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Full Length Research Paper

Nitrogen fertilization and use efficiency in an intercrop system of cassava (*Manihot esculenta* Crantz) and soybean (*Glycine max* (L) Meril.)

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Experiments were conducted at the Department of Crop Science, University of Nigeria, Nsukka Research farm during the 2008 and 2009 cropping seasons to determine the effects of intercropping cassava and soybean on cassava tuber and soybean grain yields respectively and on nitrogen use efficiency of cassava at the intercropping system. The experiment for each year was laid out in a factorial arrangement in randomized complete block design (RCBD). The treatments were the nitrogen rates, sole soybean (TGM 579), sole cassava (TMS 30572) and cassava + soy bean intercrop. Intercropping cassava with soybean showed a significant ($P \leq 0.05$) yield advantage over sole cropping system in 2008. Increased fertilizer rates up to 90 kg N/ha^{-1} increased fresh cassava yield in sole cropping system, while in the intercrop, increased application of nitrogen at 60 kg N decreased cassava tuber yield. The cassava nitrogen use efficiency (NUE) increased with increase in applied nitrogen up to 60 kg N/ha^{-1} and then decreased beyond this point. Similar trend was observed in 2009, except that total harvested cassava tuber yield was significantly higher in 2009 than that obtained in 2008. This result suggests that intercropping cassava with soybean with or without application of nitrogen is beneficial but high doses of nitrogenous fertilizer in sole soybean field is uneconomical and should be avoided.

Key words: Cassava, soybean, intercrop, sole crop, nitrogen use efficiency.

INTRODUCTION

Substantial yield advantages have been reported in intercropping systems involving legumes over the mono-cropped non-legume crops (Ayisi et al., 1997; Unkovich and Pate, 2000). These advantages are com-monly attributed to sparing effects of inputs, biophysical compatibility or better use of resources when crops are grown as sole than when in intercrop systems. Certainly, different crops may be complementary to each other and make better use of resources when grown together, but the benefit of including legumes in intercropping systems goes beyond sparing effect of nitrogen, competitive interaction between the crop components or reduced competition, especially on acidic and non fertile soils like that of Nsukka area of South- eastern Nigeria, where the use of NPK fertilizer is inevitable.

Excessive application of nitrogenous fertilizer has been reported to be high in soil nitrate levels after harvest (Gordion et al., 1993; Aarnio et al., 2003). Symbiotic nitrogen fixation therefore becomes a better alternative for sustainable crop production in the majority of soils in the Southeast ecological zone. This is because it has been shown to complement soil-nitrogen, increase nitrogen use efficiency, increase nitrogen uptake, increase apparent nitrogen recovery and other benefits as companion crop or subsequent crop (Clark and Myers, 1994; IITA, 1997; Aggarwale et al., 2002). Conflicting results of nitrogen application to soybean have been reported from response to no response of which no conclusion on the amount of fertilization at intercropping system can be drawn (Mengel et al., 1987). Affipunguh (1991) determined the safe levels of supplementary nitrogen in maize/cowpea intercrop to be 50 kg N/ha^{-1},

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while Kucey (1988) reported that nitrogen fixation in soybean ranged from 32 to 161 kg N/ha^{-1} annually. This study was therefore conducted to determine the effects of intercropping cassava with soybean on tuber and grain yields of the two crops, respectively and on nitrogen use efficiency (NUE) of cassava at the intercropping system.

MATERIALS AND METHODS

The experiments were conducted at the University of Nigeria, Nsukka (UNN) Research Farm during the 2008 and 2009 cropping seasons. The area is located at latitude 6° 52^1 N and longitude 7° 23^1 E, altitude 400 m above sea level and has a humid tropical climate. The mean annual rainfall ranges from 1600 to 2000 mm. The temperature is uniformly high throughout the year but the annual mean maximum temperature does not exceed 35°C (Asadu, 1990). The soil was derived from falsebeded sand stone parent material. It is sandy loam and has been classified as Typic Kandpaleustult or Dystric Nitosol, belonging to Nkpologu series (Obi, 1995) and the vegetation has been described as derived savanna. The experiments were done in the same location but different fields for the two years. The first experiment was on 12th April 2008 while the second was 3rd March 2009. Land was prepared each year by disc ploughing, harrowing and ridging to obtain a smooth seed bed.

The sites were under a three year grass bush fallow and contained low soil-N (0.046 mg kg^{-1}), organic matter (1.86 m g^{-1}), available P, (3.39 µg kg^{-1}) and pH in H_2O (4.7) before they were used for this study. The treatments were laid out in a factorial experiment and arranged in randomized complete block design (RCBD) having two factors, nitrogen rate and cropping system. Soybean (*Glycine max* (L) Merrill) TGM 579 and cassava (*Manihot esculenta* Crantz)) TMS 30572, were used in both experiments.

The cassava cuttings (planting materials) were obtained from a multiplication plot of the Department of Crop Science, UNN that had stayed for 10 to 12 months in the field while the soybean seeds were purchased from the Nsukka main market. The cassava cuttings were cut into 20 cm lengths and planted on the crest of the ridges at 1.0 m spacing, while soybean was drilled at 0.05 m spacing by the sides of the ridges.

Each experiment had sixteen plots of 4 x 3 m replicated 4 times having 4 ridges per plot and 1.0 m apart. Seven rates of nitrogen: 0, 15, 30, 45, 60, 75 and 90 kg N ha^{-1} and four cropping systems: sole cassava, sole soybean, cassava/soybean intercrop with barrier at root zone and cassava/soybean intercrop without barrier at root zone, were used. Root separation was done using polythene material of 0.1 mm gauge. There was uniform application of potassium and phosphorus fertilizers at the rates of 80 kg K ha^{-1} and 50 kg P ha^{-1}, respectively. The necessary husbandry practices were carried out. Manual hoe weeding was done three times.

Data collection

Measurements made were on the nitrogen content of cassava leaf, soil nitrogen after harvest, cassava tuber yield and soybean grain yield. Agronomic nitrogen use efficiency (tuber yield produced (kg) per kg N applied was calculated according to the method of Guilland et al. (1995).

Data analysis

All data collected were subjected to analysis of variance (ANOVA) according to the procedure for RCBD experiment using Genstat statistical package. Least significant difference (LSD) was used to detect differences between means.

RESULTS

The meteorological data for the period of study is summarized in Table 1. Rainfall stability was earlier and also higher in intensity in the year 2008 than 2009, while wind speed was greater in 2008 than in 2009. Soil nitrogen increased with increase in nitrogen application up to 90 kg N ha^{-1} in 2008 and it followed the same trend in 2009 (Table 2). Soil nitrogen was significantly ($P \leq 0.05$) greater in sole soybean plots than in either sole cassava or cassava/soybean intercropping systems in both years. Sole soybean cropping system significantly increased soil nitrogen at 45 and 60 kg N ha^{-1} of applied nitrogen but decreased at higher doses of N in 2008. In 2009, there was a steady increase in soil nitrogen with increase in N application up to 90 kg N per ha^{-1}. Similarly, cassava/soybean inter-cropping system significantly ($P \leq 0.05$) increased soil nitrogen when compared with sole cassava.

Intercropping cassava with soybean showed a significant ($P \leq 0.05$) yield advantage over sole cropping system in 2008 (Table 3). Increased fertilizer rates up to 90 kg N ha^{-1} increased fresh cassava yield in sole cropping system, while in the intercrop, increased application of nitrogen at 60 kg N decreased cassava tuber at increasing rate of fertilizer application. The cassava nitrogen use efficiency (NUE) increased with increase in applied nitrogen up to 60 kg N ha^{-1} and then decreased beyond this point. Similar trend was observed in 2009, except that total harvested cassava tuber yield was significantly higher in 2009 than in 2008.

On the contrary, intercropping soybean with cassava has no yield advantage over sole cropping system with respect to total soybean grain yield (Table 4). However, increased rate of applied nitrogen up to 60 kg N ha^{-1} increased grain yield in both sole and intercropped systems but a decrease in total grain yield was obtained beyond 60 kg N ha^{-1} rates in 2008. In 2009, increasing rate of N application up to 45 kg N ha^{-1} resulted in a corresponding increase in total grain yield of soybean for both sole and intercropping systems but after this point, the total grain yield decreased with increasing rates of applied nitrogen

Intercropping cassava with soybean significantly ($P \leq 0.05$) resulted in higher fresh cassava tuber yield as compared to sole cassava in 2008 and 2009 cropping seasons. Highest tuber yield was obtained at 60 kg N ha^{-1} intercrop and 90 kg N ha^{-1} sole crop in both years.

DISCUSSION

In crop production, the practice of any particular cropping

Table 1. Weather records for the site of the experiments

Month	2008				2009			
	Total rainfall (mm)	Soil temperature (°C)	Total radiation (cal/cm^2/h^{-1})	Wind speed (km h^{-1})	Total rainfall (mm)	Soil temperature (°C)	Total radiation (cal/cm^2/h)	Wind speed (km h^{-1})
January	4.6	29.2	918.2	124.0	0.0	28.1	949.9	56.5
February	0.0	30.4	930.8	151.9	45.0	31.3	849.9	109.5
March	3.0	32.6	962.1	163.3	168.2	30.4	919.9	119.4
April	173.7	31.0	868.3	167.7	164.7	29.6	811.8	75.1
May	96.6	20.7	818.7	124.2	341.9	28.3	843.1	50.2
June	206.4	28.2	745.7	93.0	196.0	27.8	717.1	51.5
July	264.8	26.4	560.7	80.9	321.4	26.4	574.8	36.5
August	185.5	25.8	544.2	72.3	345.6	25.7	481.3	35.4
September	235.6	26.8	676.2	57.5	200.6	26.5	633.8	27.7
October	210.6	27.6	760.9	53.9	227.0	26.4	669.6	20.9
November	6.1	29.8	849.0	50.7	9.9	28.9	926.9	22.3
December	36.1	28.6	746.9	65.9	0.0	28.2	1018.1	64.8

Table 2. Effects of applied nitrogen and cropping system on soil-nitrogen (%) in 2008 and 2009 cropping seasons.

Year	Cropping system	Nitrogen level (kg N ha^{-1})							Mean
		0	15	30	45	60	75	90	
	Sole cassava	0.032	0.032	0.030	0.032	0.050	0.032	0.035	0.035
2008	Sole soybean	0.166	0.168	0.168	0.171	0.171	0.166	0.166	0.168
	Cassava/soybean	0.085	0.085	0.088	0.088	0.988	0.082	0.085	0.086
	Mean	0.094	0.095	.0095	0.097	0.103	0.093	0.095	
	Sole cassava	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
2009	Sole soybean	0.157	0.157	0.157	0.157	0.158	0.160	0.160	0.150
	Cassava/soybean	0.075	0.080	0.080	0.088	0.086	0.086	0.090	0.085
	Mean	0.088	0.089	0.092	0.092	0.091	0.092	0.093	

	Year 2008	Year 2009
LSD $_{0.05}$ for 2 nitrogen means	0.012	0.020
LSD $_{0.05}$ for 2 cropping system means	0.052	0.057
LSD $_{0.05}$ for 2 cropping system x nitrogen	0.520	0.650

Table 3. Effects of applied nitrogen and cropping systems on fresh cassava tuber yield (t/ha^{-1}) and nitrogen use efficiency (NUE) in 2008 and 2009 cropping seasons.

Nitrogen level	Year 2008			Year 2009		
	Cropping system			Cropping system		
	Sole cassava	Intercropped cassava	NUE	Sole cassava	Intercropped cassava	NUE
0	8.7	11.7	3.0	9.20	12.10	3.35
15	12.3	13.8	1.50	12.90	13.96	1.65
30	15.9	21.9	5.20	16.10	22.0	5.30
45	19.8	29.9	10.10	19.85	30.10	11.0
60	22.6	30.0	7.40	23.60	30.0	7.35
75	26.7	26.1	-0.60	26.85	27.30	-0.70
90	29.1	20.7	-8.40	30.20	25.90	-4.30
$LSD_{0.05}$	2.19	3.50	1.59	2.02	3.95	1.62

NUE = Inter cropped cassava yield – sole cassava yield.

Table 4. Effects of applied nitrogen and cropping systems on soybean grain yield (t/ha^{-1}) and nitrogen use efficiency (NUE) in 2008 and 2009 cropping seasons.

Nitrogen level	Year 2008			Year 2009		
	Cropping system			Cropping system		
	Sole soybean	Intercropped soybean	NUE	Sole soybean	Intercropped soybean	NUE
0	0.44	0.30	-0.14	0.45	0.40	-0.05
15	0.54	0.34	-0.20	0.58	0.44	-0.18
30	0.74	0.45	-0.29	0.80	0.46	-0.34
45	0.60	0.40	-0.27	0.70	0.48	-0.22
60	0.61	0.33	-0.28	0.65	0.42	-0.23
75	0.51	0.30	-0.29	0.55	0.35	-0.20
90	0.51	0.31	-0.	0.50	0.32	-0.18
$LSD_{0.05}$	0.121	0.125	ns	0.250	0.105	ns

NUE = Inter cropped cassava yield – sole cassava yield; ns = not significant.

system is dependent on the prevailing conditions and farming objectives. Undoubtedly, sole cropping is mostly adopted in mechanized farming where capital outlay and environmental factors are no problems; whereas mixed farming or intercropping systems are usually aimed at maximum utilization of land and other farm inputs. In the present study, intercropping cassava with soybean produced fresh cassava that had a significant yield advantage over sole cassava in 2008 and 2009 cropping seasons. This finding corroborates with the report by Aggarwale et al. (2002) that intercropping with legumes complement soil-nitrogen, increases nitrogen use efficiency, nitrogen uptake, apparent nitrogen recovery and other benefits as companion crop or subsequent crop.

Generally, higher crop yields were obtained in 2009 than in 2008. This could be attributed to early planting in 2009 as the rain came earlier that year. Eke et al. (2008) obtained similar result when they determined the optimum planting time of okra (*Albelmoschus esculentus*) cultivars in the derived savannah. It is evident in this study that with or without applied nitrogen fertilizer, intercropping cassava with soybean resulted in increased soil nitrogen and nitrogen use efficiency of cassava in both years. However, higher doses of applied nitrogen up to 75 kg N ha^{-1} favoured cassava yield and nitrogen use efficiency of cassava but reduced total yield. It is likely that the increased doses of N led to greater leaf production (luxurious consumption) at the expense of the tuber. Other researchers had earlier reported that excessive application of nitrogenous fertilizer resulted in high soil nitrate levels after harvest (Gordion et al., 1993; Aarnio et al., 2003).

Intercropping soybean with cassava has no yield advantage over sole cropping system with respect to total soybean grain yield in the present study. However, increased rate of applied nitrogen up to 60 kg N ha^{-1} increased grain yield in both sole and intercropped systems but a decrease in total grain yield was obtained beyond 60 kg N ha^{-1} rates in 2008. This result suggests that high doses of nitrogenous fertilizer in sole soybean field are not economical and should be avoided. Clark and Myers (1994) obtained similar result when they studied intercrop performance of pearl, millet, amaranth, cowpea and soybean in response to planting pattern and nitrogenous fertilizer.

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