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Full Length Research Paper

Evaluation of *Sesbania sesban* L. (Merr) and *Mimosa invisa* L. (*Fabaceae*) as sources of nitrogen in irrigated rice on the Vertisols of the Accra Plains of Ghana

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***Sesbania sesban* L. (Merr) and *Mimosa invisa* L. (Fabaceae) were grown in rotation with lowland rice (var. KRC Baika). The experiments were conducted on three farmers' fields at the Kpong Irrigation Project (KIP) sites at Akuse (lat 6° 06' N, long 0° 07' E) and Asutsuare (lat 6° 04' N, long 0° 12' E). In Farm 1, *S. sesban* and *M. invisa* were incorporated three times, in rotation with rice, over a period of 3 years, and in Farm 2, the green manures were incorporated once and rice planted within the year. The treatments also included a control (no fertilization), recommended inorganic nitrogen (N) that is, 90 kg N ha^{-1}, *S. sesban* + 50% N and *S. sesban* + 75% N. Total dry matter and grain (paddy) yield of rice were higher in Farm 1 than Farm 2. Nitrogen contents of the *S. sesban* and *M. invisa* plants were 2.5 and 2.4% respectively. Total N of *S. sesban* ranged from 239 to 259 kg ha^{-1} and that of *M. invisa* ranged from 152 to 186 kg ha^{-1}. The single incorporation of the green manures in Farm 2 did not have a significant impact on rice growth and grain yield, while in Farm 1, *S. sesban* and *M. invisa* gave comparable yields with those under the recommended inorganic N. Grain yields under *S. sesban* + 50% N (T2) and mimosa (T4) were comparable to that under the recommended inorganic fertilizer (T5) and both were significantly higher than the control (T6); grain yields were 5.8, 5.8, 6.5 and 3.9 t ha^{-1}, in T2, T4, T5 and T6, respectively. In spite of the good performance of *M. invisa* it required upland conditions to grow and establish. The application of 50% N requirement, in addition to *S. sesban* incorporation, enhanced rice growth and yield, and resulted in 20.7% savings on nitrogen fertilizer use.**

Key words: Green manure, lowland rice, inorganic nitrogen, rotation, incorporation, total dry weight, grain yield.

INTRODUCTION

The Kpong Irrigation Project is on the Vertisols of the Accra Plains, which is within the Coastal Savanna of Ghana (Brammer, 1962). The Coastal Savanna is bordered in the South by the Gulf of Guinea, from Winneba in the West (lat 5° 20′ N, long 0° 37′ W), along the coast, through Accra (lat 5° 33′ N, long 0° 15' W) to Keta in the East (lat 5° 55′ N, long 0° 59′ E), The northern boundary is along the Akwapim-Togo mountain range that goes through Aburi (lat 5° 51′ N, long 0° 11′ W) and Kpong (lat 6° 09′ N, long 0° 04′ E).

Between 1986 and 1996, rice yields on newly cultivated land at the Kpong Irrigation Project sites at Akuse and Asutsuare, where the current study was conducted, have been observed to decline from an average of about 5 to 2.5 t ha^{-1} (Table 1). That was in spite of applying the recommended quantities of inorganic fertilizer. The decline in rice yield in the project area could be attributed to low inherent soil fertility, which is partly due to low soil organic matter levels. The soils of the Accra Plains are low in organic matter (OM) as a result of low annual

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Table 1. Trends in rice production on the vertisols at Kpong Farms (1986 to 1996).

Year	Area cultivated (ha)	Production (t)	Yield (t ha^{-1})
1986	130	654	5.0
1987	133	587	4.4
1988	142	498	3.5
1989	139	558	4.0
1990	119	294	2.5
1991	116	337	2.9
1992	182	767	4.2
1993	132	423	3.2
1994	100	378	3.8
1995	93	390	4.2
1996	95	423	4.5
Average			3.8

Courtesy, Kpong Farms Ltd, VRA, Akuse.

rainfall (700 to 1100 mm) and the annual bush fires, which reduce biomass production (Nyalemegbe et al., 2010).

The decline of rice grain yield was similar to that reported by Cassman et al. (1995), in which the yield of short duration high yielding rice varieties, under irrigation for 36 years, declined despite the best management practices. Cassman et al. (1995, 1997) identified possible causes of yield decline as reduction in genetic yield potential of more recently released varieties, climate change, long-term change in the chemistry of submerged soil that affect nutrient supply, reduction in soil N supply due to change in soil organic matter quality, change in soil and flood water microbiology, deficiencies or toxicities of nutrients other than N (such as zinc and boron), reduction of N uptake rates due to root-feeding nematodes, increasing soil bulk density and increasing insect and disease pressure due to continuous cropping.

In spite of the low inherent fertility of soil, farmers do not use adequate levels of inorganic fertilizers due to high cost. Moreover, fertilizers applied under tropical conditions, especially N fertilizers, are subject to losses e.g. through volatilization and leaching. Studies have shown that the growing of cover crops offer the best practical means of providing organic matter needed to improve the tilth, fertility and productivity of soils (Anane-Sakyi, 1995). Dreyfus and Dommergue (1980) found that *S. rostrata* showed fast growth and high N accumulation of 250 kg N ha^{-1} in 52 days. The beneficial effect of the legume crop depends on its N-fixing capacity and the biomass yield (Balasubramanian and Sekayange, 1992), and the N yield also depends on the formation of effective nodules (Giller and Wilson, 1991). The growing of green manure plants (e.g. *S. sesban* and *M. invisa*), in rotation with food crops, could bring about substantial increases in soil organic carbon content and crop available nitrogen.

In order to determine the ability of green manures to improve rice yields and the economics of using such organic fertilizers in combination with mineral fertilizers, experiments were conducted at the Kpong Irrigation Project sites at Akuse and Asutuare, where rice yields had been declining; *S. sesban* and *M. invisa* were planted in rotation with lowland rice.

MATERIALS AND METHODS

Experiments were conducted on half acre plots on three farms at the Kpong Irrigation Project sites at Akuse (lat 6° 06' N and long 0° 07' E) and Asutsuare (lat 6° 04' N and long 0° 12' E), but work on two farms were successfully concluded and presented in this paper. At the beginning of the rainy season (in March), the locally growing *S. sesban* and *M. invisa* were drilled in designated basins (8 m × 6 m), with inter-row spacing of 60 cm, planting rates of 60 kg ha^{-1} and to a depth of 2 cm (Nyalemegbe et al., 2011a). Both *S. sesban* and *M. invisa* required upland soil condition to germinate. Thereafter, *S. sesban* survived under both moist and waterlogged conditions but *M. invisa* did not survive under the waterlogged condition and needed a drier condition to establish.

After 8 to 10 weeks, when the *S. sesban* and *M. invisa* plants were at the flowering stage, two 1 m × 1 m samples were randomly taken for measurement of biomass of the two leguminous plants. Sub-samples of 1 kg fresh weight were taken and dried in an oven at 75°C for 48 h for chemical analysis. The plants were chopped up with machete, the residues incorporated into the soil with hoe and the plots moistened to enable decomposition. Two weeks after incorporating the plant residues, the basins were flooded to about 2 cm depth and four week old rice seedlings (Cv. KRC-Baika), from a nearby nursery, were transplanted, two per hill and at a spacing of 20 cm × 20 cm.

In Farm 1, the leguminous plant residues were incorporated thrice, in rotation with rice, over a period of three years and in Farm 2, there was one incorporation and rice planted within the year. The evaluation is based on the last crop of rice, after the three-year rotation and the one year rotation with *S. sesban* and *M. invisa*. The treatments were as follows: *S. sesban* only (T1), *S. sesban* + 15-15-15 NPK basal fertilizer application to give 50% of the recommended inorganic nitrogen (N) and all the phosphorus (P_2O_5) and potassium (K_2O) requirement (that is, 45 kg N ha^{-1}, 45 kg P_2O_5 ha^{-1} and 45 kg K_2O ha^{-1}, using 300 kg 15-15-15 NPK fertilizer per hectare (T2), *S. sesban* + 15-15-15 NPK basal fertilizer + ½ the remaining N requirement as top dressing, using 107 kg sulphate of

Table 2. Nutrient content of *S. sesban* and *M. invisa.*

Plants	N (%)	P (%)	K (%)
S. sesban	2.5	0.27	2.3
M. invisa	2.4	0.21	1.9

Table 3. Growth and nodulation of *S. sesban* and *M. invisa* plants.

Farm 1	TDW (t ha^{-1})	Nodules $plant^{-1}$	Total N (kg ha^{-1})	Farm 2	TDW (t ha^{-1})	Nodules ($plant^{-1}$)	Total N (kg ha^{-1})
T1	10.8	62	269	T1	8.9	58	224
T2	9.4	48	236	T2	10.8	75	271
T3	10.9	58	271	T3	8.9	67	222
*Av	10.4	56	259	*Av	9.5	67	239
+T4	7.8	26	186	+T4	6.4	69	152

*Av; Average values for *S. sesban.* +T4; Values for *M. invisa.*

Table 4. Nitrogen from incorporated *S. sesban* and *M. invisa*, and from inorganic fertilizer application.

Farm 1-Plant materials incorporated over three year period (three times)				Farm 2-Plant materials incorporated over one year period (once)			
Farm 1	N from organic source (kg ha^{-1})	N from inorganic fertilizer (kg ha^{-1})	Organic/ inorganic N (kg ha^{-1})	Farm 2	N from organic source (kg ha^{-1})	N from inorganic fertilizer (kg ha^{-1})	Organic/ inorganic N (kg ha^{-1})
T1	269		269	T1	224		224
T2	236	45	281	T2	271	45	316
T3	271	67.5	339	T3	222	67.5	290
**Av	259			**Av	239		
++T4	186		186	++T4	152		152
T5		90	90	T5		90	90
T6				T6			

** Av; Average total N of *S. sesban.* ++T4; Total N of *M. invisa.*

ammonia fertilizer (21% N) per hectare (T3), *M. invisa* only (T4), Recommended inorganic fertilizer application of 90 kg N ha^{-1}, 45 kg P_2O_5 ha^{-1} and 45 kg K_2O ha^{-1} - applied as 300 kg 15-15-15 NPK fertilizer and 214 kg sulphate of ammonia fertilizer per hectare (T5), and no fertilization (Control, T6).

Data collected included: a) Leguminous plant biomass (stem plus leaves), number of nodules and plant analyses to determine the nitrogen, phosphorus and potassium contents, at time of flowering (that is, after 6 to 8 weeks of growth); b) Growth of rice plant at flowering - plant height, tillers per hill, spikelets per panicle and total dry matter; c) Grain yield of rice crop - paddy yield; d) Soil analyses before and after field experiments - pH, nitrogen, phosphorus, potassium and organic carbon (OC) contents.

Soils pH (1:2.5, soil:water) was measured using the method indicated by McLean (1982); organic carbon was determined by the Walkley and Black wet digestion method (Nelson and Sommers, 1982); nitrogen was determined by the micro-Kjedahl digestion method (Bremner and Mulvanay, 1982); available phosphorus and potassium were extracted by Bray and Kurtz-1 method; phosphorus was determined colorimetrically and potassium by flame photometry. The statistical analysis of data was by analysis of variance (ANOVA), using the Genstat analytical software.

RESULTS

Growth, nodulation and total N of *S. sesban* and *M. invisa* plants

The N content of *S. sesban* was not much different from that of mimosa but the phosphorus and potassium contents were lower in mimosa than *S. sesban* (Table 2). The *S. sesban* plant had greater TDW (stem and leaf dry weights) than mimosa (Table 3). In both farms, the number of nodules and the total N in the *S. sesban* plants were higher than those in mimosa (Tables 3 and 4).

Soil pH, organic carbon and nitrogen contents of soil after incorporation of sesbania and mimosa

The clay, silt and sand fractions (at 0 to 15 cm depth) of the initial soil sample were: 43, 20 and 36%, respectively;

Table 5. pH, organic carbon and nitrogen contents of soil after incorporation of *S. sesban* and *M. invisa* (soil depth: 0 to 20 cm).

Farm 1-Plant materials incorporated over three year period (three times)				Farm 2-Plant materials incorporated over one year period (once)			
	pH	OC (%)	N (%)		pH	OC (%)	N (%)
T1	4.9	2.6	0.13	T1	5.4	1.3	0.06
T2	5.0	2.5	0.11	T2	5.4	1.4	0.07
T3	5.0	2.7	0.12	T3	5.5	1.4	0.06
T4	5.0	2.7	0.11	T4	5.5	1.3	0.06
T5	5.0	2.4	0.12	T5	5.4	1.4	0.07
T6	5.1	2.6	0.12	T6	5.4	1.3	0.06
LSD ($p \leq 0.05$)	ns	0.2	ns	LSD ($p \leq 0.05$)	ns	ns	ns

Table 6. Rice growth, grain yield and yield parameters in Farm 1.

Farm 1	Organic/inorganic N *(kg ha^{-1})*	Plant height *(cm)*	Tillers *(hill^{-1})*	Spikelets/ panicle	Total dry matter *(t ha^{-1})*	Grain yield *(t ha^{-1})*
T1	269	78.1	11	7	10.8	5.3
T2	281	84.1	11	8	7. 1	5.8
T3	339	75.6	12	7	9.9	5.4
T4	186	76.7	10	7	7.3	5.8
T5	90	86.0	12	7	8.8	6.5
T6		74.8	10	7	7.9	3.9
LSD ($p \leq 0.05$)		6.4	ns	ns	ns	1.8

and the organic carbon, nitrogen, phosphorus and potassium contents were: 1.6 and 0.07% as well as 11.8 and 27 mg kg^{-1}, respectively. Soil pH levels in Farm 1 were inherently lower than in Farm 2, while the OC and N contents were higher in Farm 1 than Farm 2 (Table 5). In Farm 1, soil OC content was significantly different between treatments but pH and N contents were not. The OC contents in *S. sesban* and *M. invisa* treatments (T1, T3 and T4) were higher than observed in the treatments with the recommended inorganic fertilizer application (T5). On the other hand, in Farm 2, no differences were observed.

Rice growth, grain yield and yield parameters

In Farm 1, *S. sesban* plus NPK basal fertilizer (T2) increased rice plant height and was comparable to that under recommended inorganic fertilizer application (Table 6). Generally, plant heights in Farm 2 were higher than plant heights in Farm 1. In both farms, number of tillers per hill, number of spikelets per panicle and total dry matter were not significantly different between treatments. Grain yields were generally higher in Farm 1 than in Farm 2 (Tables 6 and 7). In Farm 1, grain yields in all the green manure treatments, and their combinations with inorganic fertilizer (T1-T4), were not significantly different from each other or from the recommended inorganic fertilizer application (Table 6); this was in spite of differences in their organic and inorganic N contents. However, *S. sesban* + 15-15-15 NPK basal fertilizer and the mimosa treatments, unlike the other green manure treatments, had yields that were significantly higher than the control. Grain yields in Farm 2 had no significant treatment differences but values in the green manure treatments were generally higher than the control (Table 7).

Cost-benefit analysis of *S. sesban* use per hectare of rice

In spite of the ability of *M. invisa* to support high yield of rice, it may not be a good choice under lowland condition, as there was need to provide upland conditions for its survival. Cost-benefit analysis was, therefore, based on *S. sesban* use only. Cost-benefit analysis that was derived from unit cost of production computations (Tables 8 and 9), showed that the *S. sesban* incorporation plus basal 15-15-15 NPK fertilizer application (that is, recommended requirement of phosphorus and potassium, and 50% of the nitrogen requirement) gave an economically optimal yield of rice in Farm 1. There was, therefore, no need for top dressing with sulphate of ammonia fertilizer, and that resulted in a 20.7% savings on inorganic fertilizer use.

Table 7. Rice growth, grain yield and yield parameters in Farm 2.

Farm 2	Organic/inorganic N (kg ha^{-1})	Plant height (cm)	Tillers (hill^{-1})	Spikelets/Panicle	Total dry weight (t ha^{-1})	Grain yield (t ha^{-1})
T1	224	91.0	14	8	11.1	3.7
T2	316	94.2	12	10	12.0	4.1
T3	290	91.5	13	9	10.3	4.4
T4	152	91.7	13	9	10.4	4.1
T5	90	88.7	13	9	10.0	3.6
T6		89.6	12	9	9.7	3.5
LSD ($p \leq 0.05$)		ns	ns	ns	ns	ns

Table 8. Unit cost of rice production in 2005/2006.

Variables	**Quantity**	**Cost** ($)
Land preparation	1 ha	145.7
Labor	2 persons	392.9
Seed	103 kg	56.0
NPK 15-15-15 fertilizer	6 bags	122.6
Sulphate of ammonia	3 bags	45.7
Propanil herbicide	10 L	59.8
2-4-D herbicide	2.5 L	13.0
Chemostomp herbicide	3 L	31.8
Chemosate herbicide	2 L	9.8
Total		877.2

Table 9. Cost-benefit analysis of *S. sesban* use per hectare of rice in 2005/2006.

Item	**Cost ($)**
Inorganic fertilizer requirement	168.3
Reduction in fertilizer requirement	45.7
Seeding *S. sesban*	10.9
Savings on fertilizer use	34.8
Percentage savings on fertilizer use	20.7%

DISCUSSION

The higher grain yields in Farm 1 than Farm 2 is an indication that there has not been as much accumulation and mineralization of organic matter in Farm 2 as in Farm 1. There has been three years accumulation and decomposition of green manure in Farm 1, compared with one year in Farm 2. The higher soil OC contents in the *S. sesban* and mimosa treatments (T1, T3 and T4) than the recommended inorganic fertilizer application (T5) could be an indication of increased soil OC content as a result of carbon accumulation over the three year period.

In similar study, Singh et al. (1997) found that poultry manure sustained high grain yield of rice over a three year period of study while yield decreased with urea. They observed that when poultry manure was applied alone or in combination with urea, the poultry manure did not perform better than urea in the first year, but produced significantly greater grain yield of rice than the same rates of urea fertilizer in the third year when applied in quantities of 120 and 180 kg N ha^{-1}.

In spite of higher dry matter content, nodulation and total nitrogen in *S. sesban* than *M. invisa*, their impact on grain yield of rice did not differ. This is an indication of differences in performance of nitrogen fixing plants. Nagarajah et al. (1989), in comparing the performance of sesbania and azolla, found that in all soils, azolla released less NH_4^+ - N than sesbania and that depending on soil type, the net release ranged from 27 to 52% in azolla and 44 to 81% in sesbania. They also found that both sesbania and azolla increased NH_4^+ - N concentration above the control treatment, whereas rice straw depressed it.

S. sesban had an N content of 2.5% and total N of 239 to 259 kg N ha^{-1}, compared with 2.8% N and total N of 148.4 kg N ha^{-1} in an earlier study (Nyalemegbe et al., 2011b). On the other hand, *M. invisa* had N content of 2.4% and total N of 152 to 186 kg N ha^{-1} in the current study, compared with values of 3.2% and 152.5 kg N ha^{-1}, respectively in an earlier study (Nyalemegbe et al. 2011a). Rinaudo et al. (1983) estimated that *Sesbania rostrata* as green manure fixed at least 26.7 g N m^{-2} (that is, 267 kg N ha^{-1}), and one third of the fixed N was transferred to the crop and two thirds to the soil. In spite of the performance of *M. invisa*, it is unlikely to survive under purely lowland culture.

Conclusion

S. sesban had better establishment under the saturated conditions in the rice basin than *M. invisa* while mimosa needed a drier condition to establish. The incorporation of *S. sesban* in the soil and the supplementary application of 50% of inorganic N requirement gave rice grain yield that did not differ significantly from the recommended inorganic fertilizer application, and resulted in a 20.7% savings in nitrogen fertilizer use.

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