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Evaluation of Maize Yield in an On-Farm Maize-Soybean and Maize-*Lablab* Crop Rotation Systems in the Northern Guinea Savanna of Nigeria

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Abstract: An attempt was made to solving the problem of shortfall of fertilizer to maize production in the Northern Guinea Savanna (NGS) of Nigeria by harnessing the potentials of legume/cereal crop rotation in on-farm trials. The yield of maize that succeeded two soybean varieties and *Lablab* in a two-cycle of soybean/maize and *Lablab*/maize crop rotation in NGS Nigeria was assessed in researcher-managed and farmer-managed plots. Though maize that followed the soybean received between 5 kg N ha^{-1} from improved soybean variety (TGx 1448-2E) and 17 kg N ha^{-1} from farmer soybean variety (Samsoy-2) as N balance, this did not significantly (p = 0.05) affect the maize yields. The soybean shed 90-100% of its leaves at physiological maturity which resulted in about 110 kg N ha^{-1} N uptake. This source of N might be one of the factors responsible for the increase in maize yield that followed soybean (20 to 24%) compared with continuous maize yield plot. Maize yield in previous *Lablab* plot was significantly (p = 0.05) higher than in all other treatments. Maize yield in farmer-managed plot ranged between 0.13 and 4.53 t ha^{-1}, maize yield in researcher-managed plot was over 200% higher than maize yield in farmer-managed plot because of poor crop management on the part of the farmer.

Key words: Biological nitrogen fixation, fertilizer, maize, Northern Guinea savanna, rotation, soybean

INTRODUCTION

The use of chemical fertilizer to solve problems associated with crop production in the Northern Guinea Savanna (NGS) of Nigeria is limited because of high costs, inefficient marketing systems and inconsistent government policies on fertilizer subsidy (Manyong *et al.*, 2001). An alternative to the use of fertilizer as source of nitrogen (N), in particular in the NGS, has been to grow legumes (groundnut, cowpea and recently soybean) as a source of N in crop rotation or in mixed cropping with cereals. A cereal crop typically produces greater yields when it follows a legume than as a continuous cereal crop or following another cereal crop (Peterson and Varvel, 1989; Kaleem, 1993; Carsky *et al.*, 1997). However, the amount of soil nutrients, N especially, supplied by legumes in such systems is not enough to sustain crop production (Manyong *et al.*, 2001) due to the export of soil nutrients in grains and the common practice of removing crop residues by farmers in the NGS of Nigeria.

At present, most farmers in the NGS of Nigeria practice legume/cereal crop rotation because they know the benefits of a legume as a component of their farming systems (Sanginga, 2003). Reports showed that maize yield differences following soybean could not be attributed entirely to the carryover effect of a residual N from the previous legume crop residue, because where a negative soil N-balance in a soybean plot was observed, maize that followed had yield increase (Sanginga *et al.*, 2001). This suggests that there are other factors that contribute to better exploitation of the soil for enhanced growth, referred to as "other effects". Kamh *et al.* (1999) reported that improved soil physical and biological characteristics after the legume crop may be more important than the increased N supply. Cereal yield in legume/cereal rotation in farmers' fields may also depend on the BNF potential of the legume and management. In a related publication (Okogun *et al.*, 2005), carried out in this study area, two soybean varieties: Improved soybean (TGx 1448-2E) and local variety (Samsoy-2) fixed between 61% in farmer-managed plot and 69% in researcher-managed plot, which amounted to between 57 and 90 kg N ha^{-1}. A nitrogen balance of between 5 and 17 kg N ha^{-1} in the improved and the Samsoy-2 varieties respectively was obtained. *Lablab*, an herbaceous legume, fixed the least N from the air (48.3%) equivalent of about 22 kg N ha^{-1} (Okogun *et al.*, 2005). *Lablab* flowered in the dry season and resulted in poor seed production. Thus this trial was set up to assess the contribution of two soybean varieties and *Lablab* under farmer crop management systems on the yield of maize in a soybean/*Lablab*/maize crop rotation in farmer's fields in the NGS of Nigeria.

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MATERIALS AND METHODS

Selection of fields: On-farm study was carried out in 20 farmers' fields (1999-2003) at Kaya village, (7°13'E, 11°13'N), the Benchmark site of the International Institute of Tropical Agriculture (IITA) in the Northern Guinea Savanna (NGS) of Nigeria. Kaya is a village that belongs to the medium to high resource-use domain, which is propelled by a market-oriented strategy in agricultural production (Manyong *et al*., 1997). Fields were selected based on farmers who had been practicing crop rotation of cereals with soybean for about a decade. Farmers that practice cereal/legume crop rotation always split their fields into two; one half cropped to soybean and the other half to maize, rotating soybean and maize the following year. As our trial also involved a two-year soybean-maize rotation, we did not alter the cropping pattern. The first phase of the trial was established in the part of the field that was to be planted to soybean by the farmers. Maize was planted on the soybean fields the following year. Two full 2-year crop rotation cycles were completed in each of the farmers' fields.

Experimental design: The experiment was laid out as a factorial design with one field per farmer considered as a replicate. In each farmer's field, there were seven treatments allocated randomly to 7 plots. The treatment in each plot was maintained throughout the duration of the trial. The treatments were: 1, uninoculated improved promiscuous soybean (TGx 1448-2E); 2, inoculated improved promiscuous soybean (TGx 1448-2E); 3, uninoculated local soybean variety (Samsoy-2); 4, inoculated local soybean variety (Samsoy-2); 5, *Lablab*; 6, maize. In the second year, hybrid maize (OBA SUPER I) was planted in all the plots. Treatments 1-6 were researcher-managed and treatment 7, uninoculated soybean local variety (Samsoy-2) managed by the farmer (farmers' practice).

Field preparation: All the farmers used animal traction in ridging the fields after flattening the old ridges with hand hoeing. The ridges were made approximately 0.75 m apart. The previous treatment of each plot was maintained by preventing mixture of soils from other plots during field preparation. The size of the plot for each treatment was 12×12 m.

Seed treatment, planting and management: Maize seeds were treated with Apron plus against downy mildew (CIBA GEIGY Ltd., Basle, Switzerland). Maize was planted at 0.25 m within rows and about 0.75 m between rows on the ridges and was thinned to one plant per hill 2 Weeks after Planting (WAP). All the maize plots received a basal P application of 15 kg P ha^{-1} as Triple Super Phosphate (TSP) at planting. Each plot was split into two halves: one half received 45 kg N ha^{-1} as urea and the other half received 90 kg N ha^{-1} urea. The N fertilizer was split applied (one half at a time) at 3 and 6 WAP. Even though the trials were researcher-managed except for the farmer-managed plots, all other agronomic practices for the crop production were those that conformed, to the farmers' practices. These practices were maintained in all the fields throughout the duration of the study. However, the researcher-managed plots were more frequently weeded than the farmer-managed plots.

Sampling

Soil sampling and analysis: Before fields were prepared, bulk soil samples were collected (0-15 cm) from the fields with a 6 cm-diameter soil auger. A sub-sample was taken from each bulk sample after this had been thoroughly mixed, air-dried and ground to pass through 2 mm sieve for some chemical analyses (IITA, 1982). The soil characteristics are shown in Okogun *et al.* (2005).

Stover and grain yield: The maize stovers in each of the harvested area per plot were cut at soil level and weighed fresh in the field. Sub-samples were taken from the bulk weighed stovers and these were weighed fresh. The sub-samples were oven dried at 70°C for 72 h and weighed to determine the dry weight per hectare.

Maize grain yield was determined by harvesting all the maize cobs in the plot, leaving the first border row on each side of the plot and first two maize plants at both ends of each ridge (approximately 50 cm). The maize cobs were counted and weighed. Representative sub-samples of 10 cobs were randomly selected in each plot and weighed fresh in the field. The sub-samples were dried in an oven at 70°C to moisture content of about 8-10%. The dry maize sub-samples were used to estimate the yield of maize per hectare.

The stover sub-samples and grains were ground and analyzed for total N and P and the nutrient uptake was calculated (IITA, 1982).

Calculation for maize N balance: There were two levels of N fertilizer applied: 45 and 90 kg N ha^{-1}

N balance in TGx 1448-2E = 5 kg N

N balance in Samsoy-2 = 17 kg N

Maize N balance = N in fertilizer + N balance from legume − N uptake (shoot + grain)

Statistical analysis: Similar type and size of data were collected for the two rotational cycles. The data set for the years were pooled and analyzed using Statistical Analysis Systems (SAS, 1989) The data were subjected to ANOVA using PROC. GLM and CONTRAST procedure of the

Statistical Analysis Systems (SAS, 1989). Relationships between the maize parameters measured were assessed using PROC. CORR. SAS procedure.

RESULTS

Stover dry matter and grain yield: The maize stover Dry Matter Yield (DMY) varied significantly in the farmers' fields and the values ranged from 0.24 and 13.4 t ha^{-1} and the mean was 4.9 t ha^{-1} (Table 1). Maize stover DMY was significantly higher (p = 0.05) in plots previously planted to *Lablab* than in previous soybean plots (Table 2). Maize stover DMY was lowest in farmer-managed plot (3.2 t ha^{-1}). Maize stover DMY in researcher-managed farmer soybean variety (Samsoy-2) plots was 44% higher than stover DMY following same soybean variety in farmer-managed plots. Maize stover DMY in previous improved soybean plot was significantly higher than in the previous Samsoy-2 plot. Maize stover DMY was significantly higher in maize that received 90 kg N ha^{-1} than where 45 kg N ha^{-1} was applied (Table 3).

Maize grain yield also varied significantly across the fields. The yield ranged from 0.12 to 11.3 t ha^{-1} and the mean was 3.8 t ha^{-1} (Table 1). Maize grown in previous *Lablab* plot had the highest grain yield 5.3 t ha^{-1}(Table 2) and it was significantly higher (p = 0.05) than the maize grain yield in the previous soybean plots. Maize grain yields in previous improved (TGx 1448-2E) and farmer variety soybean (Samsoy-2) plots were not significantly different from each other (Table 2).

Nitrogen fertilizer applied at 90 kg N ha^{-1} had significantly higher (p = 0.05) maize grain yield than that of 45 kg N ha^{-1} (Table 3).

Shoot N and P and grain N and P uptake: Nitrogen and P uptake in maize stover and grain varied significantly across farmers' fields. Total N accumulated varied from 0.4 to 186.7 kg ha^{-1} for the stover and 1.8 and 180.6 kg ha^{-1} for grain. Total P accumulated in the stover ranged from 0.03 to 33.5 kg ha^{-1} with a mean of 5.8 kg ha^{-1} and the grain P accumulated ranged from 0.54 to 53.8 kg ha^{-1} in farmers' fields (Table 1). Maize stover that followed *Lablab* accumulated significantly higher (p = 0.05) N than maize stover that followed both soybean varieties and continuous maize (Table 4). The P uptake was highest in maize stover in the previous *Lablab* plot and it was significantly higher than maize P uptake in the previous plots of the soybean varieties in the researcher-managed and farmer-managed plots (Table 4). However, N and P accumulated were least in the stover of continuous maize and in farmer-managed plot. Maize stover total N and P uptake that received 90 kg N ha^{-1} was significantly higher than that of 45 kg N ha^{-1} treatment (Table 3).

Grain N uptake was significantly higher in maize that followed *Lablab* than in all other treatments. This was followed by grain N uptake in improved soybean plots, while that of farmer-managed plot was least (Table 4). The grain P uptake was not significantly different in all the

Table 1: Range of parameters measured in the farmers' fields in Kaya n = 20

Parameters (kg ha^{-1})	Minimum	Maximum	Mean±SD
Stover yield	240.00	13396.00	48480±2442
Grain yield	109.00	11288.00	38430±2787
Stover N uptake	0.38	186.74	36.29±29.01
Stover P uptake	0.03	33.49	5.770±5.35
Grain N uptake	1.79	180.62	56.83±39.25
Grain P uptake	0.54	53.76	16.25±12.71

Table 2: Effect of legume and maize residue on maize stover dry matter and grain yield in Kaya

Species	Treatment	Stover dry weight (kg ha^{-1})	Grain yield (kg ha^{-1})
TGx 1448-2E	Uninoculated	6124^{bc}	4440^{b}
TGx 1448-2E	Inoculated	6612^{b}	4545^{b}
Samsoy-2	Uninoculated	5725^{c}	4527^{b}
Samsoy-2	Inoculated	6080^{bc}	4498^{b}
Lablab	-	7575^{a}	5258^{a}
Maize	-	4319^{d}	2430^{c}
Samsoy-2	Farmer managed	3211^{e}	1672^{d}

Means that have same letter(s) are not significantly different at p = 0.05

Table 3: Effect of legume and maize residue and N fertilizer on maize stover dry weight, grain yield, stover N and P and grain N and P uptake in Kaya

			Stover N and P uptake		Grain N and P uptake	
Fertilizer (kg N ha^{-1})	Stover dry weight (kg ha^{-1})	Grain yield (kg ha^{-1})	(kg N ha^{-1})	(kg P ha^{-1})	(kg N ha^{-1})	(kg P ha^{-1})
45	5124^{b}	4385^{b}	34.0^{b}	5.8^{a}	62.9^{b}	18.5^{b}
90	6840^{a}	4903^{a}	51.0^{a}	7.7^{a}	71.6^{a}	20.9^{a}

Means that have same letters are not significantly different at p = 0.05

Table 4: Effect of legume and maize residues on maize stover N and P and July 3, 2007 grain N and P uptake in Kaya

		Stover N and P uptake		Grain N and P uptake	
Species	Treatment	(kg N ha^{-1})	(kg P ha^{-1})	(kg N ha^{-1})	(kg P ha^{-1})*
TGx 1448-2E	Uninoculated	42.5^{c}	6.6^{bc}	64.0^{b}	19.3
TGx 1448-2E	Inoculated	48.6^{b}	7.4^{b}	65.8^{b}	19.1
Samsoy-2	Uninoculated	34.8^{d}	5.7^{c}	66.1^{b}	19.5
Samsoy-2	Inoculated	39.3^{cd}	6.5^{bc}	64.5^{b}	18.8
Lablab	-	62.6^{a}	9.8^{a}	78.8^{a}	22.4
Maize	-	28.7^{e}	5.0^{d}	51.6^{c}	18.6
Samsoy-2	Farmer managed	23.8^{e}	5.2^{d}	44.1^{d}	21.1

Means that have same letter(s) are not significantly different at p = 0.05; * Not significantly different

Table 5: Coefficient of correlation between maize parameters measured in Kaya

Parameters	Stover yield	Grain yield	Stover N	Stover P	Grain N	Grain P
Stover yield						
Grain yield	0.4022**					
Stover N	0.2438**	0.4992**				
Stover P	0.1161*	0.4023**	0.6821**			
Grain N	0.1807**	0.7918**	0.3555**	0.1707**		
Grain P	0.4746**	0.9055**	0.4159**	0.3761**	0.5569**	

*: Significant at p = 0.05; **: Significant at p = 0.01

treatments even though maize grain P uptake in previous *Lablab* was highest and that in continuous maize was the least (Table 4).

Table 5 shows the relationships between some of the parameters measured. There were significant correlations between maize stover DMY and grain yield at p = 0.01 (r = 0.4022, n = 553); between maize stover DMY and grain P uptake at p = 0.01 (r = 0.4746, n= 533) (Table 5).

DISCUSSION

Data showed that suitable management practices play a major role in crop production in the study area. For instance, maize yield in farmer-managed plot was about 37% of the yield of maize in the researcher-managed plot in the previous uninoculated Samsoy-2 plot.

Another defect in the farmer management systems was late weeding for the crop. While researcher-managed plots were weeded at 3 and 6 WAP before the ridges were remoulded at 8 WAP, many farmers weeded once or at best twice by remoulding at very late periods (at flowering or near flowering period of maize). Thus the weeds and maize competed for available nutrients in the farmer-managed plot, a stress that was removed from researcher-managed plot by timely weeding. This practice may have contributed also to the significantly higher maize yield in the researcher-managed compared to maize yield following the same soybean variety in the farmer-managed plot. Even, though maize yield succeeding soybean in researcher-managed plot was about 22% higher than maize yield in the continuous maize plot (Baldock *et al*., 1981; Nafziger *et al*., 1984; Carsky *et al*., 1997) the maize yield in continuous maize cropping was higher than maize yield in farmer-managed plot. This is a pointer to the fact that adequate weeding regime is necessary for maize crop to benefit from the previous crop residues.

Yield of maize following *Lablab* was 33% higher than maize yield in the continuous maize plot and about 15% higher than maize that followed soybean varieties. Enhanced *Lablab* contribution to soil fertility as exhibited in the increase in the maize grain yield could be attributed to: (1) non N export from the field in grain of *Lablab* because seed production was poor; (2) high biomass production during the vegetative growth stage that gave high plant residue and favorable microenvironment for soil biological processes such as high incidence of earthworm casts under *Lablab* biomass and (3) longer vegetative growth period of *Lablab* compared to soybean varieties such that there was continuous accumulation of biomass more than two months after the soybean was physiologically mature.

Farmers' method of soybean harvest (cut and carry) in the NGS further reduced the residual N in the farmer-managed soybean plot. The pod chaff of soybean was exported from the field for other uses while the soybean residues were retained in the researcher-managed field. Thus, a substantial amount of nutrients, especially N, in such residues was lost in farmer-managed plot.

Even though maize grain yield in the previous *Lablab* plot was higher than maize yield in the previous soybean plots, farmers preferred soybean/maize rotation to *Lablab*/maize rotation due to the following: (1) *Lablab* requires pesticide spraying while soybean requires none, (2) *Lablab* grain yield was poor and (3) Farmers had income advantage by having good market for soybean grain before planting maize in the following season. On the other hand the farmers preferred the improved soybean grains to Samsoy-2 in soybean/maize rotation because of its high grain qualities, (bigger grains, bright golden yellow color and market price).

The maize stover DMY was significantly higher where 90 kg N ha^{-1} was applied than where 45 kg N ha^{-1} was applied. However, the fertilizer N use efficiency (maize grain yield/fertilizer applied) was higher in 45 kg N ha^{-1} than in 90 kg N ha^{-1}. Maize yield in plots that received 90 kg N ha^{-1} was about 10% higher than the maize yield that received 45 kg N ha^{-1} but the maize yield increase did not compensate for the price of the extra 45 kg N ha^{-1}.

Thus application of 45 kg N ha^{-1} to maize following soybean/*Lablab* could be adequate even though Weber *et al*. (1992), Weber (1996) recommended a higher N dose for maize production in the NGS. Soils in the farmers' fields in the NGS cannot supply this quantity of N coupled with the rapid decline of N once cropping starts (Sanginga *et al*., 2001). It is necessary to quantify the contribution of unaccounted for N in the roots and nodules underground to net N balance to understand the contribution of soybean residues to maize yield in the soybean/maize rotation.

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