the tropics including Nigeria (Fawusi, 1985). It is an age long practice of cultivation used by farmers of tropical and sub-tropical countries (Adeniyan *et al.*, 2007). Of recent, research has shifted from sole cropping due to overall productivity and other benefits derived from intercropping as compared to sole cropping (Clement *et al.*, 1992). The reasons for practicing mixed intercropping include that crops benefit from nitrogen fixation by associated leguminous crops (Papastylianou, 1988) or the residual legume nitrogen or the residues of the previous leguminous crop (Chatterjee *et al.*, 1989). Other benefits include efficient utilization of light and other resources, reduce soil erosion, suppress weed growth and thereby help to maintain greater stability in crop yields (John and Mini, 2005). A number of studies have shown that the productivity of intercropping are higher in intercropping with legumes as compared to monocropping. Many grain legumes that can be grown in mixture with roselle are cowpea, groundnut and bambara groundnut. Olasanta (1988) showed that when cassava and grain cowpea were intercropped, the LER increased significantly irrespective of the spatial arrangement (planting pattern) of the component crops. Similar to other grain legumes, cowpea, groundnut and bambara groundnut can use atmospheric N in symbiosis with highly specific root nodule bacteria in its process of protein synthesis. This process is known as symbiotic biological nitrogen fixation (BNF). In rain-fed ecosystems, BNF is often impeded by such limiting factors as moisture stress and excess moisture, nutritional deficiencies, absence of appropriate *Rhizobium* (Dakora and Keya, 1997). Lindemann and Glover (1996) observed that grain legumes may fix up to 280Kg N/ha and are not usually fertilized. Research conducted over a 3 year period (2002-2005) on BNF measured by N- difference method indicated that cowpea, groundnut and bambara groundnut derived 56%, 56% and 52% of their nitrogen, respectively from fixation representing 27, 76 and 55 Kg N/ha (Ncube *et al.,* 2007). Similarly, quoting various sources, Giller *et al.,* (1997) summarised the amount of N fixed by grain legumes in sub-saharan Africa as ranging from 11 to 201 Kg N/ha for sole cropped cowpea, 9 to 125Kg N/ha for intercropped cowpea, 2 to 58 Kg N /ha for sole cropped common bean and 0 to 71 Kg N /ha for intercropped common bean. The practice of legume/roselle intercropping is common among peasant farmers, but scientific studies are rare despite potential advantages for soil fertility restoration and increased options for plant protein sources for poor households. BNF is expected to increase the yield of bambara groundnut crop and also contribute nitrogen to the soil medium for ensuing crops where the cost of artificial nitrogen fertilizer is prohibited (Egbe *et al.,* 2013).

The objectives of this study, therefore was to evaluate the effect of intercropping on productivity, N-fixation and grain yield of some grain legumes in cowpea/roselle, groundnut/roselle and bambara groundnut/roselle intercropping systems.

MATERIALS AND METHODS

Description of Location, Soil Sampling and Analysis

A field experiment was conducted during the 2012 cropping season at two different locations. The locations were at the University of Agriculture, Teaching and Research Farm, Makurdi (7°11^{1}N, 8°41^{1}E and 400 m above sea level) in the southern guinea savannah ecological zone of Nigeria and at the Federal College of Education (Technical), Demonstration Farm, Gombe (10°20^{1}N, 11°30^{1}E and 240 m above sea level) in the northern guinea savannah ecological zone of Nigeria. The total rainfall which lasted for three to four months was 1496 mm at Makurdi and 1163mm at Gombe. A composite soil sample for each of the experimental sites from 0-30cm depth were taken with the use of an auger at random locations for physical and chemical properties of soil (Table 1). This was done before planting the 3 grain legumes and roselle control. The soil samples for each location were air dried at room temperature for one week, ground (using mortar and pestle) to pass through a 0.3mm screen for chemical analysis. Mechanical analysis was carried out by Boyoucos (Hydrometer) method as described by Udoh *et al.,* 2009. Soil pH was obtained using a 1:2.5 soil-water ratio. Organic carbon was determined by the Walkley-black wet oxidation methods as described by Page *et al.*, 1982) and organic matter was estimated by multiplying the organic carbon value by 1.729. Nitrogen in the soil was determined by micro-kjeldahl method (Agbemin, 1995). Available phosphorus was determined by using Bray 1 procedure of Molybdate blue colorimetry. Exchangeable cations were determined by ammonium acetate extraction method (IITA, 1979). Cation exchange capacity (Exchangeable bases and Exchangeable acidity) was determined by procedure outlined by IITA (1979). The entire laboratory chemical analysis for soil N and P were done at the Nicansol Soil Science Laboratory, University of Agriculture, Makurdi.

Experiment and Experimental Design

A field experiment (Biological Nitrogen Fixation) was conducted with three different nodulating legumes: cowpea (IT93K-499-35), groundnut (RMP 91) and bambara groundnut (*Adikpo)*. These legumes were grown with roselle (Ex-kano), a non-nitrogen fixing crop as control. Each crop was grown as sole and intercrops on different plots of 6m x 4m and replicated three times within a block of 48m x 4m ($192m^2$). There were eight treatments consisting of various cropping systems, which include: 1. Roselle sole, 2. Cowpea + roselle intercrop, 3. Cowpea sole, 4. Groundnut + roselle intercrop, 5. Groundnut sole, 6. Bambara groundnut + roselle intercrop, 7. Bambara groundnut sole and 8. Fallow plot.

The fallow plot was included to monitor nitrogen dynamics. The experiment was laid out in a randomized complete block design with three replications. No fertilizer was applied to any of the cropping systems or fallow plots as often practiced by farmers. The cowpea (IT93K-499-35) and groundnut (RMP 91) were obtained from the Gombe State Agricultural Development Programme (GSADP). Roselle (Ex-kano) was obtained from Kano State Agricultural and Rural Development Programme (KNARD). Bambara groundnut (*Adikpo)* was obtained from the local market at Makurdi.

Field Procedures and Data Collection

The experimental sites were cleared with matchet and levelled with hoe to obtain fine tilted flat beds between 15th-17th June in Makurdi and 19th-21st in Gombe. The land was then marked into 24 plots of 6m x 4m each with 1m alleys between replicates and 1m gaps between plots. Legume and roselle seeds were sown on 5th July and 25th June, respectively. Roselle seeds were sown 2 seeds/ stand at 60cm x 80cm. Cowpea seeds were sown 2 seeds/ stand at 60cm x 25cm. Groundnut seeds were sown 2 seeds/ stand at 60cm x 20cm, while bambara groundnut seeds were sown 3 seeds/ stand at 60cm x 30cm.

Table 1: Physical and Chemical Properties of Soil at Makurdi and Gombe in 2012

Soil Property	Makurdi 2012	Gombe 2012
% Sand	68.3	76.4
% Silt	14.3	12.56
% Clay	17.4	11.04
Texture	Sandy loam	Sandy loam
pH(Water)	6.56	6.15
Organic carbon (%)	0.77	0.47
Organic matter (%)	2.33	1.54
Total nitrogen (%)	0.29	0.03
P(Bray)ppm	11.05	14.89
CEC ($CmolKg^{-1}$)	5.82	4.45
E.C ($CmolKg^{-1}$		
Ca^{2+}	3.34	3.5
Na^{2+}	0.59	0.13
K^{+}	0.25	0.27
Mg^{2+}	0.95	0.73
Base saturation (%)	85.74	73.5

Key: ppm = part per million; C.E.C = cation Exchange Capacity; EC = Exchangeable cation

Giving plant populations of 20,833 plants/ha for roselle, 133,333plants/ha for cowpea and 166,666 plants/ ha for groundnut and 111,112 plants/ha for bambara groundnut. Roselle and bambara groundnut plants were thinned 10 days after emergence to one and two plants per stand, respectively. The plots were weeded manually using hand hoes at 2 weeks after sowing (WAS) and at 5 WAS. Insect pests were controlled by applying Karate (Lambda cyhalothrin) at the rate of 20ml per 60ml water according to manufacturers' recommendation.

At 12 WAS, five legume and roselle (non-fixing) plants were collected from each sole and intercropping plots by cutting at soil surface level, oven dried to constant weight and average shoot weight calculated. The soil samples were air-dried and ground to pass through a 0.33mm screen for chemical analysis. The oven dried shoot samples of sole and intercropped legume and roselle were milled and sieved through a 0.6mm screen for chemical analysis. N yield in the shoot of both sole and intercropped legume samples as well as roselle shoot was determined as outlined by Illger (1997) after micro-kjeldahl digestion. All the laboratory chemical analyses for plant N were done at Crop Science Laboratory, Abubakar Tafawa Balewa University, Bauchi. Using N difference method, Biological Nitrogen Fixation (BNF) was then calculated as:

N_2 fixed (Kg/ha) = N yield in legume (Kg/ha) – N yield in reference crop (Kg/ha) (Shah *et al.*, 2004).

At physiological maturity, all legume and roselle plants from each sole and intercrop plots were harvested, oven dried at 65°C to constant weight, separated into grain and shoot then weighed and converted into Kg/ha.

Data collected were subjected to analyses of variance individually for each location. The treatment means which were significantly different were separated using Duncan Multiple Range Test (DMRT) (Duncan, 1955) with the aids of Minitab (2007) and Genstat discovery software (Edition 4) (L.A.T, 2007).

The productivity of the intercropping system was determined by the land equivalent ratio (LER) which is the land area that would be required by sole crops to produce the yield achieved in intercrops (Babatunde, 2003) and was calculated as;

$$LER = YiR/YsR \times YiO/YsO.$$

Where YiR= yield of roselle in intercrop, YsR = yield of roselle in sole crop,
YiO= yield of other crop(s) in intercrop and YsO= yield of other crop(s) in sole crop.

Area x time equivalent ratio (ATER) as described by Hiebsch and McCollum (1987) as;

$$ATER = \{(RY1 \times t^{sI}) + (RY2 \times t^{s2})\}/ti.$$

Where RY1 = relative yields of base crop (roselle), RY2 = relative yield of other crop in the intercropping system

t^{s1} = Time/duration of roselle (sole), t^{s2} = Time/duration of other crop (sole),

ti = Time/ duration for the whole intercropping system.

RESULTS AND DISCUSSION

The rainfalls received at the experimental sites in 2012 (1496mm at Makurdi and 1163mm at Gombe) were considered adequate for crop growth and development. The physical and chemical properties of soil obtained for analysis fell within the ranges reported for tropical savannah soils (Uyovbisere *et al.*, 1990).

Productivity of intercropping system

The land equivalent ratio (LER) of cowpea, groundnut and bambara groundnut intercropped with roselle were all above 1.00 in 2012 at Makurdi and Gombe (Table 2). The yield advantage ranged from 41 to 55% (Makurdi) and 44 to 58% (Gombe). The highest LER of 1.55 for Makurdi and 1.58 for Gombe were obtained when groundnut was intercropped with roselle. The least LER of 1.41 (Makurdi) and 1.44 (Gombe) were recorded when cowpea was intercropped with roselle. The total LER obtained with intercropping, which was all above unity, showed an advantage of intercropping over sole cropping system in terms of the use of environmental resources for plant growth. The higher values obtained for groundnut and bambara groundnut intercropped with roselle compared to roselle sole and cowpea intercropped with roselle could be attributed to yield benefits in groundnut and bambara groundnut arising from efficient growth and seed production.

Table 2: Effect of Cropping Systems on Land Equivalent Ratio (LER) of Legume intercropped with Roselle at Makurdi and Gombe in 2012

Cropping systems(C)	Makurdi			Gombe		
	Roselle	Intercrop	Total	Roselle	Intercrop	Total
Roselle sole	1.00	-	1.00	1.00	-	1.00
Cowpea sole	-	1.00	1.00	-	1.00	1.00
Groundnut sole	-	1.00	1.00	-	1.00	1.00
Bambaranut sole	-	1.00	1.00	-	1.00	1.00
C + R	0.91	0.50	1.41	0.92	0.52	1.44
G + R	0.84	0.71	1.55	0.85	0.87	1.58
B + R	0.95	0.56	1.51	0.96	0.57	1.53
F	-	-	-	-	-	-

C+R= Cowpea +Roselle intercrop; G+R = Groundnut +Roselle intercrop; B+R = Bambaranut + Roselle intercrop; F = Fallow

Table 3: Effect of Cropping Systems on Area x Time Equivalent Ratio (ATER) of Legume intercropped with Roselle at Makurdi and Gombe in 2012

Cropping systems(C)	Makurdi			Gombe		
	Roselle	Intercrop	Total	Roselle	Intercrop	Total
Roselle sole	1.00	-	1.00	1.00	-	1.00
Cowpea sole	-	1.00	1.00	-	-	-
Groundnut sole	-	1.00	1.00	-	-	-
Bambaranut sole	-	1.00	1.00	-	-	-
C + R	0.91	0.20	1.11	0.92	0.22	1.14
G + R	0.84	0.37	1.21	0.85	0.39	1.24
B + R	0.95	0.23	1.18	0.96	0.21	1.17
F	-	-	-	-	-	-

C + R = Cowpea + Roselle intercrop; G + R = Groundnut + Roselle intercrop; B + R = Bambaranut + Roselle intercrop; F = Fallow

Babatunde, (2003) and Miyda *et al*., (2005) also reported the higher LER over sole cropping system. So, the intercropping farmers in the growing areas could be suggested to grow groundnut with roselle than either groundnut sole and roselle sole for maximum profit.

Table 3 presents' values for the area x time equivalent ratio (ATER), which ranged from 1.11 to 1.21% (Makurdi) and from 1.14 to 1.24% (Gombe). All the intercrops showed area x time equivalent ratio above unity at both locations. The highest ATER of 1.21 for Makurdi and 1.24 for Gombe were obtained when groundnut was intercropped with roselle. ATER provides more realistic comparison of the yield advantage of intercropping system over sole in terms of variation in time taken by the component crops of different intercropping systems. In all treatments, the values of ATER were generally lower when compared with the LER at equivalent plant populations perhaps due to maturity periods of the four crops of which roselle stayed longer on the land and had enough time to compensate for the legume competition. Higher ATER values of roselle+ cowpea have also been reported by Babatunde, (2003) and cotton + cowpea by Khan and Khaliq (2004).

Nitrogen fixation by grain legumes intercropped with roselle

Intercropping depressed N fixed by cowpea, groundnut and bambara groundnut intercropped with roselle at Makurdi and Gombe (Table 4). The result showed that cowpea intercropped with roselle fixed more nitrogen in the soil when compared to other intercropping systems. The lowest amount of nitrogen fixed in the soil was recorded from groundnut intercropped with roselle at both sites. The result also showed that nitrogen fixation differed significantly between sole and intercropping systems at Makurdi and Gombe in 2012. The highest amounts of nitrogen fixed in the soil of 50.07 and 50.73 kg N /ha were recorded from cowpea sole for

Makurdi and Gombe, respectively. Lower amounts of nitrogen fixed of 44.93 and 45.60 kg N /ha were recorded from cowpea intercropped with roselle for Makurdi and Gombe, respectively. The lowest amounts of nitrogen fixed of 34.63 and 34.97 kg N /ha were recorded from groundnut intercropped with roselle for Makurdi and Gombe, respectively. This is in agreement with Namibiar *et al*., (1983) and Egbe *et al.,* (2013), who observed that shading by tall cereal crops can reduce both yield and nitrogen fixation of shorter stature legumes. In addition, the highest values of nitrogen fixed of 50.07 and 50.73 Kg /ha for Makurdi and Gombe, respectively in this study was lower than the highest (63.00 Kg /ha) recorded in Egbe *et al.,* (2013). The reason could be the poor growth of reference crop (roselle), which remained unfertilised despite the fact that the soil was already low in nitrogen.

Table 4: Effect of Cropping Systems on Nitrogen Fixed by Legume at Makurdi and Gombe in 2012

	Makurdi	Gombe
Cropping systems (C)	N-fixed (Kg /ha	
Cowpea+ roselle	44.93[b]	45.60[b]
Cowpea sole	50.07[a]	50.73[a]
Groundnut+ roselle	34.63[d]	34.97[d]
Groundnut sole	35.37[d]	35.70[d]
Bambaranut+ roselle	40.00[c]	40.67[c]
Bambaranut sole	42.13[c]	42.67[c]
p-value	0.002	0.002

Means in the same column of treatments followed by different super scripts differ significantly

Grain yields of legume

Table 5 presents the results of the grain yields of various legume and reference roselle crop in 2012. Cropping systems significantly affected the grain yields of legume. Highest grain yield of 153.24 and 153.54 Kg /ha for Makurdi and Gombe, respectively were obtained from cowpea sole plots, followed by 143.62 and 143.85 Kg /ha from cowpea intercropped with roselle . The grain yield of 141.53 and 141.87 Kg /ha were obtained from bambaranut sole for Makurdi and Gombe, respectively, was statistically at par with the grain yield (139.4 and 139.65 Kg /ha) obtained from bambaranut intercropped with roselle for Makurdi and Gombe, respectively. The variations in grain yield of legume were not surprising as they were different crops and should not necessarily produce similar yields. Considerable research work has been done on different aspects of legume here and elsewhere and different grain yields have been reported. The results of this study are different from that of Egbe *et al.,* (2009) who reported a mean grain yield of 518.16 Kg/ha for pigeon pea sole and 509.69 Kg/ha for pigeon pea intercropped with maize, 142.24 Kg /ha for cowpea sole and 172.72 Kg /ha for cowpea intercropped with maize, 335.28 Kg /ha for groundnut sole and 264.16 Kg /ha for groundnut intercropped with

	Makurdi	Gombe
Cropping systems (C)	Kg/ha	
Cowpea + roselle	143.62[b]	143.85[b]
Cowpea sole	153.24[a]	153.54[a]
Groundnut + roselle	133.44[d]	133.7[d]
Groundnut sole	135.53[d]	135.87[d]
Bambaranut + roselle	139.42[c]	139.65[c]
Bambaranut sole	141.53[c]	141.87[c]
Roselle sole	115.23[e]	115.75[e]
p-value	0.005	0.005

maize, 477.52 Kg /ha for bambara groundnut sole and 335.28 Kg /ha for bambara groundnut intercropped with maize in a moist savannah woodland of Nigeria. The variation in grain yield could be attributed to different environmental conditions, different genetic or varietal potential or different soil environment.

Table 5: Effect of cropping systems on grain yield of various legume and reference roselle crop at Makurdi and Gombe in 2012
Means in the same column of treatments followed by different superscripts differ significantly

CONCLUSION

This study estimated the effect of various grain legume intercropped with roselle on productivity, N fixation and grain yields. This experiment has shown that intercropping was a productive venture as depicted by yield advantages of 41%-55% and 44%-58% for Makurdi and Gombe, respectively. It means the intercropping farmers in the growing areas could be suggested to grow groundnut with roselle than either groundnut sole and roselle sole for maximum profit. Intercropping depressed N-fixation and grain yields. Sole cowpea fixed the highest amount of N (50.07Kg /ha) and (50.73 Kg/ha) for Makurdi and Gombe, respectively, while groundnut intercropped with roselle fixed the lowest amount of N (34.63 Kg/ha) and (34.97 Kg/ha) for Makurdi and Gombe, respectively. The highest grain yield of 153.24 and 153.54 Kg/ha were obtained from sole cowpea for Makurdi and Gombe, respectively, followed by 143.62 and 143.85Kg/ha obtained from cowpea intercropped with roselle. Further research should focus on the role of nodulation in N fixation by grain legume. Estimation of root N and litter N contents should be included wherever possible.

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