Mucuna pruriens and its Effect on some Physical, Chemical and Biological Properties of a Forest Acrisol

S. Agyenim Boateng
CSIR-Soil Research Institute, Academy Post Office, Kwadaso-Kumasi, Ghana
Email: soils@africaonline.com.gh; sagyenimboateng@yahoo.com

Abstract

The effect of *Mucuna pruriens*, a herbaceous legume, on some properties of a forest acrisol was examined in RCBD experiment of four treatments: control, NPK fertilizer, mucuna incorporation and mucuna mulch. At flowering, the fresh biomass was cut at soil level, chopped up and applied to the soil either by incorporation or as mulch. In both cases, mucuna improved the physical, chemical and biological properties of the soil. Available soil moisture content increased from 9.54% to values between 10.20% and 11.40% while bulk density reduced from 1.42 to 1.36 Mg $m^{-3.}$ Total N increased from 0.14% to 0.18%. Organic C and K levels did not change while P was slightly reduced. Earthworm populations in the mucuna plots were three times higher than those plots without mucuna. Mucuna suppressed weed growth. These improvements in the physical and chemical properties are indicators of the potential of *M. pruriens* in enhancing crop yields.

Introduction

The inherent low fertility status of soils in Ghana is a major contributing factor to low crop yield levels. Chemical fertilizers have been used to provide nutrients to crops in order to ensure sustainable yields. The limitation of chemical fertilizers on the physical conditions of the soil is of major concern, especially when viewed against the background of low organic matter levels of the soils in certain parts of the country.

With the increasing cost of these inputs emphasis is now shifted towards the use of biological management systems. *Mucuna pruriens* var. Utilis, a herbaceous legumi-nous crop, has been used as a cover crop and green manure elsewhere in Latin America, India and Asia. It is lately gaining popularity in Ghana. Although several reports have been made on its positive effect on crop yields (Fischler, 1996; Agyenim Boateng, 1997; van Noordwijk *et al*., 1995; Sanginga *et al*., 1996a), few data exist on its effect on the soil. Becker (unpublished; cited in Carsky *et al*., 1998) observed a 3–9% increases in soil organic matter after a short mucuna fallow compared with a weedy fallow, although the difference was not statistically significant. After one season of mucuna, Carsky &Tian (unpublished; also cited in Carsky *et al*.,1968) recorded 12% higher total N compared to natural fallow at one site but no difference at another site. Nitrogen levels were slightly increased from 0.99% to values over 1% at Ejura in the forest savanna transition zone of Ghana when mucuna was incorporated or used as mulch (Agyenim Boateng, 1997).

Improvement in the physical and chemical properties of soil is an indication of a fertile soil which contributes immensely to the good performance of crop. The objective of the present study is to examine the effect of mucuna on some physical, chemical and biological properties of a Forest Acrisol in Ghana for sustainable agricultural production.

Materials and methods

Mucuna pruriens was grown on a Forest Acrisol (locally, Akroso series) at Kwadaso in the semi-deciduous rain forest zone of Ghana. The treatments were (i) control (i.e. without green manure or mineral fertilizer input), (ii) mineral fertilizer (i.e. 51–30–30 kg NPK/ha), (iii) mucuna incorporated and (iv) mucuna used as surface mulch (non-incorporation). The experiment was a randomized complete block design with four replications. Plot size per treatment was 50 m^2.

Mucuna seeds were sown at 60 cm between rows 30 cm within rows. The crop was allowed to grow up to the flowering stage when it was cut, chopped up and placed on the soil surface as a mulch, and incorporated into the soil. Incorporation was done manually with the hoe. The mineral fertilizer consisted of four 50 kg bags of 15-15-15 NPK and two 50 kg bags of sulphate of ammonia per hectare. The soil was sampled for analysis before planting, at flowering, 4 weeks after mulching and incorporation, and 3 months after mulching and incorporation.

The following chemical analyses were carried out: (1) soil *p*H in water solution (1:2.5); (2) organic carbon by Walkley and Black wet combustion method; (3) total N by the macro-Kjedahl method; (4) available P by Bray P1 method and (5) exchangeable K, Ca, Mg and Na were extracted with 1.0 *N* neutral ammonium acetate solution. Potassium and Na were determined with the flame photometer, while Ca and Mg were determined by titration with EDTA solution. Exchangeable acidity (Al and H) was determined by the titration method after extraction with 1.0 *N* KCl. Effective cation capacity (ECEC) is the sum of 1.0 *N* NH_4OAC exchangeable bases plus 1.0 *N* KCl exchangeable acidity.

Particle size analysis was determined by the Bouyoucos method. Bulk density of the soil was determined by the core method, and available moisture content (AMC) determined by using the formula,

$$AMC = FC - PWP$$

where FC is field capacity and PWP is permanent wilting point.

Harvested plant samples of mucuna at flowering were taken and oven-dried at 70 °C for 48 h for biomass assessment and nutrient analysis following standard analytical methods. Weed count was done by using a 0.5-m quadrat. Nodulation was done by uprooting the plants, counting the number of nodules produced and cutting them open to examine effectiveness. An average of four plants was sampled. Earth-worm populations during the course of the study were enumerated**.**

Results and discussion

Characteristics of the soil

Initial soil properties of the experimental site are presented in Table 1. The mechanical analysis indicated that the soil was a sandy loam. Bulk density value (1.42 Mg m^{-3}) was slightly high as is common to such tropical soils in the country with values between 1.35 and 1.4 Mg m^{-3}. According to Young (1976), organic carbon value of 1.07% for the experimental site was low while total nitrogen and available phosphorus values of 0.14% and 17.85 mg kg^{-1}, respectively, were moderate. The soil was extremely acidic, with a *p*H value of 4.7. Generally, the soil was low in exchangeable bases, with potassium value (0.22 c mol kg^{-1}) being moderate. Base saturation was, however, high (91%).

TABLE 1

Some physical and chemical properties of the soil at the start of the experiment (top 0 -20 cm)

Parameter	*Description*
pH (H_2O)	4.7
Org. C (%)	1.07
Org. matter (%)	1.81
Total N (%)	0.14
Available P (mg kg^{-1})	17.85
Aðvailable K (mg kg^{-1})	31.20
Exchangeable cations (cmol kg^{-1}):	
K 0.22	
Ca	2.32
Mg	0.56
Na	0.09
(Al + H)	0.30
ECEC (cmol kg^{-1})	3.49
Base saturation (%)	91
Particle size (%):	
Sand	73.5
Silt	13.5
Clay	13.0
Bulk density (Mg m^{-3})	1.42
Plant available water (%)	9.54

Characteristics of the mucuna plant

Some chemical and microbiological properties of the mucuna at the flowering stage when biological growth was at peak are presented in Table 2. Dry matter yield in the present study was higher than those reported by the following researchers: Muhr (1997), 4.8 t ha^{-1}; Drechsel, Steiner & Hagedorn (1996), 1.3–3.5 t ha^{-1} and Quintana (1987): 4.9 t ha^{-1}. Bowen (1987) and Fischler (1996) observed the same dry matter yield. However, Lathwell (1990), Klein (1994) and Sanginga *et al*. (1996a) noted higher yields of 6.7 t ha^{-1}, 7.4 t ha^{-1} and 7.7 t ha^{-1}, respectively.

TABLE 2

Some properties of Mucuna pruriens *var.* utilis *at flowering stage*

Parameter	*Description*
Dry matter (t ha^{-1})	5.6

Moisture content (%)	74.2
Total nutrients (%)	3.49
N	0.27
P	1.58
K 1.76	
Ca	0.38
Mg	
Nodulation (per plant):	
Total number	13
Number of effective nodules	6
Dry weight of effective nodules (g)	0.9

Scanty data on nutrient composition of mucuna exist. Tian, Kang & Brussard (1992) found 6% N in mucuna leaves and petioles. Comparable figures have been reported from related leguminous green manure plants. Leucaena contains on a dry weight basis 3.0–3.5% N, 0.27% P, 1.40% K and 0.80% Ca (Brewbaker & Hilton, 1979). The number of nodules and effective ones per plant (13 and 6 respectively) is rather low compared with other legumes such as cowpea with over 50 nodules and canavalia with an average of 30.

In field experiments at four savanna sites, Sanginga *et al*. (1996b) found that nodule number at 16 weeks after planting (WAP) ranged from 3 to 27 per plant. However, the dry weight of effective nodules (0.9 g) per plant is consistent with what is reported in the literature. Inoculation with suitable strain is likely to improve the nodulation of the plant. Ladha, Miyan & Garcia (1989), studying the effect of inoculation on nodulation found that *Sesbania rostrata* produced 17 nodules without inoculation and 78 nodules with inoculation.

Effect of mucuna pruriens *on soil chemical properties*

At flowering, the soils in the mucuna plots relative to the control suffered slight decreases of soil *p*H, organic carbon, available P and available K levels except that of nitrogen. These decreases were probably due to crop uptake. The change of 16% in N may be ascribed to N fixation by mucuna. Carsky *et al.* (1998) reported that published estimates of the amounts of N derived from the atmosphere by mucuna ranged from less than 20 to more than 200 kg/ha.

There were no significant changes in *p*H 4 weeks after addition of mucuna biomass to the soil (Table 3). Organic matter decreased with incorporation of mucuna but increased when mucuna was surface-applied. This decrease may be due to tillage during incorporation as a result of enhanced oxidation of organic matter leading to its rapid decomposition and loss (Agboola, 1990). Non-incorporation (without tillage), i.e. mucuna mulch, added some amount of organic matter from the decomposing mucuna residues. However, nitrogen levels increased over 20% when mucuna was incorporated as green manure. Non-incorporation maintained the nitrogen level. This observation is important since green manure legumes are used largely to increase nitrogen and soil organic matter (Agboola & Fayemi, 1972; Allison, 1973; Quintana, 1987).

TABLE 3

*Some chemical properties of the soil at flowering and 4 WAA of mucuna stages of the experiment (0 - 20 cm)**

Time of sampling	*Soil pH H (H_2O)*	*Organic C %*	*Organic matter %*	*Total No.%*	*Available P mg kg^{-1}*	*K mg kg^{-1}*
At flowering:						
Control	4.6(4.7)	0.80(1.07)	1.38(1.81)	0.12(0.14)	8.65(17.85)	28.00(31.20)
Mucuna plots	4.7	0.82	1.42	0.14	13.45	30.20
At four weeks after mucuna application:						
Control	4.8	0.82	1.41	0.11	11.80	31.20
51-30-30 kg NPK ha^{-1}	4.6	0.86	1.48	0.14	21.45	15.60
Mucuna incorporation	4.7	0.78	1.34	0.18	8.95	30.60
Mucuna used as mulch	4.6	0.90	1.55	0.13	10.00	31.20

*Values were from bulked samples of treatments
Initial values in parentheses
WAA – weeks after application

Available phosphorus and potassium did not show any appreciable increase for mucuna incorporation from the initial levels. It may be that P and K mineralization was still taking place. Similarly, non-incorporation did not greatly improve P and K levels (although they were slightly higher than incorporation).

At 3 months after mucuna application to the soil (Table 4), *p*H levels did not change much. Organic matter levels dropped further from the previous levels by 0.18 units in the non-incorporated and 0.05 units in the incorporated plots. The falls might be explained by the fact that mucuna residues decompose rapidly so that by the end of the 3 months period most of the materials had decomposed, especially for the mulch plots. Tian, Kang & Brussard (1992) observed mucuna decomposition rate to be among the highest in the leaves and petioles in a group of 10 herbaceous and woody species. It would, therefore, not be expected to contribute substantially to increasing soil organic matter content.

TABLE 4

*Effect of Mucuna pruriens on chemical properties of the soil**

Treatment	pH (H_20)	Org.C	Org. Matter	Total N	Exchangeable cations Ca	Mg	K	Na	T.E.B[1]	Ex.Acid	ECEC
	----%----		----cmol kg^{-1}----							(%)	(mg/kg)
Control	4.8(4.7)	0.71(1.07)	1.22(1.81)	0.08(0.14)	3.36(2.32)	0.88(0.56)	0.17(0.22)			0.09	4.50
51-30-30 kg NPK ha^{-1}	4.6	0.75	1.29	0.10	2.64	0.24	0.13			0.09	3.10
Mucuna incorporation	4.8	0.75	1.29	0.14	2.96	0.64	0.17			0.09	2.86
Mucuna mulch	4.8	0.79	1.37	0.12	2.16	0.56	0.13			0.09	2.94

*Values were from bulked samples of treatments

[1]T. E. B. - Total exchangeable bases

The mucuna plots had higher organic matter levels than the control. It would seem that the added biomass added some amount of organic matter to the soil, especially from the incorporation and, therefore, could reduce its rapid decline. Larger increases of organic matter levels are likely with more repeated applications of mucuna biomass to the soil as reported by Buanec & Jacob (1981), Allison (1973), and Agboola & Fayemi (1972).

Nitrogen levels decreased from 0.18% and 0.13% to 0.14% and 0.12% for incor-poration and mulched treatments, respectively, by the third month. This could be due to several factors including the loss by leaching and volatilisation. This level of nitrogen in the soil from the mucuna-treated plots after 3 months is appreciable since it exceeded the control by 75% and chemical fertilizer by 40%.

Available phosphorus increased slightly from 8.95 mg kg^{-1} at 4 weeks after mucuna application to 18.95 mg kg^{-1} and 10.00 mg kg^{-1} to 14.00 mg kg^{-1} at the end of the 3 months period. The results confirm the findings of Agboola (1975) and Kahnt (1983) that legume green manures are known to increase phosphorus content of soils when cut and applied to the soil.

For the exchangeable bases no change was observed for sodium. Potassium levels decreased from 0.22 to 0.13 c mol kg^{-1} for the mulched and 0.17 c mol kg^{-1} for the incorporation. However, magnesium increased from 0.38 to 0.56 and 0.64 c mol kg^{-1} while calcium levels increased from 2.32 to 2.96 c mol kg^{-1} when mucuna was incorporated but decreased to 2.16 c mol kg^{-1} when surface applied. According to Agboola (1975) carbon dioxide and organic acids released during decomposition of green manures may act on insoluble soil minerals thereby, releasing nutrients into the soil solution. No appreciable change in *p*H was observed. Changes in soil *p*H due to green manuring are complex and dependent on soil type and conditions (Meelu *et al*., 1994).

Effects of Mucuna pruriens *on some physical properties of the soil*

Mucuna improved the moisture content of the soil from 9.54% to between 10.20% and 11.40% (Table 5). This is consistent with the findings of several workers (e.g. Biswas, Roy & Sahu, 1970; Kang, Grimme & Lawson, 1985) demonstrating moisture retention in soils upon green manure addition. Moisture retention in non-incorporated mucuna plots was better than the incorporated plots. This was because the mulch material could better conserve soil moisture.

TABLE 5

*Effect of Mucuna pruriens on physical properties of the soil**

Treatment	Plant available water (%)	Bulk density (Mg m^{-3})
Control	9.44 (9.54)**	1.43 (1.42)**
NPK (Chemical fertilizer)	9.21	1.44
Mucuna incorporation	10.20	1.36
Mucuna mulch	11.40	1.39

* Values were from bulked samples of treatments

( ) **Values at the beginning of the experiment

Bulk density was slightly reduced after application of mucuna. The effect was more pronounced when the manure was incorporated (from 1.42 to 1.36 Mg m^{-3}). Organic matter exerts a favourable influence on soil conditions by lowering bulk density as reported by several authors including Darra, Jain & Uzzaman (1968) who observe a decrease of bulk density from 1.46 to 1.36 Mg m^{-3} and Jiao, Gu & Zhang (1986) who noted a change from 1.39 to 1.31 Mg m^{-3}.

Effect of Mucuna pruriens *on some biological properties of the soil*

Mucuna pruriens has a high potential for controlling weeds, including some obnoxious ones like *Imperata cylindrica* (Table 6). Weed pressure, notably *Chromolaena odorata* and *Imperata cylindrica,* was highest on the control plots without mucuna. On the contrary, weed population on the mucuna plots was low. These results agree with the findings of several works on mucuna in relation to weed control. Akobundu &Poku (1984) reported that within 19 weeks, mucuna could completely cover plots infested with *Imperata cylindrica*. Osei Bonsu, Asibuo & Asafu-Agyei (1995) observed that spear grass (*Imperata cylindrica*) was almost absent on plots with mucuna. Mucuna grows and forms a dense canopy to shade undergrowths.

TABLE 6

Weed control effect of mucuna after 90 days of growth

Treatment	*Weed species (No. m^{-2})* Chromolaena odorata	Commelina *spp.*	Roethboelia exaltata	Ageratum conyzoides	Imperata cylindrica	*Stump regrowth*	*Others*	*Total*
Control	25	9	15	19	32	3	5	108
Mucuna (live)	1	1	1	–	2	1	2	8

* Values were from bulked samples of treatments

The thick canopy of mucuna might have provided suitable temperature, good moisture regime and aeration conducive to the survival and breeding of earthworms (Table 7). According to Meelu *et al.* (1994) green manures, by providing energy and nutrients, encourage the growth and activity of desirable soil organisms (including earthworms) that play a key role in transforming and liberating plant nutrients in the soil. Plots with mucuna resulted in more earthworm populations than those without mucuna. This implied that the activity of earthworms in the soil increased with the addition of the legume resulting in increased aeration of the soil and its infiltration, formation of fine-textured soils and improvement of nutrient status of the soil. This increase in earthworm populations as a result of the presence of the legume is in agreement with the findings of several investigators of legume green manures (Kutte & Mann, 1968; Darra, Jain & Uzzaman, 1968; Yaacob & Blair, 1984).

TABLE 7

Earthworm populations after four weeks of mucuna application to the soil

Treatment	Population (number/m^2)	Fresh weight of worms (g/m^2)
Bare	40	9.2
Mucuna incorporation	124	31.00
Mucuna mulch	136	39.44

* Values were from bulked samples of treatments

Conclusion

Mucuna increased soil N levels by about 20%. Maintenance of organic matter is likely if mucuna fallow is part of the fallow systems in the country. *M. pruriens* reduced bulk density by 0.06 units and increased available water content by between 0.75 and 1.95 units. Earthworm population tripled and weed growth suppressed. The fertility of the soil can be improved by the use of mucuna technology to ensure sustained crop yields. Further research is needed to identify ecozones where the mucuna technology is applicable.

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