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Nitrogen contribution of some selected legumes to a sorghum based cropping system in the southern Guinea savanna of Nigeria

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Field experiments to assess the Nitrogen (N) contribution of legumes to a sorghum based cropping system in the southern Guinea savanna of Nigeria were carried out during the 2004 and 2005 cropping seasons. The studies were conducted at the experimental station of the National Cereals Research Institute, Badeggi, Nigeria (09° 451 N, 06° 71 E). The experimental design was a split plot randomised complete block replicated three times. Species of herbaceous legumes (Canavalia ensiformis, Mucuna cochinchinesis), and grain legumes (Cowpea - [Vigna unguiculata] varieties L25 and IR48) as well as a fallow control were assigned to the main plots. N levels (0, 20, 40 and 60 kg/ha) were assigned to the sub plots. Plant residues of *M. cochinchinesis* and *V. unguiculata* -IR48 had the highest percent of N content (1.55 and 1.54% respectively), while C. ensiformis had the lowest (0.93%). Only the two cowpea varieties had C:N ratio of less than 30:1. The lignin and polyphenols content of all the legumes species were less than the critical levels of 15 and 4% respectively. The soil textural classification is of sandy loam with low initial N and cation exchange capacity. Application of N fertilizer to soils incorporated with legumes resulted in significantly higher mineral N (NO_3 and NH_4-N) accumulation than those without fertilizer N in both soil and sorghum N. Generally, higher mineral N was recorded in legume residue incorporated treatments than the control. Application of up to 40 kg N/ha to sorghum grown after incorporation of legumes except canavalia resulted in significantly higher yield of sorghum than those after fallow control.

Key words: Nitrogen, Sorghum, canavalia, mucuna, cowpea.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most important world cereal, following wheat, maize, rice and barley. It is a staple food in the drier parts of tropical Africa, India and China. Africa accounted for 59% of the total world area devoted to sorghum production (VASAT, 2004). In Nigeria, sorghum is a widely produced and consumed staple in the savanna and it is an important cereal in terms of both the volume of production and total land devoted to the crop. It is also used as a feed for livestock and industrially in breweries. Sorghum is often planted either in rotation or intercropped with other crops such as maize, groundnut, cowpea and soyabean.

A major stress for sorghum production in the Savanna apart from rainfall is Nitrogen (N). This is because the

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soils are characteristically low in organic matter and subjected to very rapid soil nutrient depletion and degradation, thus constituting a rapid threat to agricultural productivity in this region. For instance, Onwueme and Sinha (1999) reported that, sorghum removes 102 kg N, 46 kg P_2O_5 and 104 kg K_2O from 1 ha of land to obtain a grain yield of 3 t/ha. The soils can hardly supply the quantities of nutrients required and yield levels decline rapidly once cropping commences.

Intensive land use and high yield on soils of low inherent fertility can be achieved only by raising the nutrient levels. Smallholder farmers can do this traditionally by bush fallow systems. However, the fallow length had been considerably reduced in many areas as a result of population pressure or scarcity of labour to clear the fallow land; this has led to decreased soil productivity . Access to inorganic fertilizer by small holder farmers is limited due to high cost of procurement (Osunde et al., 2004). Additionally, farming approaches based on sole use of organic fertilizers cannot provide all the required increment for agricultural productivity (Giller, 2002). It is, therefore logical that, efficient use of organic resources supplemented with mineral fertilizers may be an optimal strategy for smallholder farmers. Most studies, however, have included animal manures and crop residues as the organic additions while there has been relatively little research on the use of alternative higher quality organic resources, such as leguminous cover crops and tree species. Legumes can contribute N to cereal based systems when their above and below ground residues decompose to supply N to subsequent cereals.

However, in smallholder farming systems, legume crop residues have a high value to farmers as fodder and or fuel but their immediate value in maintaining soil fertility is often not perceived (Muhamman and Gungula, 2006). There is therefore, a critical need for research to quantify the role legume residues play in the maintenance of soil fertility in order to promote the most efficient management of these scarce resources.

This study was carried out with the following objectives:

(i) To quantify N contribution from incorporated legume residues to a subsequent sorghum plant
(ii) To evaluate different combinations of inorganic fertilizer and legume residues for optimal nutrient availability to sorghum plant.

MATERIALS AND METHODS

The experiment was conducted at the experimental station of National Cereals Research Institute, Badeggi (09° 45 ^{1}N; 06° 7^{1}E) during the 2004 and 2005 cropping seasons. Badeggi lies in southern Guinea savanna agro-ecological zone, characterized by a unimodal rainfall (1000 to 1200 mm) which lasts between May and October. The temperature range is between 26 and 32°C. Soils at Badeggi are Ultisols (USDA Soil Survey Staff, 1975), derived from Nupe Sand stone parent materials. They are of low fertility, indicating multiple deficiencies due to low mineral reserve and high leaching intensity and response well to fertilizer application (Enwezor et al., 1989). The field used for this experiment has been under continues cultivation of intercropping cereals with legumes and other arable crops for 5 to 8 years before the experiment was conducted.

Treatments and experimental design

The treatment consisted of plant residues of two herbaceous legumes, two grain legumes and a fallow plot. The herbaceous legumes were *Mucuna conchinensis* (mucuna) and *Canavalia ensiformis* (canavalia), while the grain legumes were *Vigna unguiculata* (cowpea) varieties L25 and IR48. These were used in combination with four rates of N fertilizer (0, 20, 40, and 60 kg/ha). The experimental design was a split plot fitted to a randomized complete block design. Legume residues and fallow were assigned to main plot. N rates were assigned to sub-plot. An equivalent of 60 kg N/ha from legume residues was incorporated to soil. This was determined after analyzing the N content of the various legumes.

Soil sampling and analysis

Prior to land preparation, twenty soil cores were randomly sampled at 0 to 20 cm and bulked to form a composite for determination of the initial soil fertility status. Soils were also sampled after the cropping of legumes. Routine physico-chemical analyses were carried out according to Anderson and Ingram (1993).

Land preparation

Initial land preparation was done by ploughing followed by two harrowing one week later. Each sub plot measured 4 × 3 m. Legumes were planted at a spacing of 25 × 25 cm. Single plants per stand were maintained for mucuna and canavalia species, while two cowpea plants were maintained per stand. Cowpea varieties were planted 3 weeks earlier than the herbaceous legumes to give room for harvesting of grains before biomass incorporation into soil. A starter dose of 20 kg N, 20 kg K_2O and 20 kg P_2O_5 per hectare was applied as NPK 15: 15: 15 at 2 weeks after planting (WAP).

Plant analysis

Prior to incorporation, sub-samples of legume residues were analysed for chemical composition as described by Anderson and Ingram (1993). Total Carbon of plant tissue was determined according to Amato (1983) and total N by the Kjeldahl method. Lignin and cellulose contents were analysed using the acid detergent fibre (ADF) method. Total exchangeable polyphenols was determined according to the Folin-Denis method. The protein-binding capacity of polyphenols was determined by applying the plant extracts to a chromatography paper and reacting with bovine serum albumin following the method of Dawra et al. (1988).

Sorghum establishment

Six weeks old healthy sorghum seedlings from a nursery bed were directly transplanted into the field 1 week after the incorporation of legume residues. Two plants of sorghum per stand at intra-row spacing of 50 cm were maintained on ridges spaced 100 cm apart. N application was done according to each treatment at two equal split doses (2 and 6 weeks after transplanting) using urea as N source. Fertilizer at 30 kg/ha each of P_2O_5 and K_2O were applied to

Table 1. Soil physical and chemical characteristics at the experimental site before and after cropping of legumes.

Soil properties	Before cropping	After cropping of legumes				
		Con	Can	Muc	L25	IR48
Physical properties						
Sand (%)	88.2	-	-	-	-	-
Silt (%)	9.3	-	-	-	-	-
Clay (%)	2.5	-	-	-	-	-
Textural class	Sandy loam	-	-	-	-	-
Chemical properties						
pH in H_2O	5.8	5.4	5.0	5.4	5.5	5,3
Organic C (%)	1.01	0.85	0.85	0.84	0.93	0.75
Organic matter (%)	1.74	1.46	1.46	1.44	1.60	1.29
Total N (%)	0.07	0.146	0.125	0.05	0.07	0.09
Available P (µg/g)	17.81	25.72		22.3	20.1	27.36
Exchangeable acidity (cmol/kg)	0.14	-	22.63	2	1	-
Exchangeable K (cmol/kg)	0.10	-	-	-	-	-
Exchangeable Ca (cmol/kg)	1.20	-	-	-	-	-
Exchangeable Mg (cmol/kg)	2.25	-		-	-	

- = Data not available, Con = Control (fallow), *Can = Canavalia ensiformis, Muc = Mucuna cochichinesis,* L25 = Cowpea (var. L25), IR48 = Cowpea (var. IR48).

all the plots using single super phosphate and muriate of potash respectively at 2 weeks after transplanting.

Mineral N in soil and sorghum plant

Mineral N (NH_4+N and NO_3-N) was monitored during the plant growth by randomly sampling three sorghum plants per plot from two inner rows at 3, 6, and 9 weeks after incorporation (WAI). At each sampling period, a composite of three soil sub samples per plot was taken at 0 to 20 cm depths from the centre of the ridge, and in the furrows in all plots to measure mineral N in the soil. Whole plants were sampled during the vegetative stage, while six-leaf samples were taken when approximately 50% of the plants had headed. Sampled plant materials were oven dried at 65°C for 72 h and milled for N determination.

Sorghum grain yield

Sorghum grain yield was determined by harvesting the two inner rows of sorghum. The panicles were cut and shelled and the grains sun-dried to approximately 14% moisture content. The grains were then weighed and yield per hectare basis was determined.

Statistical analysis

All data were subjected to analysis of variance (ANOVA), using the MSTAT package. Means separation was done according to LSD.

RESULTS

Soil characteristics

The initial soil physical and chemical characteristics before and after cropping of legumes are shown in Table 1. The soil textural class was a sandy loam with pH of 5.8, low in organic carbon (1.01%) and total N (0.07%). Available P was moderate, while exchangeable cations content was generally low. After cropping of legumes, the pH, organic carbon and organic matter levels were slightly reduced, while available P was generally increased. Total N was increased in all plots except where mucuna was cropped.

Biomass production and yield of grain legumes

Cowpea L25 had grain yield of about 1 t/ha in 2004 and 0.8 t/ha in 2005, while variety IR48 yielded about 0.8 and 0.9 t/ha, respectively (Table 2). In both years, *M. cochinchinensis* produced the largest biomass (about 3 t/ha), followed by *C. ensiformis* (2.3-3 t/ha), the two cowpea varieties produced similar biomass in both years. Biomass yield was generally higher in all the legumes in 2004 than in 2005.

Legume plant residues characteristics

The chemical composition of plant residues at incorporation is shown in Table 3. *M. cochinchinensis* residue had the highest percentage of Carbon content, while the 2 cowpea varieties had the lowest. *M. cochinchinensis* and *V. unguiculata* var. IR48 had N content of more than 1.5%, while *C. ensiformis* and *V. unguiculata* L25 had values lower than 1.5%. However, only the 2 cowpea varieties had residue Carbon to

Table 2. Mean grain yield and biomass production (dry matter) of legumes used as short fallow rotation with sorghum.

Legumes	Grain yield (t/ha) 2004 2005	Biomass production (t/ha) 2004 2005
Cowpea (var. L25)	1,02 0.82	2,80 2.29
Cowpea (var. IR48)	0.83 0.87	2,63 2.40
Canavalia ensiformis	-	3,11 2.29
Mucuna cochinchinesis	-	3,30 3.15

Table 3. Chemical composition of legume residues incorporated.

Legume species	Chemical composition								
	Carbon (%)	Total N %)	Lignin (%)	Polyphenol (%)	Cellulose (%)	C:N	PP:N	L:N	(PP + L):N
C. Ensiformis	37	0.93	0.03	1.96	0.24	37.76	2.11	0.03	2.14
M. cochinchinesis 77	77	1.55	0.81	1.99	0.35	49.68	1.28	0.52	1.81
Cowpea (var. L25)	33	1.28	0.06	0.91	0.48	25.78	0.71	0.05	0.76
Cowpea (var. IR48)	26	1.54	0.02	0.89	0.68	16.88	0.58	0.01	0.59

N = Nitrogen, C = Carbon, L = Lignin, PP = Polyphenol.

Nitrogen ratio of less than 30:1. Lignin content, was generally low (0.02 to 0.6%), except in residues of mucuna which had 0.81% content. Canavalia and mucuna had twice the polyphenol content of the 2 cowpea varieties (0.89 to 0.91%), while the cowpea varieties had higher cellulose content (0.48 to 0.68%) than canavalia or mucuna (0.24 to 0.35%). Similarly, the herbaceous legumes had much higher polyphenol-nitrogen and polyphenol + lignin : nitrogen ratio than the cowpea varieties.

Effect of legume residue incorporation and N-fertilizer application on Nitrate N in soil cropped to sorghum

At 3 WAI of legume residues, there was significant interaction between legume residue incorporation and N fertilizer application on $N0_3$-N content of soil cropped to sorghum in 2004 and 2005 (Figures 1 and 2). In 2004, incorporation of canavalia residue resulted in significantly higher $N0_3$-N than other treatment with application of 0 to 40 kgN/ha. Application of 20 and 60 kg N/ha resulted in significantly higher $N0_3$-N in legume residue incorporated plots than the control. In 2005, incorporation of legume residues did not significantly influence $N0_3$ N content in plots without N fertilizer application. However, there was a significant increase of $N0_3$-N, when application of up to 40 kgN/ha was applied to legume incorporated plots.Similarly, at 6 WAI of legume residues, significant interaction between the residue incorporation and fertilizer N application in both years was recorded (Figures 3 and 4). In 2004, incorporation of canavalia resulted in significantly higher $N0_3$-N when 20 and 40 kg N/ha was applied to sorghum field. Generally, legume incorporated plots resulted in significantly higher $N0_3$-N than the control. In 2005, application of 40 and 60 kgN/ha resulted in significantly higher $N0_3$-N in sorghum field than other treatments except those incorporated with cowpea variety L25 residue at 20 kg/ha.

At 9WAI, the interaction of legume residue incorporation and fertilizer N application on soil $N0_3$-N was significant only in 2005 (Figure 5). Increasing fertilizer N application of up to 40 kg/ha significantly increased $N0_3$-N content of legume incorporated field. However, there was no significant difference of $N0_3$-N content in legume incorporated soil with application of 0 and 60 kg N/ha.

Effect of legume residue incorporation and N-fertilizer application on Ammonium N in soil cropped to sorghum

At 3 WAI, the interaction between legume incorporation and fertilizer N application was significant in both years of experimentation (Figures 6 and 7). In 2004, incorporating mucuna and cowpea variety IR48 resulted in significant increase of soil NH_4-N with increasing fertilizer N application. However, plots incorporated with legume residues accumulated higher NH_4-N than the control when 20 and 60 kg N/ha was applied. In 2005, the interaction was inconsistent but the highest NH_4-N was obtained when mucuna residue was incorporated with application of 40 kgN/ha.

Similarly in 6 WAI, the interaction between legume

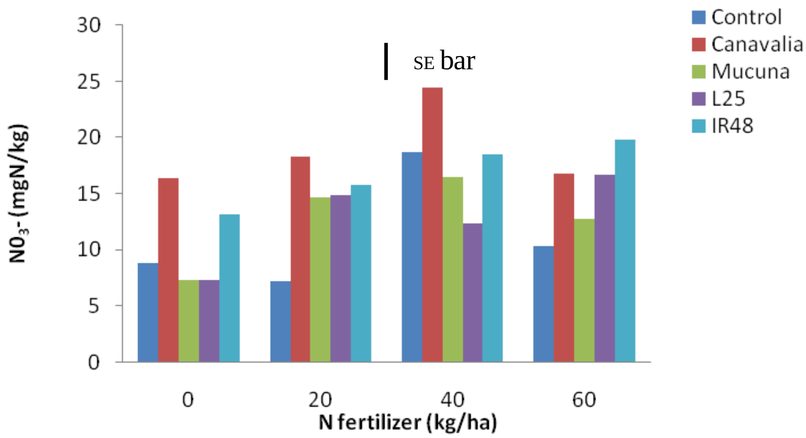

Figure 1. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 3 WAI in 2004.

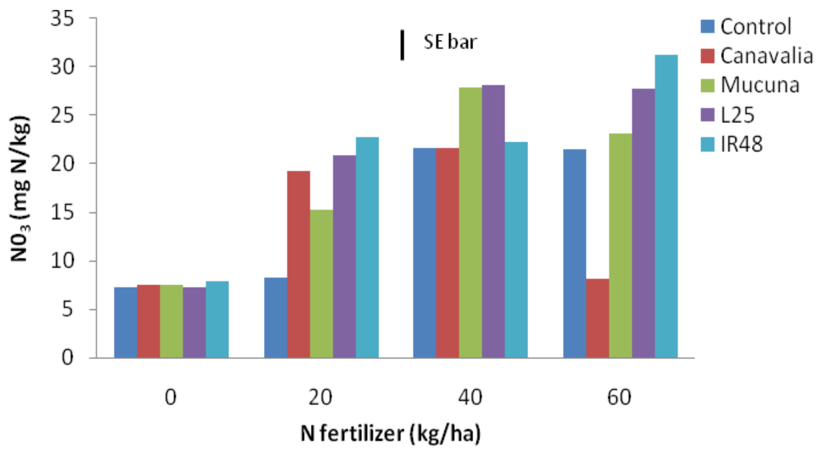

Figure 2. NO_3 Nin soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 3 WAI in 2005 cropping season.

incorporation and fertilizer N application was significant in both years of experimentation (Figures 8 and 9). Incorporation of legume residues resulted in significant increase of NH_4-N with increasing N application in 2004. In 2005, the interaction was inconsistent but application of 40 and 60 kgN/ha produced significantly higher NH_4 -N in legume incorporated plots than the control.

Effect of legume residue incorporation and N fertilizer application on total N content in sorghum plant

The main effect of legume residue incorporation on the percentage of N content of sorghum plants at 6 and 9 WAI and fertilizer N at 3 and 9 WAI was significant in 2004 (Table 4). Incorporation of residues from cowpea (var. IR48) and herbaceous legumes to sorghum plots resulted in significantly higher N content in sorghum than that of control plot at 6 WAI. While at 9 WAI, sorghum plot incorporated with residues from canavalia resulted in significantly higher N content than the rest treatments. N fertilizer application however require 40 Kg N/ha at 3 and 9 WAI to significantly produced higher N in sorghum plants than the lower rates of N application. The interaction between legume residue incorporation and N fertilizer application was significant only at 9 WAI.

The main effect of legume residues incorporation and fertilizer N on the percentage of N content of sorghum at 6 and 9 WAI in 2005 was significant (Table 5). At 6 WAI, sorghum plot incorporated with residues from cowpea (var. IR48) and mucuna resulted in significantly higher N content in sorghum than the control plot. In contrast, at 9 WAI, sorghum plot left fallow accumulated more N than those incorporated with legumes. Significant higher N content was obtained when sorghum was applied 60 kg N/ha at both 6 and 9 WAI. The interaction effect of incorporating legume residue and fertilizer N application was significant only at 3 and 6 WAI.

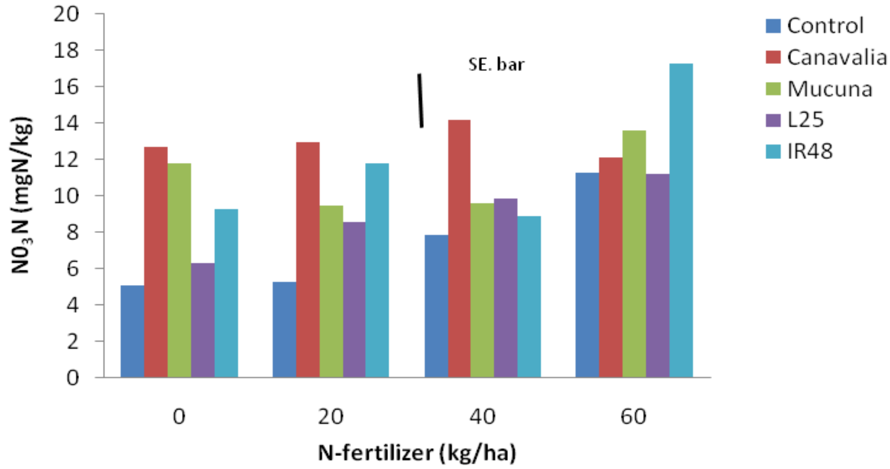

Figure 3. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 6 WAI in 2004.

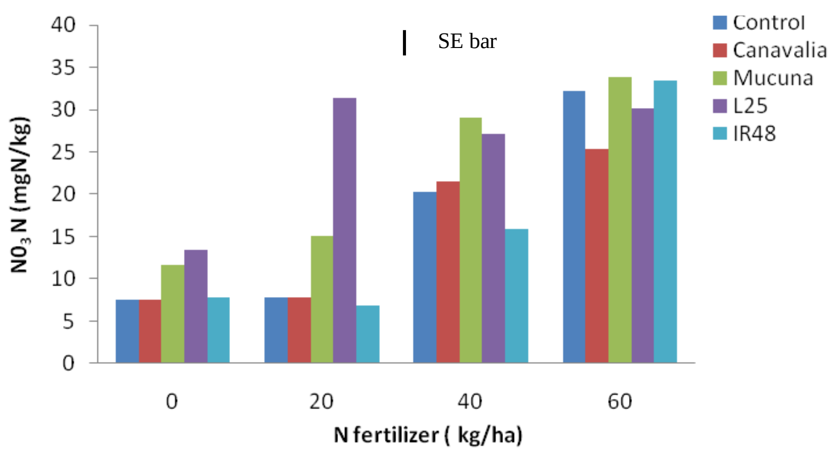

Figure 4. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 6 WAI in 2005.

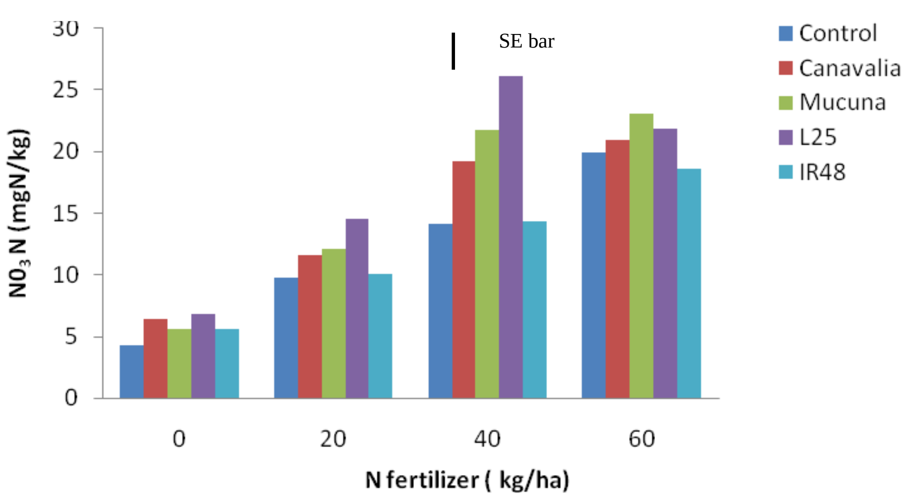

Figure 5. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 9 WAI in 2005.

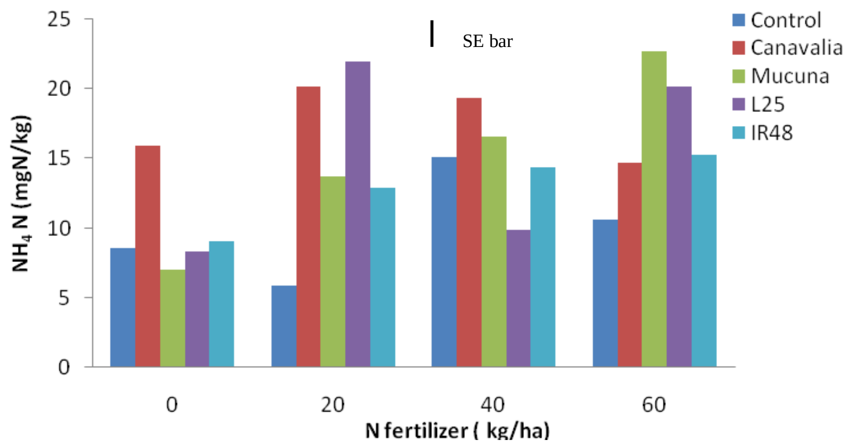

Figure 6. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 3 WAI in 2004.

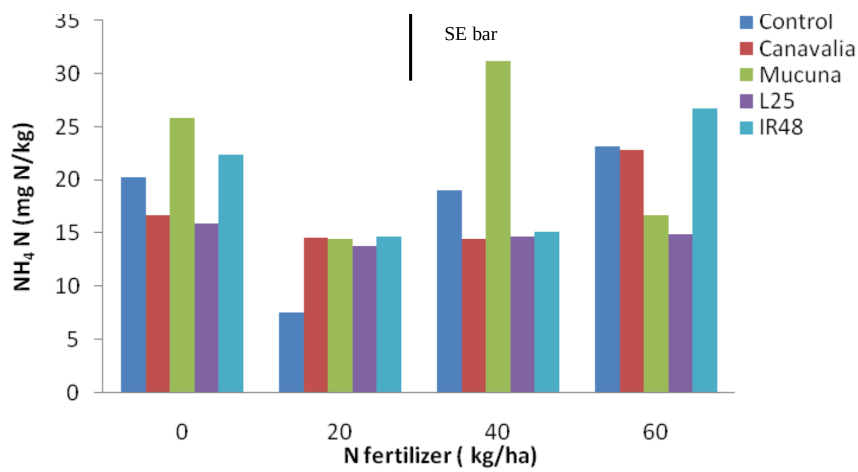

Figure 7. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 3 WAI in 2005.

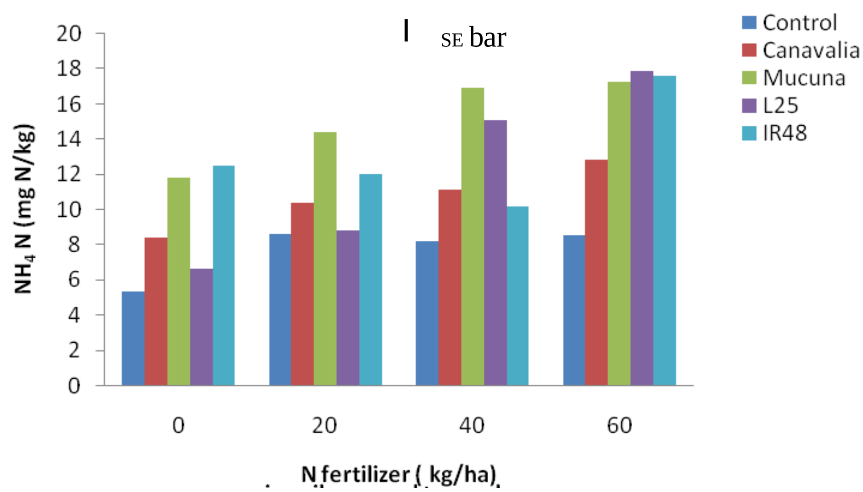

Figure 8. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 6 WAI in 2004.

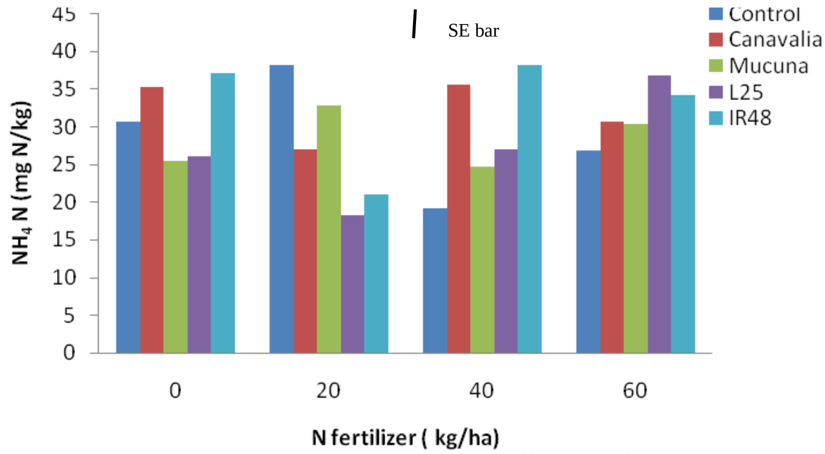

Figure 9. NO_3 N in soil cropped to Sorghum as affected by legume residue incorporation and N fertilizer application at 6 WAI in 2005.

Table 4. Effect of legume residue incorporation and fertilizer N application on nitrogen content of sorghum plant during the 2004 cropping season.

Treatment	Total N – content (%)		
	3 WAI	6 WAI	9 WAI
Legumes(L)			
Control (fallow)	1.45[a]	1.68[c]	0.41[bc]
C. ensiformis	1.27[a]	2.02[ab]	0.65[a]
M. cochichinesis	1.41[a]	1.90[abc]	047[b]
Cowpea (var. L25)	1.49[a]	1.84[bc]	0.27[c]
Cowpea (var. IR48)	1.48[a]	2.11[a]	0.38[bc]
SE±	0.240	0.138	0.113
Nitrogen (N) (Kg/ha)			
0	1.25[b]	1.83[a]	0.38[b]
20	1.36[b]	1.92[a]	0.33[b]
40	1.61[a]	1.91[a]	0.40a[b]
60	1.44[b]	1.98[a]	0.63[a]
SE±	0.159	0.098	0.240
Interaction (L × N)	NS	NS	* *

*Means followed by the same letter in both column and row are not significantly different at 5% level of probability according to Duncan's multiple range test, NS – Not significant, WAI is week after legume residue Incorporation.

legume incorporation showed that, sorghum grown after incorporation of canavalia did not significantly increase sorghum yield (Table 6). However, in 2005, legume incorporation and fertilizer N application had significant effect on sorghum grain yield. Yield of sorghum grown after incorporation of cowpea varieties were significantly increased. Fertilizer N application of up to 40 Kg N/ha significantly increase sorghum grain yield. The interaction between legumes residue and fertilizer N application on grain yield in 2005 was significant (Table 7). At 0 kg N/ha, grain yield obtained from sorghum grown after *mucuna* and cowpea (Var. IR48) was significantly higher than that of the other legumes and the fallow control. At 20 kg N/ha, grain yields obtained from sorghum grown after herbaceous legumes were similar to that of the control, but significantly lower than that of sorghum after the cowpeas. At 40 kg N/ha, growing of sorghum after legumes with the exception of *canavalia* had significantly higher grain yield than the control. In contrast, at 60 kg N/ha, grain yield obtained from sorghum grown after fallow control and *canavalia* were similar but significantly higher than that of sorghum after *mucuna* and cowpea

Table 5. Effect of legume residue incorporation and fertilizer N application on nitrogen content in sorghum during the 2005 cropping season.

Treatment	N content (%)		
	3 WAI	6 WAI	9 WAI
Legumes(L)			
Control (fallow)	1.64[a]	0.87[b]	0.73[a]
C. ensiformis	1.54[a]	0.24[c]	0.41[b]
M. cochichinesis	1.54[a]	1.81[a]	0.33[bc]
Cowpea (var. L25)	1.92[a]	0.79[b]	0.22[c]
Cowpea (var. IR48)	1.90[a]	1.92[a]	0.31[a]
SE±	0.44[0]	0.18[6]	0.125
Nitrogen(N) (kg/ha)	1.78[a]	1.07[b]	0.30[b]
0	1.65[a]	0.78[c]	0.44[ab]
20	1.77[a]	1.12[b]	0.35[ab]
40	1.62[a]	1.53[a]	0.52[a]
60	0.243	0.218	0.172
SE±	* *	* *	NS
Interaction (Lx N)			

*Means followed by the same letter in a column of each factor are not significantly different at 5% level of probability according to Duncan's multiple range test, ** Significant at 1% level of probability NS: Not significant, WAI: Week after legume residue incorporation.

Table 6. Effect of incorporating legume residues and fertilizer N on the grain yield of sorghum.

Treatment	Grain yield (kg/ha)	
	2004	2005
Legumes (L)		
Control (fallow)	1018.5	573.2[c]
Canavalia ensiformis	899.9	567.9[c]
Mucuna cochinchinesis	1243.4	625.2[bc]
Cowpea (var.L25)	1171.8	725.8[ab]
Cowpea (var. IR48)	1137.2	810.7[a]
LSD (P = 0.05)	NS	114.40
Nitrogen (N)		
0	1011.2	597.3[b]
20	944.5	622.7[ab]
40	1131.4	709.1[a]
60	1289.6	713.1[a]
LSD (P = 0.05)	NS	98.47
Interaction (LxN)	NS	**

Means followed by the same letter in a column of each factor are not significantly different at 5% level of probability using LSD, ** Significant at 1% level of probability, NS = Not significant.

beginning of the experiment. The soil pH, organic carbon and organic matter were altered. The decrease in these soil properties especially the organic matter may be due to microbial activities around the soil rhizosphere. The organic components are used as substrate by the microbes to generate energy for the N fixation. This also explains the increase in soil N after the legumes and fallow. The increase in available P may be attributed to the action of the roots of these plant species (Varhadler et al., 2003).

Table 7. Interaction of legume residue (L) incorporation and nitrogen (N) fertilizer on grain yield of sorghum in 2005.

Treatment	0	20	40	60
Control (fallow)	341.7^{h}	580.3^{c-h}	483.3^{e-h}	887.3^{ab}
C. ensiformis	408.3^{gh}	377.7^{gh}	605.3^{c-g}	880.3^{ab}
M. cochichinesis	789.0^{a-d}	419.7^{gh}	817.0^{abc}	475.0^{fgh}
Cowpea (var. L25)	547.3^{d-h}	1002.7^{a}	736.0^{b-e}	617.0^{c-g}
Cowpea (var. IR48)	900.0^{ab}	733.3^{b-e}	903.7^{ab}	705.7^{b-f}
LSD (P = 0.05)		202.20		

Means followed by the same letter in both row and column of each factor are not significantly different at 5% level of probability using LSD.

Biomass production and chemical composition of the legumes

The aboveground biomass production of the herbaceous legumes (*mucuna* and *canavalia*) was larger than that of the grain legumes despite the fact that the grain legumes were planted 3 weeks before the herbaceous legumes. *Mucuna* and *canavalia* growth were more vigorous and both plant species cover the ground within a short period of time. This result was similar to earlier report by Chibudu (1998), who observed the least biomass production in cowpea compared to Velvet Bean and Sunhemp in different sites of Zimbabwe. Equally the C: N ratio in the case of *mucuna* and *canavalia* were wider than that of the grain legumes. The higher ratio was due to the large carbon content of herbaceous legumes. The percentage of N of *mucuna* was high enough as green manure crop but due to higher carbon content, the C: N ratio was increased and made it not suitable as green manure crop.

Mineral N in soil and sorghum plant

Generally, the mineral N (NO_3 and NH_4-N) in soil and total N in sorghum as influenced by legume residue incorporation and N fertilizer application indicated significantly higher N accumulation in legume incorporated treatments than the control. Likewise, application of N fertilizer significantly increased soil mineral N content. The increase due to legume incorporation is an indication of positive N contribution by legume species. Similar findings have been reported by Egbe and Ali (2010), who reported an increase in N yield of maize and soil N when incorporated with food legumes in moist savanna of Nigeria. Differences observed in mineral N accumulation of various legume species used in the experiment could be attributed to the quality and quantity of legume residue applied as indicated in Tables 2 and 3. Similar findings were reported by Tanimu et al. (2007) on maize plant. The interaction of legume residue incorporation and N fertilizer application signifies that, there were synergistic effects that exceed the effect of applying a single kind of amendment with the same level of nutrients. Higher mineral N accumulation resulting from N fertilizer application to soil in which legume residue were incorporated compared to soils without N application is an indication that, a starter N is required to reduce the immobilization capacities of legumes. This mean that, at the initial stage on where the initial soil N is low as in the case of this experimental site, some amount of N fertilizer is needed to enhance mineralization of legume N. This agrees with Kumwenda et al. (1998), who reported an improvement in N release in soil when inorganic and organic residues were combined.

Sorghum grain yield

The main effect of incorporating legumes on sorghum grain yield indicated that, higher yield of sorghum could be obtained from incorporating cowpea varieties than other legumes. Incorporation of herbaceous legumes resulted in similar grain yield with that of sorghum following fallow control treatments. The reason for the lower yield of sorghum plants grown after herbaceous legumes may be attributed to the fact that these legumes were planted 3 weeks after the cowpeas and may not exhibit its full potential for N-fixation. The lower N content especially by the *C. ensiformis* is an indication that, there was not sufficient N fixed by the herbaceous legumes to make any sufficient yield difference on the subsequent sorghum plants grown after it. Similarly, the C: N ratio of *canavalia* and *mucuna* at the time of incorporation were higher than that of cowpeas. Although the N content was higher but due to higher C content, the C: N ratio appeared higher in herbaceous legumes. This may result into N being tied up and thereby making it unavailable to sorghum plants initially. Earlier reports indicated that organic materials added to soils with C: N ratio greater then 30:1 with 1.5% or less N will result in the initial N immobilization or tie-up (Cueto-Wong et al. 2001, Rosales et al., 2002).

Incorporation of legume residues and application of N-fertilizer resulted in significant interaction in sorghum yield in 2005. Generally, growing of sorghum after all the legumes except canavalia despite application of N fertilizer resulted in significantly higher grain yield of sorghum. This signifies positive contribution of legumes to subsequent sorghum grown after it. Kumwenda et al. (1998) and Tanimu et al. (2007) reported similar results on maize grown in rotation with legumes and N-fertilizer application. This positive contribution may be due to the higher N-use efficiency in terms of agronomic efficiency of applied N to sorghum when grown after legumes except canavalia. The low yield experienced with sorghum grown after canavalia is because of its woody nature. It may require more than a single cropping season for decomposition to fully occur. This made it contribute less N to the cropping system within a single season. Similar results were reported by Asibou and Osei-Bonsu (1999) on maize in forest-savanna transition zone of Ghana. Application of 40 kg N/ha appeared optimum for sorghum grown after legumes. This is because, there was no yield difference recorded when compared with the application of 60 kg N/ha to sorghum grown after fallow.

Conclusion

The results obtained indicated that, contribution from legumes alone could not meet up with the requirement of N for sorghum production. This is in particular to soils of low inherent fertility as in the experimental area. However, a supplementary application of 40 kg N/ha may be necessary for optimum yield of sorghum plant.

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