Regenerative capacity and factors influencing the management of *Mucuna pruriens* var. *utilis* live-mulch

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ABSTRACT

The regenerative capacity of *Mucuna pruriens* var. *utilis* live-mulch and factors affecting its management were investigated. Six plots of mucuna (each measuring 48 m^2) were established at an intra-row spacing of 40 cm and inter-row spacing of 80 cm. The number of days to canopy closure after planting and after the first, second and third trimmings were recorded. The trimming frequency for early-maturing and late-maturing maize varieties and the biomass yield and number of active nodules per plant were determined. *Mucuna pruriens* attained complete canopy closure 55 days after planting (DAP). The number of days required for complete canopy closure after the first, second and third trimmings were 34, 32 and 26, respectively. The number of trimmings (60 to 90 DAP) varied from 0-1 (for early-maturing maize) to 1-2 (for late-maturing maize). The fresh biomass yields at the first, second and third trimmings were 12364, 5941 and 7209 kg ha^{-1}, respectively; while litter yield ranged from 469 to 914 kg ha^{-1}. The effective nodule count per plant varied from 4 (45 DAP) to a maximum of 63 (120 DAP). The N yield (90 days after planting mucuna) was 179 kg ha^{-1} of which 60 kg ha^{-1} mineralizable N could be provided for an intercrop. Significant positive relationships were established between biomass yield, N content of mucuna plant, days after planting, and number of effective nodules per plant. The study showed that it would be appropriate to trim *M. pruriens* two times (at 60 DAP and 34 days after first trimming) during the intercropping of a late-maturing maize crop to reduce competition between maize crop and live-mulch for water and plant nutrients in the soil.

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RÉSUMÉ

Ahmed, M. R., Osei, B. A. & Bonsu, M.: *La capacité régénératrice et les facteurs influençant l'aménagement de paillis vif* Mucuna pruriens *var.* utilis. La capacité régénératrice de paillis vif *Mucuna pruriens* var. *utilis* et les facteurs influançant son aménagement étaient étudiés. Six lots de mucuna (de 48 m² chacun) étaient cultivés avec un espacement 40 cm intra-rayons et un espacement de 80 cm inter-rayons. Les nombres de jours à la fermeture de la canopée après la plantation et après les tailles premières, deuxièmes et troisièmes étaient enregistrées . La fréquence de la taille pour les variétés de maïs de maturation tôt et de maturation tardive, le rendement de la biomasse et le nombre de nodule actif par plante étaient déterminés. *Mucuna pruriens* ont atteint une fermeture complete de la canopée 55 jours après la plantation. Le nombre de jours exigés pour la fermeture complète de la canopée après les tailles premières, deuxièmes et troisièmes étaient respectivement 34, 32 et 26. Les nombres de taille (60-90 jours après plantation) variaient de 0-1 (pour le maïs de maturation tôt) à 1-2 (pour le maïs de la maturation tardive) . Les rendements de biomasse fraîche aux tailles premières, deuxièmes et troisièmes étaient 12364, 5941 et 7209 kg ha^{-1}, respectivement, alors que le rendement de litière variait de 469 à 914 kg ha^{-1} . Le compte effectif de nodule par plante variait 4 (45 jours après plantation) à un maximum de 63 (120 jours après plantation). Le rendement d'azote (A) (90 jours après plantation de mucuna) était 179 kg ha^{-1} dont 60 kg ha^{-1} d'A minéralisable pourrait être disponible à une culture associée. Des rapports positives considérables étaient établis entre le rendement de biomasse, la teneur d'A de la plante mucuna, les jours après la plantation et le nombre de nodules effectifs par plante. L'étude montrait qu'il serait approprié de tailler légèrement *M. pruriens* deux fois (60 jours après plantation et 34 jours après la taille première) pendant l'association culturale de la culture du maïs d'une maturation tardive afin de réduire la concurrence pour l'eau et les nutriments de plante dans le sol entre la culture maïs et le paillis vif.

Introduction

Traditional cropping systems based on short cropping and long fallow periods maintained soil fertility at a low but adequate level for non-intensive agriculture in the past (Balasubramanian & Nnadi, 1980). With the progressive intensification of cropping and the subsequent reduction in the fallow period, most soils cannot supply nutrients adequate enough to meet the requirements of crops (Balasubramanian & Nnadi, 1980).

The use of inorganic fertilizers may, therefore, seem inevitable if the food needs of most economies of sub-Saharan Africa, with an average growth rate of 3 per cent per year, are to be met (McNamara, 1985; Anane-Sakyi, 1995). However, the high prices of chemical fertilizers have hindered their use (Mulongoy & Akobundu, 1992) by most small-scale farmers in Ghana (Anane-Sakyi, 1995).

New technologies that do not only enhance food production but also maintain ecological stability and preserve the natural base of the soil need to be developed (IITA/AABNE, 1992). Planting of leguminous plants, purposely selected for their ability to protect the soil and restore its fertility, is an attractive alternative (Cobbina, 1992). The selected legumes should be able to regenerate degraded soil physical conditions and restore organic matter and nutrients at a relatively fast rate (Cobbina, 1992). The production of biomass and the nitrogen content of mucuna vary widely under different agro-climatic conditions, age of the crop, and soil management practices (Meelu *et al*., 1992). The accumulation of N and dry matter yield are related to the age of the legume species (Meelu *et al*., 1992). Dry matter yield of mucuna may range from 2 to 10 t ha^{-1} within 16 to 18 weeks after planting (WAP), depending on the climatic conditions within the year (Balasubramanian & Sekayange, 1992). The N yield of mucuna varies from 182 to 252 kg ha^{-1} (Meelu *et al*., 1992).

For the beneficial effects of mucuna to be accrued, it must be properly managed (Prinz, 1986). Management factors which affect the N yield of the legume include height and frequency of trimming, plant density and spacing, and also the timing of trimming during the cropping season (Duguman, Kang & Okali, 1988; Kang, Reynolds & Attah-Krah, 1989). The formation of effective nodules also has an influence on the N yield of the legume cover crop (Giller & Wilson, 1991).

The objectives for the study were to examine the regenerative capacity of mucuna, to establish the most appropriate frequency of trimming mucuna for the establishment of an arable crop of maize, and to determine the relationships among factors that influence the management of mucuna.

Materials and methods

The study was conducted on an Ochrosol (Brammer, 1962) or Acrisol (FAO/UNESCO, 1988) at the University of Cape Coast Teaching and Research Farm in the Central Region of Ghana.

Six plots (each measuring 4 m × 12 m) were established. Each plot was partitioned into two sub-plots with dimensions of 4 m × 6 m and 4 m × 6 m. The sub-plots were used to determine N yield, biomass accumulation and nodule count, and also for studying the regenerative capacity of mucuna. The mucuna was established on the plots at an intra-row spacing of 40 cm and inter-row spacing of 80 cm.

The results on canopy closure were taken from the other sub-plots. The plants were trimmed at the inter-row positions and the number of days to the second canopy closure recorded. Two more successive trimmings were applied and the days to canopy closure recorded. The amount of fresh biomass collected from each trimming and the litter biomass at the time of each trimming were also measured.

The sub-plots were used to determine dry matter yield, N accumulation, and nodulation. The above-ground fresh biomass within a 1 m × 1 m quadrant was randomly sampled. The dry matter content was determined following the procedure of Anderson & Ingram (1993). The fresh biomass was oven-dried at 60 °C for 48 h and the dry matter yield determined. The total N content of mucuna was determined following the procedure of Stewart *et al.* (1974). The root system of the plant was removed from the soil using a 60 cm × 40 cm metal cylinder. The soil, together with the roots, was soaked in a basin of water and the nodules sorted out and counted. A sharp razor blade was used to dissect the nodules and the transverse sections viewed under a microscope to detect any pinkish colouration. The total number of nodules with the pinkish colouration was recorded as the number of effective nodules produced per plant.

Results and discussion

Regenerative capacity and biomass yield of Mucuna pruriens *var.* utilis

The canopy formed by the above-ground parts of mucuna was completely closed 55 days after planting (Table 1). The large foliage and vigorously growing vines of mucuna could cover the ground completely within a short period (Haririah, 1992), and subsequently suppressed most obnoxious weeds.

TABLE 1

Period for Complete Ground Cover After the Establishment and Management of Mucuna pruriens *var.* utilis

Canopy closure	*Number of days to canopy closure*	*SE*
After planting	55	2
After first trimming	34	1
After second trimming	32	4
After third trimming	36	1

Values are means of six replications
SE is the standard error of means

The ground was completely covered for the three successive trimmings of mucuna between 26 and 34 days. The regeneration of mucuna live-mulch after the first trimming was slower, but became more rapid after the third trimming. The management of mucuna could have induced a more vigorous vegetative growth after each successive trimming as has been observed by Kang & Mulongoy (1992).

The number of days taken to attain complete ground cover after trimming is an important parameter in managing a live-mulch of mucuna, especially when it is incorporated with an arable crop of maize. Table 2 shows the estimated frequency of trimming which may be required for different varieties of maize at varying periods of the establishment of the live-mulch of mucuna. The number of trimmings required to establish an arable crop of maize is minimal when the management (trimming) of the live-mulch of mucuna is started 90 DAP for cultivation of late-maturing maize (Okomasa) varieties (Table 2). Consequently, the labour costs involved in trimming mucuna intercropped with maize could be reduced. This is desirable because, according to Mulongoy & Akobundu (1992), labour intensity can make the adoption of a technology by the smallholder farmer difficult because of increased production costs.

The fresh biomass yield of three successive trimmings of mucuna ranged from 5943 to 12378 kg ha^{-1} (Table 3). The fresh biomass derived from the first trimming was the highest. This could be due to the longer period over which photosynthates accumulated in the plant. There was a good positive correlation between biomass yield and age of the leguminous crop ($r = 0.90$, $P < 0.01$). The fresh biomass yield was greater for the third trimming than for the second (Table 3). Management practices such as pruning and trimming temporarily disrupted the source of photosynthates, resulting in a rapid senescence of part of the root system and leaves (Kang & Mulongoy, 1992). When plants are trimmed a second time, root and leaf development is stimulated (Kang & Mulongoy, 1992). There could have been a consequential increased accumulation of photosynthates (and hence biomass) after each successive trimming. This possibly accounts for the higher biomass yield of the third trimming compared to the second.

TABLE 2

Trimming Frequency for Different Maize Varieties at Varying Periods of Mucuna pruriens *var.* utilis *Live-mulch Establishment*

Time of trimming (days after planting mucuna)	*Number of trimmings required**	
	Early-maturing maize (75-day variety)	*Late-maturing maize (120-day variety)*
60	1	2
75	0	2
90	0	1

* Number of trimmings estimated by considering that no trimming is required at 165 days after planting when the vegetative growth of mucuna is less vigorous, and at 180 days after planting when the plant dries up and produces seeds.

TABLE 3

Biomass Yield of Mucuna pruriens *var.* utilis

Period	*Biomass yield (kg ha^{-1})*	
	Fresh (Mean ± SE)	*Litter (dry) (Mean ± SE)*
At first trimming	12364 ± 23	557 ± 2
At second trimming	5941 ± 8	914 ± 19
At third trimming	7209 ± 7	469 ± 5

* Means of six replications

Dry litter biomass was greatest at the second trimming and smallest at the third (Table 3). Although litter biomass is directly related to fresh biomass accumulation (Salisbury & Ross, 1978), trimming has a greater influence on litter biomass accumulation. After the first trimming, the senescence and abscission of leaves was greater (Kang & Mulongoy, 1992). This could account for the higher litter biomass production at the second trimming compared to the first. The litter biomass was less at the third trimming compared to the second. This could be ascribed to the stimulation of root and leaf development and the reduced senescence and abscission of leaves (Kang & Mulongoy, 1992).

Effective nodule count and N yield of Mucuna pruriens *var.* utilis

The effective nodule count per plant varied from 4 (45 DAP) to a maximum of 63 (120 DAP) (Table 4). The effective nodule count was minimal 45 DAP owing to the many developing and immature nodules. The increased number of active nodules between 90 and 135 DAP mucuna ensured a higher legume-rhizobium symbiosis and nitrogen fixation. This led to the progressively increased accumulation of nitrogen in *M. pruriens* (Table 4). The N could be available to an associated non-legume through sloughing of nodules, decay of root systems, and decomposition of vegetative materials in the soil.

As much as 179 kg N ha^{-1} (90 DAP) was accumulated (Table 4). Studies on N mineralization and total nutrient uptake of *M. pruriens* have shown that 60 kg N ha^{-1} mineralizable N is provided for plant use when incorporated into the soil 90 DAP, and 45 kg N ha^{-1} subsequently used by an intercrop of early-maturing (75 days) maize variety (Ahmed, 2001). *Mucuna pruriens* can, therefore, be a major source for supplementing the nitrogen reserves in the soil.

Relationships among factors that influence management of live-mulch (management factors)

The N yield of mucuna correlated positively with number of days after planting ($r = 0.920$, $P < 0.001$) (Table 5). The linear relationship relating N yield to number of days after planting was expressed by the regression equation as $Y = 1.83 (X) – 32.25$, where Y is the N yield (kg ha^{-1}) and X is the number of days after planting mucuna. Eighty-five percent of the variation in N yield

TABLE 4

Effective Nodule Count and N Yield of Mucuna pruriens *var.* utilis

Days after planting mucuna	*Effective nodules per plant*	*N yield (kg ha^{-1})*
45	4	28.12
60	9	53.80
75	13	107.14
90	26	179.11
106	38	191.31
120	63	198.88
135	59	205.77
150	53	208.70

* Means of six replications

could be attributed to the age of the plant. Evans *et al*. (1989) have also reported significant linear relationships between N yield and age of some leguminous plants, implying that the accumulation of N in mucuna is affected by the age of the plant and increases as a function of time. As the plant develops, more soil N is absorbed and the plant fixes much atmospheric N, if factors affecting N fixation are favourable (Giller & Wilson, 1991). Factors such as moisture stress, high soil temperature, inadequate aeration, soil acidity, and nutrient (P, Ca, Mg and Mo) deficiencies adversely affect N fixation (Giller & Wilson, 1991). If these factors are unfavourable and limiting, the accumulation of N in the leguminous plant could be hindered and the N content may decrease over time (Morris *et al*., 1986).

The linear relationship between N yield and fresh biomass yield was significant with a correlation coefficient of 0.980 (Table 5). The regression of N yield on fresh biomass yield was expressed by the regression equation as Y = 0.004 (X) – 14.32, where Y is the N yield (kg ha^{-1}) and X is the fresh biomass (kg ha^{-1}). A positive correlation was also established between N yield and dry matter yield ($r = 0.94$, $P < 0.001$) (Table 5). This relationship was represented by the regression equation as Y = 0.02 (X) – 10.21, where Y is the N yield (kg ha^{-1}) and X is the dry matter yield (kg ha^{-1}).

The results of the study showed that 88 and 96 per cent of the variation could be accounted for by dry matter yield and fresh biomass yield, respectively. Tisdale *et al*. (1993) also found significant positive correlations between N yield and biomass yield for different legume species. An increase in the biomass yield of mucuna could result in an increase in the quantity of N fixed, if the factors affecting N fixation are not limiting.

TABLE 5

Simple Linear Correlation Coefficient Between Variables Influencing the Management of Mucuna pruriens *var.* utilis

Variable	*N yield*	*Days after planting*	*Fresh biomass yield*	*Dry matter yield*	*Litter biomass*
N yield	-	-	-	-	-
Days after planting	-0.920**	-0.840*	-	-	-
Fresh biomass yield	0.980***	0.840*	-	-	-
Dry matter yield	0.970**	0.830*	0.990***	-	-
Litter biomass	0.870**	0.980***	0.780**	0.760*	-
Effective nodules	0.850**	0.930***	0.820**	0.790*	0.950***

* Significant at $P < 0.05$
** Significant at $P < 0.01$
*** Significant at $P < 0.001$

Nitrogen fixation depends on the photosynthate available to the leguminous plant (Ayanaba, 1980). A high legume biomass could result in more radiant energy being intercepted and more photosynthates being produced, resulting in an increase in nodule activity. Ayanaba (1980) supported this assertion by reporting that the inadequate supply of assimilates to root nodules results in a decline in nitrogenase activity and subsequently reduced N fixation. Nitrogen yield correlated positively with the number of effective nodules per plant (r = 0.850, P<0.01) (Table 5). The regression equation representing this linear relationship was Y = 3.57 (X) + 34.21, where Y is the N yield (kg ha^{-1}) and X is the number of effective nodules per plant. Seventy-two percent of variation in N yield could be attributed to the number of effective nodules.

Effective nodules are considered to be those that contain the nitrogenase enzymes. Nitrogenase enzymes contain iron-sulphur proteins, referred to as non-haem iron proteins (leghaemoglobin) (Giller & Wilson, 1991), which impart a pinkish colouration to the cortex of the root nodule. The N is reduced to NH_3 by nitrogenase enzymes, which occur in root nodules. The presence of root nodules containing the nitrogenase enzyme (effective nodules) will result in the efficient fixation of N_2 (Giller & Wilson, 1991). This could account for the close relationship between N yield and the number of effective nodules formed. However, because 72 per cent of the variation in N yield could be attributed to the number of effective nodules, other factors such as soil moisture regime, soil temperature, nutrient levels, and the legume species could account for the variation in N yield of mucuna. When these factors are limiting, the survival or rate of growth of free-living microorganisms is reduced (Giller & Wilson, 1991). The process of plant infection and nodule development may be interrupted and ineffective nodules are produced. Accordingly, N fixation will be hindered even after an initial symbiosis has been established between the microorganisms and the legume (Giller & Wilson, 1991).

The coefficient of determination (R^2) for the significantly correlated relationships between N yield and the other *M. pruriens* management factors ranged from 0.720 to 0.980. This implied that each of the management factors was a good predictor of the N yield of mucuna. The most closely related variables to N yield were fresh biomass and dry matter yields, which accounted for between 85 and 96 per cent of the variation in N yield. Fresh biomass and dry matter yields could, therefore, be the final choice as the most appropriate variables that can be used to predict the N yield of mucuna. This is relevant in estimating the N yield of mucuna.

A significantly high correlation was observed between fresh biomass and dry matter yields (Table 5). The linear relationship established between fresh biomass and dry matter yields was expressed as Y = 0.204 (X) – 198.85, where Y is the dry biomass yield (kg ha^{-1}) and X is the fresh biomass yield (kg ha^{-1}). Fresh biomass yield accounted for 99 per cent of the variation in dry matter yield, and could be reliably used to predict dry matter yield. A linear relationship between dry and fresh biomass has been reported by Salisbury & Ross (1978) who explained that the dry matter yield of above-ground parts of non-woody plants constituted 10 to 20 per cent of the fresh biomass.

The correlation coefficient recorded when biomass (fresh and dry) yield was regressed on litter biomass was significant at the 5 per cent level (Table 5). The accumulation of above-ground biomass over time was initially slow. As more biomass accumulated, litter biomass increased more rapidly owing to the greater extent of leaf senescence and abscission (Salisbury & Ross, 1978).

Fresh biomass and dry matter yields were correlated to the number of days after planting (Table 5). Meelu *et al*. (1992) have also reported a significant linear relationship between dry matter production and the age of some leguminous crops used for green manuring. The cumulative effect of the interception of more radiant energy, absorption of water, and the use of carbon dioxide to synthesise carbohydrates over time (Salisbury & Ross, 1978) could be the reason for the increase in biomass yield.

Conclusion

The vigorously growing leguminous cover crop of *Mucuna pruriens* var. *utilis* could ensure complete ground cover after 2 months of establishment. Within this time span, the thick carpet of mucuna suppressed all obnoxious weeds.

The study showed that it would be appropriate to trim *M. pruriens* two times (at 60 DAP and 34 days after the first trimming) during the intercropping of a late-maturing maize crop. This could ensure minimal effects of competition between the live-mulch and the maize crop. Labour costs involved in managing the live-mulch could also be reduced. Small-scale farmers, with limited resources at their disposal, may not adopt live-mulch cropping if it is more labour-intensive than the traditional cropping systems.

The significantly positive correlation coefficients and high coefficients of determination between biomass yield and N yield signified that biomass yield (fresh and dry) could be good predictors of N yield of *M. pruriens*. The N yield of fresh biomass, managed and immediately applied to the soil, could be estimated from the regression equation relating N yield to the fresh biomass yield of *M. pruriens*.

The accumulation of N in *Mucuna pruriens* var. *utilis* was quite substantial. It ranged from 107 kg ha^{-1} within 75 days to 209 kg ha^{-1} after 150 days of establishment of the live-mulch of *M. pruriens*. Adequate mineralizable N could be provided for use by an intercrop of early-maturing (75 days) maize variety when incorporated around flowering time and when incorporated into the soil at 90 DAP for late-maturing maize.

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