Effect of Management of Mucuna (*Mucuna pruriens* var. *utilis*) Live-Mulch on Some Properties of a Haplic Acrisol

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Received: October 2003 Accepted: October 2005

Resumé

Mahama, A. R., Osei, B. A., Bonsu, M. & Frimpong, K. A. *L'Effet de la Gestion du paillis actif de Mucuna (Mucuna pruriens* var. *utilis) sur quelques propriétés physiques et chimiques d'un Haplic Acrisol.* L' effet des pratiques de la gestion du paillis actif de Mucuna (*Mucuna pruriens* var. *utilis*) sur quelques propriétés physiques et chimiques d' un Haplic Acrisol était étudié dans une parcelle d' expérimentation en utilisant un dessin du bloc complète et randomisé avec cinq replications. Les pratiques des gestions utilisées étaient sans paillis actif (contrôle) paillis actif avec paillis de mucuna crée par vaporization de gramozone, paillis actif avec mucuna taillé et enlevé, paillis actif avec mucuna taillé de surface appliquée et paillis actif avec mucuna taillé, labouré dans le sol. La gestion de paillis actif n'a pas influencé des changements en sol pH. Pourtant, les changements en carbon organique du sol (de -14.80 à 20.73%) et l'azote du sol (de -1.64 à 6.58%) étaient considérablement affectés par les pratiques de la gestion. Egalement, les changements en porosité complète du sol (de -8.88 à 10.51%), la disponibilité de la capacité de l'eau de la plante (de -3.20 à 2.79%) et la densité sèche en bloc (de -4.86 à 7.09%) étaient également affectés par les pratiques utilisées de la gestion ($P<0.05$). Le traitement du mucuna incorporé a produit des changements très positifs dans les propriétés du sol par rapport à tous les autres traitements ($P<0.05$). Il est donc la meilleure option de gestion au niveau de l' amélioration du sol.

Mots clés: *Mucuna pruriens*, la gestion de paillis actif, les propriétés du sol chimiques et physiques.

Abstract

The effect of management practices of mucuna (*Mucuna pruriens* var. *utilis*) live-mulch on some physical and chemical properties of a Haplic Acrisol was investigated in a field experiment using a randomized complete block design with five replications. The management practices used were: no live-mulch (control), live-mulch with mucuna mulch created by spraying with gramozone, live-mulch with mucuna trimmed and removed, live-mulch with trimmed mucuna surface-applied, and live-mulch with trimmed mucuna ploughed into soil. Soil samples were analysed before and after imposing the management

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practices. Live-mulch management did not influence changes in soil pH. However, the changes in soil organic carbon (from -14.80 to 20.73 %) and soil nitrogen (from -1.64 to 6.58 %), were significantly affected by the management practices. Similarly, changes in total soil porosity (from -8.88 to 10.51 %), plant available water capacity (from -3.20 to 2.79 %), and bulk density (from -4.86 to 7.09 %) were also affected by the management practices used ($P < 0.05$). The mucuna-incorporated treatment produced very positive changes in soil properties compared to all the other treatments ($P < 0.05$). It is, therefore, the best management option in terms of soil improvement.

Keywords: *Mucuna pruriens*, live-mulch management, physical and chemical soil properties.

Introduction

The productivity of soils under long-term cultivation in Ghana has been declining over the years. Natural fallow has long been the main practice to maintain soil fertility in the tropics. However, as its effects only become significant after a period of at least five years, natural fallow is no longer possible in the context of increasing population (Bathes *et al.*, 2004). The replenishment of soil nutrients has been hampered by the application of low levels of chemical fertilizers and the addition of insufficient quantities of organic matter to the soil.

The inclusion of a legume in the cropping system could be a way of addressing the declining productivity of soils (Hardter, 1989). Many authors have underlined the advantage of legume-based cover crops over natural fallow in Africa for controlling weeds and erosion, and enriching the soil in organic matter and nitrogen (Voelkner, 1979; Raunet *et al.*, 1999; Carsky *et al.*, 2001). Herbaceous legumes are useful as live mulches or as intercrops. Pueraria and Mucuna are the most commonly used species to maintain or improve soil fertility and control erosion (Wilson and Lal, 1986). Mucuna, as an annual species, establishes fast and provides good groundcover. However, due to its fast growth, mucuna may compete with the cultivated crops for nutrients and water. Periodic partial slashing of mucuna around the cultivated crops may therefore be necessary (Kirchhof and Salako, 2000).

Different live-mulch management practices could improve soil properties to varying degrees (Akobundu, 1987). The nitrogen fixed by leguminous crops is, however, prone to leaching, volatilization, and denitrification within a short time (Mulongoy and Akobundu, 1992). This is because the nitrogen-rich leaves of nitrogen-fixing legumes decompose very rapidly under tropical conditions. There is the need to find ways of controlling the leaching, volatilization and denitrification processes in order to make the nitrogen from leguminous live-mulch available to crops.

The objective of the study was, therefore, to evaluate the influence of the different live-mulch management practices on nitrogen, organic carbon, pH, bulk density, total porosity, and plant available water capacity of a Haplic Acrisol. It is expected that the best management practice will improve the physical properties and chemical fertility of the soil and thereby increase crop productivity.

Materials and methods

The experiment was carried out between March and August, 2000 on a Haplic Acrisol (FAO/UNESCO, 1988) at the University of Cape Coast Teaching and Research Farm. The experimental field was initially ploughed and harrowed. Single super phosphate and muriate of potash were applied as basal fertilizer at 60 kg ha^{-1} P_2O_5 and 40 kg ha^{-1} K_2O respectively. A randomized complete block design with five replications was used. The treatments imposed were: T_1 (control with no live-mulch), T_2 (live-mulch with mucuna trimmings (at a rate of 5.4 t ha^{-1}) created by spraying with gramozone applied (at a rate of 5 l ha^{-1}), T_3 (live-mulch with trimmed mucuna removed), T_4 (live-mulch with trimmed mucuna surface applied at a rate of 5.4 t ha^{-1}), and T_5 (live-mulch with trimmed mucuna ploughed into the soil at a rate of 5.4 t ha^{-1}).

There were 25 plots, each measuring 4.8 m x 11.2 m. *Mucuna pruriens* was first established at a spacing of 80 cm between rows and 40 cm within rows for a period of three months. The mucuna was then managed at the inter-row positions in the major season according to the appropriate treatments. Soil was sampled before and after the management practices were imposed. Some soil properties were determined on composite soil samples taken from the top soil (0-20 cm). The bulk density of the soil was measured as a ratio of the mass of oven-dried to the volume of the soil. Porosity was extrapolated from the bulk density and particle density values of the soil. Plant available water capacity was determined using the procedure described by Anderson and Ingram (1993). Soil pH was determined in a soil: water ratio of 1:2.5. The Walkley and Black wet oxidation method was used to determine soil organic carbon. Total nitrogen was determined by the micro Kjeldahl method involving digestion and distillation. Data were subjected to analysis of variance (ANOVA) and treatment interactions were identified using least significant difference (LSD) at 0.05 level of probability.

Results and Discussion

Effect of live-mulch management practices on some soil physical properties

The change in mean bulk density of the soil (B_D), from the time of planting of the live-mulch to the end of the cropping season, was largest for the control plots (T_1), and least for the mucuna-incorporated plots (T_5) (Table 1). These changes were significantly different. The surface-applied mucuna plots with (T_2) or without gramozone treatment (T_4) and the treatment with trimmed

Table 1. Changes in soil physical properties as affected by mucuna live-mulch management practices.

Soil property	*Treatment* T_1	T_2	T_3	T_4	T_5
Bulk density ($g\ cm^{-3}$)					
Initial	1.41	1.44	1.40	1.40	1.41
Final	1.51	1.37	1.37	1.37	1.30
Percentage change	7.09a	-4.86b	-2.14b	-2.14b	-7.80c
LSD (0.05)	2.085				
Total porosity (%)					
Initial	44.84	43.83	44.84	45.39	44.61
Final	40.86	45.95	39.69	46.33	49.30
Percentage change	-8.88c	4.81b	-11.49c	2.07b	10.51a
LSD (0.05)	2.958				
Plant available water capacity (mm $H_2O/10^3$ mm soil depth)					
Initial	47.78	48.08	48.08	48.37	47.62
Final	46.25	49.30	46.71	49.72	48.04
Percentage change	-3.20b	2.54a	-2.85b	2.79a	0.88a
LSD (0.05)	0.547				

Notes:

T_1 = No live-mulch (Control).

T_2 = Live-mulch + growth of mulch controlled by gramozone and trimmings surface applied.

T_3 = Live-mulch + mucuna trimmings removed.

T_4 = Live mulch + mucuna trimmings surface applied.

T_5 = Live mulch + mucuna trimmings incorporated into soil.

mucuna removed (T_3) recorded significantly smaller changes in B_D values than the control plots (T_1). The changes in B_D between the mulched plots, T_2 and T_4 were not significantly different (Table 1). Incorporation of *Mucuna pruriens* resulted in a significant improvement in the organic carbon level of the soil (Table 2). The organic matter derived from mucuna after decomposition apparently improved soil structure as a result of increased total soil porosity and decreased B_D for T_5 compared to the control (Jiao *et al.*, 1986).

Surface mulching of the soil resulted in a reduction in its B_D value as earlier observed by Dalzell *et al.* (1987). The improved soil structure as shown by increased total soil porosity might have accounted for the difference in mean B_D between plots mulched with mucuna (T_2 and T_4) and the control (T_1).

The percentage change in total porosity (Pt) value was significantly greater for the mucuna incorporated (T_5) and mulched plots (T_2 and T_4) than either the control (T_1) or on plots on which mucuna was trimmed and removed (T_3). There was also a significant difference between the surface-applied mucuna plots and the mucuna-incorporated plots (T_5). Soil organic material obtained from mucuna, either as surface mulch or incorporated, might have promoted the activities of soil-living organisms (FAO, 1996), resulting in increased soil organic matter as observed in T_2, T_4 and T_5. The complete removal of the mucuna trimmings (T_3) and the absence of any organic material (T_1) led to a decrease in the organic matter of the soil (Balasubramanian and Nnadi, 1980) and subsequent reduced porosity. On the other hand, the surface mulch and the incorporated mulch significantly increased porosity of the soil. These might be the possible reasons for the significantly greater Pt of the mulched plots (T_2 and T_4) and mucuna-incorporated plots (T_5) compared to the control (T_1) and plots on which mucuna was trimmed and removed (T_3). The similarity in the change in Pt for the surface-applied mucuna plots, with (T_2) and without gramozone (T_4) could be attributed to the similar levels of organic matter accumulation.

The change in plant available water capacity (PAWC) was largest in the mulched (T_2 and T_4) and mucuna-incorporated (T_5) plots, and least in the control plot (Table 1). Though the PAWC values for treatments T_2, T_4, and T_5 were not significantly different, they were significantly greater than T_1 and T_3 ($P < 0.05$). There was also no significant difference between T_1 and T_3 (Table 1). The organic matter derived from the incorporation of mucuna in T_5 might account for the increase in the water retention by increasing the extent of water retention pores and specific surface area of soils (Khaleel *et al.*, 1981; Clapp *et al.*, 1986). This may explain the significantly greater PAWC value for T_5 compared to T_1 and T_3. The use of organic mulch on the surface soil (T_2 and T_4) decreased cumulative soil moisture evaporation compared to the bare plots (T_1).

Effect of live-mulch management on soil chemical properties

The percentage change in soil pH values was not significantly different among the treatments (Table 2). Kute and Mann (1968) reported similar results on the effect of green manuring and mulching on soil pH.

Table 2. Changes in soil chemical properties for different live-mulch management practices.

Soil property	*Treatment*				
	T_1	T_2	T_3	T_4	T_5
Soil pH					
Initial	5.54	5.44	5.45	5.54	5.24
Final	5.44	5.37	5.36	5.44	5.26
Percentage change	-1.81a	-1.29a	-1.65a	-1.81a	0.88a
LSD (0.05)	2.085				
Organic carbon (%)					
Initial	0.84	0.90	0.81	0.88	0.82
Final	0.72	0.95	0.69	0.95	0.99
Percentage change	-14.28c	7.14b	-14.80c	7.95b	20.73a
LSD (0.05)	1.97				
Total N (%)					
Initial	0.063	0.073	0.061	0.075	0.076
Final	0.062	0.074	0.060	0.077	0.081
Percentage change	-1.59d	1.37c	-1.64d	2.67b	6.58a
LSD	0.301				

Notes:

T_1 = No live-mulch (control).
T_2 = Live-mulch + mucuna + gramozone.
T_3 = Live-mulch + mucuna trimmings removed.
T_4 = Live mulch + mucuna trimmings surface applied.
T_5 = Live mulch + trimmings incorporated into soil.

There was a significant difference in percentage change in soil organic carbon (Table 2) between the T_1 and T_2, T_4 and T_5. The change in organic carbon was greater in T_5 than T_2 and T_4. There was no significant change in organic carbon between T_1 and T_3 (Table 2). Decay of above ground parts of *Mucuna pruriens* added to the soil, either as surface mulch (T_2 and T_4) or as green manure (T_5) contributed to the organic carbon accumulation in the soil. This may explain the greater accumulation of organic carbon on mucuna-incorporated (T_5) and mulched (T_2 and T_4) plots compared to the plots on which mucuna was neither surface-applied nor incorporated (T_1 and T_3). The removal of organic material from the soil, as in T_1 and T_3, deprived the soil of its organic matter build-up (Balasubramanian and Nnadi, 1980). The rate of organic matter decomposition would be greater when mucuna was incorporated than surface-applied, resulting in greater organic carbon in T_5 than other treatments.

Mahama (2001) has shown that *Mucuna pruriens* accumulated 11 t ha^{-1} of dry matter in 135 days after planting and stored 209 kg N ha^{-1} in the shoot within 150 days. The addition of mucuna to the soil could therefore account for the significantly high percentages in the total soil N in T_2, T_4 and T_5 compared to T_1 and T_3. There was, however, no significant variation in total soil N between surface mulched and mucuna-incorporated plots.

Conclusion

In the Haplic Acrisol studied, the four practices (live-mulch whose trimmings were created by spraying gramozone was used as mulch, live-mulch with mucuna trimmed and trimmings removed, live-mulch with mucuna trimmed and surface-applied, and live-mulch with trimmed mucuna ploughed into soil) used for the management of mucuna live-mulch were effective, at different rates, in changing the properties of the soil.

They changed the physical properties (bulk density, total porosity, and plant available water and chemical fertility (organic carbon and total nitrogen) significantly. The incorporation of mucuna trimmings into the soil resulted in the most significant soil improvement. Many resource-poor Ghanaian farmers often struggle to find any form of organic material to add to their soils or to use as a mulch to improve the soil. The study shows that mucuna live-mulch whose trimmings are ploughed into the soil has the potential to fulfill this purpose.

References

Akobundu, I. O. 1987. *Weed Science in the Tropics. Principles and Practice.* Chichester, John Wiley and Sons Ltd.

Anderson, J. M. & Ingram, J. S. I. 1993. *Tropical Soil Biology and Fertility. A Hand Books of Methods*. Wallingford, CAB International, UK.

Balasubramanian, V. & Nnadi, L. A. 1980. Crop residue management and soil productivity in savanna areas of Nigeria. In *Organic Recycling in Africa.* pp.106-120. FAO Bulletin No. 43. Rome.

Bathes, B., Azontonde, A., Blanchart, E., Girardin, C., Villenave, C., Lesaint, S., Oliver, R. & Feller, C. 2004. Effect of a legume cover crop (*Mucuna pruriens* var. *utilis*) on soil carbon in an Ultisol under maize cultivation in Southern Benin. *Soil Use and Management* 20: 231-239.

Carsky, R. J., Becker, M. & Hauser, S. 2001. Mucuna cover fallow system: potential and limitations. In *Sustaining Soil fertility in West Africa* (Eds G. Tian, F. Ishida & D. Keatinge). pp. 111-135. Soil Science Society of America Special Publication Madison, WI.

Clapp, C. E., Stark, S. A., Clay, D. E. & Larson, W. E. 1986. Sewage sludge organic Matter and soil properties. In *The Role of Organic Matter in Modern Agriculture* (Eds Y. Chen & Y. Avnimelech). Nijhoff Publishers Dordrcht, Netherlands.

Dalzell, H. W., Biddlestone, A. J., Gray, K. R. & Thurairajan, K. 1987. Soil Management *Compost Production and Use in Tropical and Sub-tropical Environment.* FAO Soils Bulletin No. 56:96-98.

FAO/UNESCO. 1988. Food and Agricultural Organisation/United Nations Educational, Scientific and Cultural Organisation. FAO/UNESCO. *Soil Map of the World. Revised Legend.* FAO, Rome.

FAO. 1996. Food and Agriculture Organisation. Sustainable cropping systems in The Brazilian Cerrados: Identification of analogous land for agrotechnology transfer in the savanna zones of the developing world. *Integrated Crop Management* 1: FAO, Rome.

Hardter, R. 1989. Utilization of nitrogen and phosphorous by intercropping and sole cropping systems of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata*) on an Alfisol in northern Ghana. *Nyankpala Agricultural Research Report.* No. 5. NAES.Tamale.

Jiao, B., Gu, R. & Zhang, X. 1986. *Chinese Green Manuring.* Beijing Publishing House of Agriculture, China.

Khaleel, R., Reddy, K. R. & Overcash, M. R. 1981. Changes in soil physical properties due to organic waste applications. *Journal of Environmental Quality* 10:133-141.

Kirchhof, G. & Salako, F. K. 2000. Residual tillage and bush-fallow effects on soil properties and maize intercropped with legumes on a tropical Alfisol. *Soil Use and Management* 16:183-188.

Kute, S. B. & Mann, H. S. 1968. Effect of green manuring on physical, chemical and biological properties of the soil. *Indian Journal of Agronomy* 13: 20-25.

Mahama, A. R. 2001. Productivity of a Haplic Acrisol as affected by *Mucuna pruriens* live-mulch management practices. M.Phil. Thesis, Department of Soil Science, University of Cape Coast, Ghana.

Mulongoy, K. & Akobundu, I. O. 1992. Agronomic and economic benefits of nitrogen contributed by legumes in live-mulch and alley-farming systems. *IITA Research* 4: 12-15.

Raunet, M., Seguy, L. & Fovet-Rabot, C. 1999. Semis direct sur converture vegetale permente du sol de la technique au concept. In *Gestion Agrobiogique de sol et des Systemes de Culture* (Eds F. Rasolo & M Raunet). CIRAD Montpellier, France.

Voelkner, H. 1979. Urgently needed: an ideal green mulch crop for the tropics. *World Crops* 31: 76-78.

Wilson, G. F. & Lal, R. 1986. New concepts for post-clearing land management in the tropics. In *Land Clearing and Development in the Tropics* (Eds R. Lal, P. A. Sanchez & R. W. Cummings Jr). A. A. Balkerma, Rotterdam.