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On-farm evaluation of biological nitrogen fixation potential and grain yield of *Lablab* and two soybean varieties in the northern Guinea savanna of Nigeria

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Abstract

Several legumes with high biological nitrogen fixation (BNF) potentials have been studied in on-station trials. The processes involved in BNF and the benefits of these species to crop production need to be evaluated using farmers' management practices in farmers' fields. An on-farm trial with 20 farmers was conducted in the northern Guinea savanna (NGS) of Nigeria. The aims were to evaluate the BNF potentials of an improved soybean variety (TGx 1448-2E) and a local variety (Samsoy-2) when inoculated with *Bradyrhizobium* strains, and of *Lablab* in farmer-managed and researcher-managed soybean-maize and *Lablab*-maize crop rotation systems. The level of soil P was generally low with more than 50% of the fields having less than the critical P level. The plant available P content was statistically significantly ($P = 0.05$) correlated with P in grain ($r = 0.60$), P in the shoot ($r = 0.68$), grain yield ($r = 0.40$) and nodule weight ($r = 0.35$). Variations in plant parameters (nodulation, shoot dry matter, percentage nitrogen derived from the air [%Ndfa], grain yield, and nutrient uptake) among and within farmers' fields were attributed to differences in soil fertility and crop management. About 60% of the fields were moderately fertile, sufficient to support legume establishment, while about 30% of the farmers' fields had a low fertility level. For farmers in the study area to benefit from the BNF potentials of the legumes, an external P fertilizer input was necessary as well as suitable crop management practices because all parameters measured in the researcher-managed plots were higher than in the farmer-managed plots.

Introduction

Farmers in the northern Guinea savanna (NGS) of Nigeria know the importance of legumes, especially grain legumes. They include them in their cropping systems although not because they know that legumes fix atmospheric nitrogen (N). Their reason is that legumes, such as cowpea, groundnut, and recently soybean, stabilize yield and serve as sources of protein for their families (Akinyele 1991; Sanginga et al. 2001). The production and utilization of soybean in the NGS have increased greatly for over a decade and it has become the second crop after maize in the NGS of Nigeria (Sanginga et al. 2001) in supplying family food and improving farmers' income. The diffusion of soybean production in the NGS was accelerated by the introduction of the improved high yielding soybean lines from International Institute of Tropical Agriculture (IITA) to replace the farmers' varieties. One of these, TGx 1448-2E, the soybean genotype used in this trial, had better qualities (higher grain and fodder yields, higher BNF potential, less shattering, and better control of *Striga*) than Samsoy-2 (local variety). Both varieties have almost the same maturity dates (Dashiell and Sanginga 1998).

Although much research has been done on legumes, not much progress has been made in transferring BNF technologies to farmers because the N_2 fixation processes are not easily understood in the farmers' environment. Sanginga et al. (1997) observed that the major N sources for soybean were N derived from the air (Ndfa; 84 kg N ha^{-1}) and N derived from the soil (Ndfs; 75 kg N ha^{-1}). The former provided 46% of the plant total N, and the latter 43% in ^{15}N fertilizer applied at 20 kg N ha^{-1}. Also, two late maturing soybean genotypes derived more of their N requirement from N fixation than the early maturing varieties. TGx 1660-19F derived 125 kg N ha^{-1} (52% of its N requirement) and Br 17060 derived 110 kg N ha^{-1} (50%) while IAC 100 and TGx 1485-1D derived 38 kg N ha^{-1} (36%) for the early maturing soybean variety. The N balance ranged from − 8 to 43 kg N ha^{-1}, depending on the cultivar and inoculation treatment (Sanginga et al. 1997). Improved grain legumes with high BNF potentials are selected in on-station research. However, the BNF measured in the fields at research stations may not always be a good indicator of what is to be expected in the farmers' fields (Sanginga 2003). Crop management and nutrient deficiencies may restrict the development of a population of free-living rhizobia in the rhizosphere, limit the growth of the host plant, restrict nodulation itself, and have an adverse effect on the functioning of the nodule, especially BNF (Sanginga et al. 2001). For instance, despite the importance of BNF in improving low soil fertility, especially the N status of the soil, little is known of how much N_2 is fixed under farmers' management conditions in farmers' fields, and of the differences between the yields of legumes and associated crops in researcher-managed and farmer-managed plots.

There is a high rate of depletion of N in the savanna fields of the NGS of Nigeria due to the cut and carry methods of farmers when harvesting crops. The performance of these legumes and benefits thereof for farmers need to be evaluated in farmers' fields where there are variations in soil nutrient status and management practices. N fixation by many legumes is limited by nutrient deficiencies in the soil, especially of P (Chien et al. 1993; Ofosu-Budu et al. 1993; Sanginga et al. 1995). This study was carried out to assess the influence of farmer-crop management practices and soil conditions on the growth and BNF of soybean and *Lablab* in the NGS of Nigeria.

Materials and methods

Experimental design

The experiment was laid out as a factorial design with each farmer's field as a replicate. In each field, there were seven treatments allocated at random to six plots measuring 12 m × 12 m. 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; (treatments 1–6 were researcher-managed) and 7, uninoculated soybean local variety (Samsoy-2) managed by the farmer (farmers' practice). The treatment in each plot was maintained throughout the duration of the trial

In the researcher-managed plots (treatments 1–6), some agronomic practices for crop production were in conformity with the farmers' practices; these were maintained in all the farmers' fields throughout the duration of the study. In the farmers' practice plot (treatment 7), farmers were allowed to proceed with their normal crop production without interference from the researchers.

Selection of fields

A 4-year (1998–2002) on-farm study was carried out in 20 farmers' fields located within 10 km of Kaya village (7°13′ E, 11°13′ N) in northern Nigeria. Kaya is a village in the medium to high resource-use domain which is driven by a market-oriented strategy in agricultural production (Manyong et al. 1997). Detailed economic and biophysical characterization of the study area has been reported by Manyong et al. (2001). Fields were selected from locations where farmers had been practising crop rotation of cereals with soybean for about a decade. In the study area, farmers split their fields into two parts; in each growing season, the farmers crop one half to soybean and the other half to maize. In the following cropping season, soybean is planted in the previous maize plot and maize is planted in the previous soybean plot. As our trial also involved a 2-year soybean-maize rotation, we did not alter this cropping pattern. Maize was planted on these fields the following year. The other half of the field that had been planted to maize previous year was now planted to soybean to establish a similar experimental crop rotation. Two full cycles were completed in each part of the farmers' fields during the experimental period.

Land preparation

All the farmers used animal traction in ridging the fields after flattening the old ridges with hand hoes. The ridges were made approximately 0.75 m apart. A portion of the farmers' fields prepared for soybean cropping was measured and used as the experimental field. The size of each plot for each treatment was 12 m × 12 m.

Inoculant preparation

The two *Bradyrhizobia* strains (R25B and IRj 2180A) used were IITA elite strains isolated from soybean nodules. Equal volume of the liquid cultures of the strains were mixed under sterile conditions, and inoculated into peat. The peat culture was then incubated at 37 °C for 2 weeks (Beck et al. 1993). The culture was removed from the incubator and kept in the refrigerator till needed to inoculate soybean seeds in the field before planting.

Seed treatment and planting

Two varieties of soybean were planted in all the fields, the local variety (Samsoy-2) and an improved variety (TGx 1448-2E). Both varieties were surface sterilized (Vincent 1970) and inoculated with the peat culture of the mixture of R25B and IRj 2180A bradyrhizobial strains as described by Somasegaran and Hoben (1994).

Soybean was planted by drilling the seeds in an open groove on the ridges, and they were covered with soil. The uninoculated soybean plots were planted before the inoculated plots to avoid contamination. No further inoculation was done after the first year of the study (1998). Maize and *Lablab* seeds were planted at 25 cm within rows and at about 75 cm between rows on the ridges. The seedlings were thinned 2 weeks after planting (WAP) to one plant per hill at 10 cm within-row spacing for soybean, and 25 cm for maize, and two plants per hill for *Lablab*. A maize plot was included as a reference crop during the soybean cropping season and as a control to assess the residual effects of the soybean on the following season's maize crop.

Sampling

Soil sampling

Before fields were prepared, bulk soil samples were collected (0–15 cm) from the fields with a 6 cm-diameter soil auger. Each field was divided into 4 blocks and 60 cores of soil were taken per block as bulk samples. A subsample, for chemical analyses, was taken from each bulk sample after it had been thoroughly mixed and ground to pass through a 2 mm sieve.

Vegetative sampling for shoot biomass, nodule, and nitrogen fixation measurement

At 50% podding of the soybean plants, five plants in each plot of soybean and *Lablab* were randomly selected and cut at about 2 cm above soil level. The shoots were weighed fresh, later air dried for 3–4 days before finally being oven dried at 70 °C for 72 h.

The stumps of the five plants in each plot were bled immediately after being cut in the field by fixing silicon rubber tubing over the stumps. The sap that flowed into the tube from the stumps was collected with syringes and poured in glass vials. An equal volume of ethyl alcohol was immediately added to the sap in the vials and it was placed in ice in a cooler. The samples were kept frozen in the laboratory until analysis. The ninhydrin technique for amino-N and the salicylic acid technique for NO_3^- analysis were used as described by Peoples et al. (1989). The optical density (absorbance) of the standards (allantoin acid) and each sample were read in a CECIL 2031 spectrophotometer at 525 nm. The following calculations were done to determine the percentage nitrogen derived from the air (%Ndfa) in accordance with the procedure of Peoples et al. (1989).

Calculations

Total N in sap sample (Tot. N sap) = ureide + NO_3 + amino-N conc. Relative ureide index % = Ureide × 100/Tot. N sap

But ureide contains 4N atoms, thus ureide N is calculated as 4 × ureide molar conc. Therefore, Relative ureide index % = 4 × Ureide /(4 × Ureide + amino acid + nitrate) × 100.

Subsequently, the proportion of plant N from nitrogen fixation was estimated in Peoples et al. (1989).

Nodulation

The root stumps were excavated; nodules that became detached from the roots were carefully picked from the soil and brought to the laboratory. The roots and nodules were washed under running tap water in a 1 mm mesh, to remove adhered soil. The nodules were then detached from the roots, counted, and weighed.

Grain yield

In each year, 100 representative soybean plants were randomly harvested in a 15 m^2 area of each plot; the pods were removed and weighed fresh in the field. The pods were air dried and, threshed; the grain seeds were oven dried at 70 °C for 72 h and weighed. The weight was then used to estimate soybean grain yield/ha. After drying, shoot and grain were ground and analyzed for percentage total N (%TN) and total P (%TP) using the methods outlined by IITA (1982).

Lablab grain yield was not determined because its fruiting period coincided with the dry season when the cattle of the pastoral farmers browsed the plant shoots and pods.

Statistical analysis

A data set of similar type and size was collected for each of the years. The data for the years were pooled for statistical analysis and subjected to ANOVA using PROC. GLM and CONTRAST procedure of the Statistical Analysis Systems (SAS Institute Inc., 1989). The mean separation was done using Duncan Multiple Range Test.

Results

There were wide variations in the nutrient status of farmers' fields (Table 1). The pH of the soils ranged from 5.1 to 6.3. The available P (Bray-I) was generally low; only 1 field had adequate soil P (Bray-I P) above 15 mg P kg^{-1} soil; 4 fields were within the critical range (10.0–14.0 mg P kg^{-1} soil); about 15 of the farmers' fields had low P (2.0–8.0 mg kg^{-1} soil).

Nodulation and nodule biomass

Soybean nodule fresh weight within farmers' fields ranged between 0.01 and 9.4 g $plant^{-1}$ (Table 2). *Lablab* had the lowest number of nodules.

Nodulation in uninoculated Samsoy-2 variety in the researcher-managed plot was significantly higher than the nodulation in the farmer-managed plot (Table 3). The improved soybean variety had less nodulation than the Samsoy-2 variety (Table 3). However, nodule fresh weight of the inoculated improved soybean variety was not significantly different from the Samsoy-2 variety, whether inoculated or not.

Shoot dry matter and grain yield

There were large variations in the yields of soybean shoot dry matter and grain in farmers' fields. The shoot dry matter ranged from 2.4 to 166.3 g $plant^{-1}$ and the mean was 30.7 g $plant^{-1}$ (Table 2). However, shoot production in *Lablab* was not significantly different from shoot dry matter yield of the improved soybean variety,

Table 1. Soil characteristics in the farmers' fields (n = 20) in Kaya.

Parameter	Minimum	Maximum	Mean	Stdev*
pH (H_2O)	5.1	6.3	5.5	0.36
%TN	0.045	0.076	0.062	0.008
Avail P (mg kg^{-1})	1.0	51.0	8.6	9.89
Exch. Mg (cmol (+) kg^{-1})	0.3	1.9	0.7	0.34
Exch. K (cmol (+) kg^{-1})	0.1	0.8	0.26	0.14
Exch. Ca (cmol (+) kg^{-1})	1.2	4.8	2.3	0.89

*Standard deviation

Table 2. Ranges of soybean parameters measured in the farmers' fields (n = 20) in Kaya.

Parameter	Minimum	Maximum	Mean	Stdev*
Shoot dry wt (g $plant^{-1}$)	2.4	166.3	30.7	21.9
Nodule biomass (g $plant^{-1}$)	0.01	9.4	1.8	1.6
%Ndfa	6.2	81.7	64.1	11.9
Grain yield (kg ha^{-1})	93	5309	1454	989
Shoot N uptake (kg N ha^{-1})	9.3	309.4	109.7	71.8
Shoot P uptake (kg P ha^{-1})	0.5	41.1	9.2	7.4
Grain N uptake (kg N ha^{-1})	2.4	284.7	76.5	52.4
Grain P uptake (kg P ha^{-1})	0.2	28.8	5.6	5.0

*Standard deviation

whether inoculated or not (Table 4). The inoculated improved soybean cultivar (TGx 1448-2E) produced a higher amount of shoot dry matter. However, this was not statistically different from the uninoculated improved variety but significantly higher than that of Samsoy-2 variety, whether inoculated or not (Table 4). The inoculated improved soybean had a grain yield of about 700 kg ha^{-1} more than the inoculated Samsoy-2 variety; the grain yield of uninoculated improved soybean was over 800 kg ha^{-1} more than the yield of the uninoculated Samsoy-2 variety (Table 4). The soybean grain yield of the Samsoy-2 variety in the researcher-managed plot was over 250 kg ha^{-1} more than the same type of soybean in the farmer-managed system.

Table 3. Effect of inoculation on soybean nodulation, and nodule fresh weight in Kaya.

Legumes species	Inoculation	Number of nodule $plant^{-1}$	Nodule fresh weight g $plant^{-1}$
TGx 1448–2E*	Uninoculated	44.3^{c}	1.66^{b}
TGx 1448–2E*	Inoculated	55.0^{bc}	2.44^{a}
Samsoy-2*	Uninoculated	61.1^{ab}	2.12^{a}
Samsoy-2*	Inoculated	68.1^{a}	2.44^{a}
*Lablab**		6.7^{d}	0.62^{c}
Samsoy-2**	Uninoculated	46.9^{c}	1.53^{b}

Values that have same letters in a column are not significantly different at P = 0.05
*Researcher-managed plot
**Farmer-managed plot

Nitrogen fixation, shoot and grain N and P uptake

The %Ndfa in farmers' fields ranged from 6.2 to 81.7 (Table 2), and inoculated improved soybean had the highest %Ndfa. *Lablab* had the lowest %Ndfa. The lowest %Ndfa among the soybean plots was observed in the farmer-managed plot (Table 5). The uninoculated Samsoy-2 variety planted in the researcher-managed plot fixed 5% more N than the same variety planted in the farmer-managed plot.

Inoculation had a slight effect on shoot N and P uptake (Table 5). The shoot N uptake across fields ranged from 9.3 to 386.4 kg N ha^{-1} (Table 2). The shoot P uptake ranged from 2.4 to 63 kg P ha^{-1} and closely followed the variations in shoot N uptake. The grain N and P uptake followed the same pattern as the shoot N and P uptake. The Samsoy-2 variety in farmer-managed plots had lower values for measured parameters than the same type of soybean in researcher-managed plots. Nodule number correlated significantly with the nodule biomass at P = 0.01 (r = 0.708), and nodule biomass correlated significantly with grain yield at P = 0.01 (r = 0.292). Also shoot biomass correlated significantly with the grain yield (Table 6). Significant correlations existed between soil total N and available P and several soybean parameters (Table 7). There was, in particular, a strong correlation between available P and shoot P at P = 0.01 (r = 0.645), and between available P and grain P at P = 0.01 (r = 0.532).

Table 4. Effect of inoculation of soybean varieties on shoot and grain yield in Kaya.

Legume species	Inoculation	Shoot dry weight g plant^{-1}	Grain yield kg ha^{-1}
TGx 1448–2E*	Uninoculated	31.5[a]	2010[a]
TGx 1448–2E*	Inoculated	32.5[a]	2160[a]
Samsoy-2*	Uninoculated	25.4[b]	1182[b]
Samsoy-2*	Inoculated	26.3[b]	1457[b]
*Lablab**		30.5[a]	ND
Samsoy-2**	Uninoculated	18.4[c]	931[c]

Values that have same letters in a column are not significantly different at $P = 0.05$
ND = Not determined
*Researcher-managed plot
**Farmer-managed plot

Discussion

The variations in the data among farmers' fields to a large extent depended on the native soil fertility (Table 1). For instance, most of the soils in the farmers' fields were slightly acidic (Table 1), and had very variable P levels. The high variability in soil P in the farmers' fields might be responsible for the high variations in %Ndfa (Tables 1 and 2). BNF in legumes requires adequate levels of soil nutrients, such as P, and micronutrients (Sanginga et al. 1995). The crucial concern is to reach the minimal soil fertility level required for good soybean establishment and BNF. Soils in about 75% of the farmers' fields had a soil P status below the critical level of 15 mg P kg^{-1} soil. (Mokwunye 1981, 1996; Wong et al. 1991). A high yielding soybean variety, such as TGx 1448-2E requires enough P and also a starter dose of N for proper establishment because soils in the NGS of Nigeria have low N level. Even though soybean can acquire P in the soil through other mechanisms, the roots of plants dependent on BNF had been reported to have a higher concentration of P than those supplied with nitrate (Breeze and Hopper 1987). Highest %Ndfa was observed in soybean in the farmer's field that had high P level (Data not shown).

Table 5. Effect of inoculation on soybean and Lablab %Ndfa^{+}, shoot N and P uptake and soybean grain N and P uptake in Kaya.

Legume species	Inoculation	%Ndfa	Shoot N uptake kg ha^{-1}	Shoot P uptake kg ha^{-1}	Grain N uptake kg ha^{-1}	Grain P uptake kg ha^{-1}
TGx 1448–2E*	Uninoculated	66.2[b]	135.8[a]	12.3[a]	85.0[b]	6.5[b]
TGx 1448–2E*	Inoculated	68.6[a]	141.0[a]	11.3[a]	98.5[a]	7.5[a]
Samsoy-2*	Uninoculated.	66.7[b]	119.2[b]	9.9[bc]	62.3[c]	4.7[c]
Samsoy-2*	Inoculated	66.9[ab]	127.2[ab]	9.9[bc]	70.1[c]	5.1[c]
*Lablab**		48.3[d]	45.2[d]	4.6[d]	ND	ND
Samsoy-2**	Uninoculated	61.2[c]	98.2[c]	8.5[c]	47.5[d]	3.4[d]

Values that have same letters in a column are not significantly different at $P = 0.05$
$^{+}$Biological nitrogen fixation
ND = Not determined
*Researcher-managed plot
**Farmer-managed plot

Table 6. Coefficient of correlation between parameters measured in the trials in Kaya.

	Shoot wt	Nodfwt	%Ndfa	Grain yield	Shoot N	Shoot P	Grain N
Shoot wt							
Nod fwt	0.2421						
%Ndfa	– 0.2008**	0.3932**					
Grain yld	0.2188**	0.2956**	NS				
Shoot N	0.8961**	0.4252**	0.2149**	0.5045**			
Shoot P	0.6996**	0.3939**	NS	0.6415**	0.8542**		
Grain N	0.1903**	0.3133**	NS	0.9779**	0.4186**	0.5831**	
Grain P	0.1836**	0.2645**	NS	0.9292**	0.4714**	00.7090**	0.9420**

**Significant at $P = 0.01$
NS = Not significant

Table 7. Coefficient of correlation between %TN, available P, and average plant parameters in Kaya.

	%TN	Avail. P	Shoot wt	Nodfwt	%Ndfa	Grain yld	Shoot N	Shoot P	Grain N	Grain P
%TN		0.2842**	0.4016**	0.2384**	NS	NS	0.3706**	0.3801**	NS	NS
Avail. P	0.2842**		0.2906*	0.3514**	NS	0.3104**	0.3508**	0.6445**	0.3822**	0.5322**

*Significant at $P = 0.05$
**Significant at $P = 0.01$
NS = Not significant

We observed that some of the farmers' crop management practices might have far-reaching effects on the performances of soybean in their plots. The farmers' usual practice was to plant any seed with a small hoe (planting hoe). Also farmers planted soybean in heaps of up to 10–15 seeds/hill on the ridge. They covered seeds with a heavy mass of soil and trod upon it to compact the soil over the seeds. These practices contributed to the low emergence of soybean seedlings in the farmer-managed plots. In addition, farmers sowed soybean seeds about 40–50 cm apart within rows resulting in a low population of soybean/ha compared with the researcher-managed plots, where soybean population was 200,000 plants ha^{-1}.

Planting depth has a positive or detrimental effect on soybean emergence and yield and 7.5 cm planting depth has been considered optimum (Stucky 1979). Soybean planted at a depth of 7.5 cm with closer inter-rows of 51 cm had a higher yield than when planted at 5 cm or below 7.5 cm with interspacing of 76 cm (Stucky 1979; Onwueme and Sinha 1991).

Farmers' soybean crop management did not include timely weeding. The first weeding was done in the researcher-managed plots at 3–4 WAP, but most farmers (about 90%) did not initiate their first weeding until 6–7 WAP. About 60% of the farmers weeded twice. No weeding was done earlier than 6 WAP while the second weeding (remoulding) was done at about 10–11 WAP. In extreme cases, some farmers did not weed but just remoulded the ridges. In the researcher-managed plots, the second weeding was done at 6–7 WAP, and the third weeding with remoulding of the ridges was done at 10 WAP. The weeding regimes of the researcher-managed plot did not give room for competition between the crops and weeds. In farmers' plots untimely weeding affected the performance of the crops. Because of the omission of one weeding before the ridges were remoulded, the farmer-managed plot was usually weedy. The pressure of weeds on the crops was severe because farmers' planting pattern gave a lot of spacing between crops. All these contributed in part to the poor performance of soybean in the farmer-managed plot compared with the researcher-managed plot. The longer weeds remain, the more competitive they are and the more difficult they become to control. Losses in yields of soybean can be predicted from weed densities (Akobundu and Poku 1987).

Data showed that Samsoy-2 did not have increased N fixation although it responded to rhizobial inoculation by forming more nodules than the improved soybean variety. Visual observation showed that the improved soybean variety had more vigorous growth; it covered more ground area than Samsoy-2 and this translated into better biomass production, N fixation, N and P uptake, and grain yield.

The improved soybean variety (TGx 1448-2E) is a late maturing soybean variety. It has been reported that levels of N_2 fixed are often insufficient to offset the N removed with the harvested soybean grain (Sisworo et al. 1990; Buresh and De Datta 1991). Sanginga et al. (1997) reported net gains of N in some other late maturing soybean lines. The N benefit of a grain legume to the soil depends on the N fixing capability of the legume, the native fertility of the soil (Sanginga et al. 1997), the effectiveness of the indigenous *Bradyrhizobia* sp., and methods of crop management. The quantification of the contribution by BNF to crop yield in the study is missing because the percentage of N_2 fixed contained in the roots and nodules is not accounted for. Earlier reports have shown that roots and stems accounted for about 11% of the total N for soybean (Buresh and De Datta 1991). This is low, compared to the percentage exported from the fields in soybean grain, chaff, and stems in the NGS of Nigeria. The farmers' cut-and-carry system of harvesting could further reduce the fraction of the 11% of total N.

Evaluation of N fixation by soybean under field conditions is difficult since the amount of symbiotically fixed N decreases with an increase in available N (Bhangoo and Albritton 1976). In other words, gaining an adequate understanding of the enhancement of BNF and the benefits thereof in farmers' fields is a complex exercise because of various interacting factors that influence the success of the BNF contribution to sustaining crop production. Principal among them is P, which has significant correlations with many of the parameters measured (Table 7).

Even though farmers in the tropics may not be able to apply the recommended rate of fertilizer because of high costs, and other associated problems (Honlonkou et al. 1999), adequate management of the crop residues especially from improved germplasm can improve their crop yield and sustain BNF. However, the use of chemical fertilizers, especially P fertilizer, to supplement the nutrient cycling from the crop residues for proper crop production cannot be completely ignored. Maintaining an optimum population of soybean could enhance the benefits of BNF by increased production of litter residues and root biomass. Since the weather is very harsh on the environment in the NGS, especially during the hot dry season, grain legumes such as soybean that produce a low shoot/root ratio with high BNF potentials might be of immense assistance in improving the soil N status. Despite these problems, farmers keep on practising legume/cereal rotation. It shows that, with a little encouragement and some practical demonstration, farmers may invest a little more to get closer to the required optimum population of soybean in the field to benefit their cereal crops.

Even though *Lablab*, a herbaceous legume covered the ground more rapidly, and also produced high biomass, numerous problems were observed apart from its low BNF potentials compared with the soybean varieties. It had a long vegetative growth period to fruiting; required pesticide spraying 2-3 times, and was prone to fungal attack. The requirement for these inputs may not make it attractive to farmers.

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