African Journal of Agricultural Research Vol. 5(24), pp. 3354-3359, 18 December, 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.220

Full Length Research Paper

Measuring the benefits of biological nitrogen fixation of soybean (*Glycine max* (l.) Merrill) in cassava *(Manihot esculenta* crantz) and soybean intercrop

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Accepted 16 February, 2010

The measurement of the benefits of biological nitrogen (N) fixing properties of soybean in cassava and soybean intercrop was conducted at the University of Nigeria, Nsukka between 2000, 2001 and 2002. Changes in soil nutrient concentration were measured at 0 – 30 cm. The effects of N- fertilization on cassava tuber yield and soil-N were monitored for the three seasons using factorial in randomized complete block design. There was no apparent shading effect during the growth of the two crops. Soybean was harvested 110 days after planting, while cassava was harvested at 4, 8 and 12 months after planting in each year. Cassava tuber yield was highest at intercrop X 60 and intercrop X 45 kg N ha^{-1} (30.0 and 29.9 t. ha^{-1}) x tuber yield of intercrop X 45 kg N ha^{-1}. The result indicates that 60 kg (90 - 30) of applied nitrogen could be spared per hectare by intercropping cassava with soybean due to soybean nitrogen fixation. Grain yield of soybean may not be compromised by intercropping with cassava. Soil - N increased from 0.042 mg kg^{-1} before the experiment to 0.168 mg kg^{-1} in sole soybean system and 0.086 mg kg^{-1} in intercrop system at 8 months after planting and 0.150 mg kg^{-1} in the sole soybean and 0.085 kg mg^{-1} in intercrop system in 12 months after planting. The highest land equivalent ratio (LER) of 2.3 and area × time equivalent ratio (ATER) of 1.8 were obtained at 45 kg N ha^{-1} in the intercrop system.

Key words: Soybean, nitrogen fixation, cassava, intercrop.

INTRODUCTION

Biological nitrogen fixation has great potential to compensate for the short falls in availability of fertilizers in African farming system (Danso, 1992). Some workers have investigated nitrogen fixed by legume crops and estimated how much nitrogen is contributed to the companion crop in intercropping systems (Giller, 1992). Intercropping low growing legumes with tall cereals has been a common practice in many tropical countries (Mason and Leihner, 1988). Oforsu et al. (1995) reported nitrogen transfer to sorghum when intercropped with soybean and a higher dry matter in intercropped sorghum than in the mono crop. They noted the more the roots of companion crops were intermingled, the greater the amount of nitrogen transferred. Ayisi et al. (1997) intercropped canola with soybean in strips and reported reduction in fertilizer requirement due to the intercropping. Tijani and Akinnifesi (1996) determined the compatibility of soybean and cassava intercrop in the South Western Nigeria, and reported improved yield of cassava when intercropped with soybean.

Cassava (*Manihot esculenta* Crantz) is a crop that is well adapted to a wide range of ecological conditions, being tolerant to low soil fertility, drought and pest (Tewe,

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Abbreviations: MAP, Month(s) after planting; **LER,** land equivalent ratio; **ATER,** area × time equivalent ratio.

1992) and has been reported as the 4th most important staple of the tropics, providing food and income for more than 750 million people annually (FAO, 1992).

Since its introduction into Nigeria in 1908, soybean (*Glycine max*. (L) Merrill) has been grown primarily as a sole crop (Ogunwolu, 1991) yet it has been shown to be able to fix atmospheric nitrogen up to 417 kg N ha^{-1} (LaRue and Patterson, 1981). Fertilizer-nitrogen requirement of soybean is generally low, ranging from 15–30 kg N ha^{-1} (Mulongony, 1992) and nodulation is reduced with increased nitrogen fertilization (Shibles et al., 1975). From limited trials and observations, it has been shown that soybean and cassava can be intercropped based on their morphological characteristics. With careful selection of agronomic practices, methodologies of nitrogen supply to the intercrop, planting time and spatial arrangements, cassava should benefit from biologically fixed nitrogen of intercropped soybean. It is therefore the objective of this study to assess the benefit of biologically fixed nitrogen by soybean when intercropped with cassava and estimate the nitrogen fertilizer need of the system.

MATERIALS AND METHODS

Three experiment of cassava/soybean intercrop were conducted in 2000, 2001 and 2002 at the University of Nigeria, Nsukka Utisol using factorial in randomized complete block design (RCBD), with two factors: nitrogen rates and cropping systems.

Soybean (*G. max* (L) Merril) TGM 579 obtained from IITA Ibadan and cassava (*M. esculeta* Crantz) TMS 30572, obtained from cassava research unit of Soil Science Department, University of Nigeria, Nsukka were used. Fertilizer materials were urea (46% N) as nitrogen source, single supper phosphate (18% P_2O_5) as phosphorus source and muriate of potash (60% K_2O) as potassium source.

In experiments 1 and 3, twelve (12) plots of 4 × 4 m were replicated three times with 4 levels of nitrogen (0, 15, 30 and 45 kg N ha^{-1}) respectively. Each plot contained two rows of soybean by the sides of the ridges at row spacing of 10.0 cm and a central row of cassava on the crest of the ridges at a plant distance of 1.0 m. There was no soybean by the sides of sole cassava ridges; also there was no cassava on the crest of sole soybean ridges. In experiment 2, nitrogen levels increased from 0 to 90 kg N ha^{-1} (0, 15, 30, 45, 60, 75 and 90 kg N ha^{-1}). Three cropping systems were maintained: sole cassava, sole soybean and cassava/soybean intercrop in all the experiments. There was uniform application of potassium and phosphorus fertilizers at the rates of 80 kg ha^{-1} of potassium and 50 kg ha^{-1} of phosphorus to all the plots through all the experiments. All the fertilizer materials were applied at 14 days after planting using row application method. Weeds were controlled manually.

Soybean was harvested 110 days after planting while cassava was harvested 4, 8 and 12 months after planting. Soil samples at 0–30 cm were taken from all the plots; composite samples were made for each treatment and were analyzed for total Kjeldahl nitrogen using macro Kjeldahl method for soil analysis (AOAC, 1984). Statistical analysis was done using statistical analytical system (SAS). Combined analysis of variance (ANOVA) was done using the general linear model procedure GLM to determine variations in yield between the system efficiency.

RESULTS AND DISCUSSION

The clay-loam soils before the treatment application in experiments 1, 2 and 3 were generally acidic with soil pH (H_2O) ranging from 4.4 to 4.7% while the total nitrogen was in the range of 0.034 to 0.045%.

Tuber yield of cassava

Yield of fresh cassava increased with increasing rate up to 45 kg N ha^{-1} in 2000 and 2002 (Tables 1 and 2) and up to 90 kg N ha^{-1} in 1996 (Table 3) at 4 MAP in all the systems.

The significant increasing rate to the highest nitrogen levels (45 and 90 kg N ha^{-1}) (in sole cassava) over the lower nitrogen rates of applied nitrogen in the three years, showed that only applied nitrogen was available at 4 MAP and did not satisfy the nitrogen need of cassava at all the levels of applied nitrogen at 4 MAP. This view is further suggested by the fact that sole cassava at 4 MAP produced more yield than intercropped cassava where competition for applied nitrogen was stiffer, biologically fixed nitrogen may not have become available to the intercropped cassava.

At eight months after planting (8 MAP), fresh tuber yield of intercropped cassava was significantly higher than sole cassava and intercropped cassava with barrier at all nitrogen rates except at zero and 90 kg N ha^{-1} (Tables 1, 2 and 3). Intercropped system yielded higher than sole crop probably because, fixed nitrogen has been made available with time (8 MAP) from the intercropped soybean, except in the intercropped system with barrier where cassava was barred from n-fixation and transfer. Similarly, at 12 months after planting, (Table 1), tuber yield was significantly higher at intercrop system without barrier than in sole at all nitrogen levels from zero nitrogen to 60 kg N ha^{-1}. The extra nitrogen was probably derived from nitrogen fixation of the associate legume crop. This finding agrees with Leihner (1988) who observed that the amount of nitrogen fertilizer recommended for cassava would be reduced if cassava were grown in association with efficient n-fixing legumes.

At 8 MAP, (Table 4), the tuber yield on intercrop X 45, 60, 75 and 90 kg N ha^{-1} did not differ among themselves but were significantly higher than at intercrop X 0, 15 and 30 kg N ha^{-1}. At 12 MAP, highest tuber yield was at intercrop X 45 and 60 kg N ha^{-1} N (29.9 and 30.0 kg ha^{-1}, respectively). In the sole crop system the highest tuber yield was at sole X 90 kg N ha^{-1}. This showed that the intercrop system gained extra nitrogen probably, the nitrogen fixed by the associate legume crop. This finding agrees with the finding of Bandyopadhyay and De (1986), Eaglesham et al. (1982) and Leihner (1988) who observed that some nitrogen was taken up by sorghum grown concurrently with nitrogen fixers.

Table 1. Effect of applied nitrogen and cropping system on tuber yield of cassava (t. ha^{-1}) at 4, 8 and 12 (MAP) in 1995.

Cropping system	Nitrogen level (kg N ha^{-1})				
	0	15	30	45	Mean
4 MAP					
Sole cassava	1.93	2.10	2.28	2.50	2.22
Intercropped without barrier	1.38	1.58	1.54	2.20	1.84
Intercropped with barrier	0.04	0.05	1.25	1.65	0.95
Mean	1.24	1.40	1.81	2.12	
F-$LSD_{0.05}$ for N = 0.23 CS = 0.02 N x CS = 0.40					
8 MAP					
Sole cassava	5.75	9.50	16.00	18.50	12.44
Intercropped without barrier	9.00	12.75	18.25	26.00	16.50
Intercropped with barrier	6.25	8.00	9.75	7.00	7.75
Mean	7.00	10.08	14.67	17.17	
F-$LSD_{0.05}$ for N = 2.42 CS = 2.10 N x CS = 4.19					
12 MAP					
Sole cassava	14.00	18.50	21.50	26.25	20.06
Intercropped without barrier	15.25	22.00	27.00	35.25	24.88
Intercropped with barrier	4.50	5.75	11.00	9.50	7.69
Mean	11.25	15.4	19.83	2 .67	
F-$LSD_{0.05}$ N = 3.42 CS = 3.01 N x CS = 6.02					

N = nitrogen; CS = Cropping system; N x CS = nitrogen x cropping system; NS = non significant.

Table 2. Effect of applied nitrogen and cropping system on tuber yield (t. ha^{-1}) of cassava at 4, 8 and 12 (MAP) in 1997.

Cropping system	Nitrogen level (kg N ha^{-1})				
	0	15	30	45	Mean
4 MAP					
Sole crop without barrier	0.29	0.44	0.53	0.63	0.47
Sole crop with barrier	0.33	0.22	0.18	0.11	0.21
Intercrop without barrier	0.46	0.57	0.60	0.87	0.63
Intercrop with barrier	0.17	0.2	0.26	0.36	0.25
Mean	0.39	0.36	0.39	0.50	
$LSD_{0.05}$ for N = 0.016 CS = 0.016 N x CS = 0.033					
8 MAP					
Sole crop without barrier	4.75	8.5	14.0	48.5	11.44
Sole crop with barrier	4.0	5.75	7.25	7.0	6.0
Intercrop without barrier	8.0	10.75	12.25	24.0	13.0
Intercrop with barrier	5.62	6.85	8.23	6.21	6.73
Mean	5.59	7.96	8.93	13.93	
$LSD_{0.05}$ for N = 1.55 CS = 1.55 N x CS = 2.54					
12 MAP					
Sole cassava without barrier	16.79	18.48	21.83	34.6	22.93
Sole cassava with barrier	9.88	10.64	10.89	11.7	10.78

Table 2. Contd.

Intercropped cassava without barrier	16.44	22.73	19.93	31.14	22.56
Intercropped cassava with barrier	7.89	8.9	9.7	10.33	9.21
Mean	12.79	15.19	15.51	21.94	
$LSD_{0.05}$ for N = 2.82 CS = 2.82 N x CS = 5.64					

N = nitrogen; CS = Cropping system; N x CS = nitrogen x cropping system; NS = non significant.

Table 3. Effect of applied nitrogen and cropping system on cassava tuber yield (t. ha^{-1}) at 4, 8, and 12 MAP.

Cropping system	Nitrogen level (kg N ha^{-1})							
	0	15	30	45	60	75	90	Mean
4 MAP								
Sole crop	0.49	0.48	0.58	0.58	0.67	0.87	0.91	0.65
Intercrop without barrier	0.31	0.44	0.48	0.42	0.51	0.53	0.59	0.47
Mean	0.40	0.46	0.53	0.50	0.59	0.70	0.75	
$LSD_{0.05}$ for N = 0.025 CS = 0.015 N x CS =0.04								
8 MAP								
Sole crop	4.09	4.21	4.66	4.97	5.36	5.81	6.09	5.02
Intercrop without barrier	4.23	5.61	5.83	6.82	6.89	6.87	6.32	6.02
Mean	4.16	4.91	5.25	5.90	6.13	6.34	6.21	
$LSD_{0.05}$ for N = 0.25 CS = 0.13 N x CS = 0.36								
12 MAP								
Sole crop	8.70	12.30	15.90	19.80	20.70	22.70	24.90	17.86
Intercrop without barrier	11.70	13.80	24.60	29.90	30.00	26.10	20.70	22.40
Mean	10.20	13.10	20.30	24.90	25.40	23.50	22.80	
$LSD_{0.05}$ for N = 0.83 CS = 1.55 N x CS = 2.19								

Table 4. Effects of applied nitrogen and cropping system on Soil-N (mg.kg^{-1}) after the harvest of cassava at 4, 8 and 12 MAP.

Cropping system	Nitrogen level (kg N ha^{-1})							
	0	15	30	45	60	75	90	Mean
4 MAP								
Sole cassava	0.032	0.034	0.034	0.034	0.064	0.037	0.037	0.039
Sole soybean	0.157	0.154	0.149	0.164	0.089	0.120	0.109	0.135
Cassava/soybean	0.101	0.134	0.138	0.131	0.090	0.091	0.099	0.112
Mean	0.075	0.104	0.107	0.110	0.081	0.083	0.082	
$LSD_{0.05}$ N = 0.018 CS = 0.043 N x CS = 0.065								
8 MAP								
Sole cassava	0.032	0.032	0.030	0.032	0.050	0.032	0.035	0.035
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	0.088	0.082	0.085	0.086
Mean	0.094	0.095	0.095	0.097	0.103	0.093		
$LSD_{0.05}$ N = NS CS = 0.052 N x CS = 0.075								

Table 4. Contd.

12 MAP								
Sole cassava	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Sole soybean	0.157	0.157	0.157	0.157	0.158	0.160	0.160	0.150
Cassava/soybean	0.078	0.080	0.088	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	
$LSD_{0.05}$ N = NS CS = 0.044 N x CS = 0.061								

N = nitrogen; CS = Cropping system; N x CS = nitrogen x cropping system; NS = non significant.

The tuber yield at sole X 90 kg N ha^{-1} was equivalent to tuber yield at intercrop X 30 kg N ha^{-1} at 8 MAP. Similarly, the tuber yield at sole crop X 90 kg N ha^{-1} was equivalent to tuber yield at intercrop X 45 kg N ha^{-1} at 12 MAP (Table 4), and tuber yield at 45 and 60 kg N ha^{-1} under intercrop were statistically similar. Above 60 kg N ha^{-1}, tuber yield decreased significantly with increasing nitrogen rate. This suggests therefore that cassava reached its response limit to nitrogen with 45 kg N ha^{-1} at intercrop system in the three consecutive cropping seasons: 2000, 2001 and 2002. At sole crop, the response to nitrogen continued up to 45 kg N ha^{-1} in 2000 and 2002; and to 90 kg N ha^{-1} in 2001. This study therefore shows that the extra nitrogen available to cassava, which was derived from nitrogen fixation at both 8 and 12 MAP, could be assumed to be equivalent to 60 kg N ha^{-1} (90 - 30) at 8 MAP and 45 kg N ha^{-1} (90 - 45) at 12 MAP of applied nitrogen in 3 months duration of soybean crop. This finding agrees with that of LaRue and Patterson (1981) who reported that soybean fixes between 45 - 217 kg N ha^{-1} annually. There was little or no additional benefit from added nitrogen when the applied-N was above 45 kg N ha^{-1} in soybean/cassava intercrop system.

Soil nitrogen

Soil nitrogen (Table 4) was lowest at sole cassava compared with all the cropping systems. At four months after planting there was no significant difference in soil nitrogen between sole soybean and intercrop system, but soil nitrogen under sole soybean (0.135 mg kg) and intercrop system (0.112 m kg) where on the average three times higher than the soil nitrogen in sole cassava (0.039 mg kg). This suggests that although nitrogen has been fixed by soybean and was detectable in the soil, it has not been taken up by the cassava to make any difference since the yield of intercrop cassava (0.47 t.ha) was lower than sole cassava (0.62 t. ha^{-1}) at 4 MAP (Table 3). At 8 and 12 MAP, soil nitrogen under intercrop has become significantly lower than that under soybean, suggesting that cassava the companion crop has taken up extra (fixed) nitrogen from the soil. At 8 months after planting (Table 4) soil nitrogen under sole soybean (0.168 mg kg^{-1}) and intercrop system (0.086 mg kg^{-1}) were four times and two times higher than soil nitrogen under sole cassava (0.035 mg kg^{-1}), respectively. While at 12 months after planting (Table 4) sole soybean (0.150 mg kg^{-1}) and intercrop (0.085 mg kg^{-1}) had soil nitrogen 5 times and 2.8 times higher than soil nitrogen under sole cassava (0.030 mg kg^{-1}), respectively. These findings confirm that cassava benefited from nitrogen fixed by soybean when grown together. Soils under soybean and intercrop system had significantly higher nitrogen than the soil nitrogen before the experiment which was 0.042 mg kg^{-1} after 12 months of planting and subsequent crops grown on such soils should benefit from the residual soil nitrogen.

System efficiency

In 2000, the land equivalent ratio and area × time equivalent ratio of intercrop were above unity and were highest at 30 kg N ha^{-1}. In 2002, LER and ATER increased with increasing nitrogen rate up to 45 kg N ha^{-1}. LER at all nitrogen rates was greater than unity while ATER X 90 kg N ha^{-1} was less than unity.

Conclusion

This study confirms that cassava/soybean intercropping system is a productive system, which has both economic and environmental benefits. Low nitrogen fertilizer requirement for the production of high yield of cassava in intercrop will result in reduction of the cost of procurement of fertilizer, labor input and higher land use advantage. Also the problem of leaching of excess nitrogen, which may occur as a result of fertilizer application to the system into ground water, will be reduced due to its full utilization by an accompanying cassava crop. The growth of a non nitrogen-fixing crop (cassava) intercropped with an efficient nitrogen-fixing legume (soybean) was compatible. There seems to be good utilization of photosynthetically active radiation with no apparent shading effect in the crop association. The cassava/soybean system is also a potentially sustainable system because it builds the soil by leaving it richer in nitrogen than before cropping.

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