Nitrogen mineralization trends of applied *Mucuna pruriens* var. *utilis*

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ABSTRACT

The effect of method of applying *Mucuna pruriens* var. *utilis* on the release of mineral nitrogen in an acid soil was investigated in the laboratory. The above-ground parts of *M. pruriens* were dried, milled and applied at a rate of 0.3 g 100 g^{-1} of field moist soil. Two methods of applying milled *M. pruriens* were used, namely surface application (T2) and incorporation (T3). The control treatment (T1), involving soil only, was also used. The treated soil samples were incubated at room temperature for periods ranging from 0 to 90 days while maintaining their contents at 60 per cent water holding capacity. At the end of the appropriate incubation period, the mineral N contents of the soil samples were measured by extracting soil with 2 *M* KCl, filtered and the filtrates were then steam-distilled. The mineral N released increased with increasing incubation period. The T1, T2 and T3 had cumulative NH_4^+-N values of 5, 5 and 8 kg ha^{-1}, respectively, after the 90 days' incubation period. The incorporation treatment had the largest amount of NO_3-N (66 kg ha^{-1}), followed by the surface application treatment (54 kg ha^{-1}). The control treatment had the least (10 kg ha^{-1}). The soil into which *M. pruriens* was incorporated (T3) had larger cumulative amount of mineral N (74 kg ha^{-1}) than either T2 (59 kg ha^{-1}) or T1 (15 kg ha^{-1}). The efficiency of mineral N released from *M. pruriens* was 45 per cent for T2 and 61 per cent for T3. The results indicated that *M. pruriens* var. *utilis*, when applied to the soil, could be a potential source of mineral N for crop production.

RÉSUMÉ

AHMED, M. R., OSEI, B. A. & BONSU, M. : *Les tendances de la minéralisation d'azote de* Mucuna pruriens *var.* utilis *appliqué.* L'effet de la méthode d'application de *Mucuna pruriens* var. *utilis* sur le dégagement d'azote (A) minéral dans un sol acide était enquêté au laboratoire. Les parties au-dessus du sol de *M. pruriens* étaient séchées, moulues et appliquées á raison de 0.3 g 100 g^{-1} de sol humide du champ. Deux méthodes d'application de *M. pruriens* moulue étaient employées: à savoir, application superficielle (T2) et incorporation (T3). Le traitement de contrôle (T1) consistant le sol seulement était utilisé. Les prélèvements de sol traités étaient incubés à une température ambiante pour des périodes variant entre 0 et 90 jours en gardant le contenu d'eau à 60% de la capacité de rétention d'eau. A la fin de la période d'incubation appropriée, les contenus de minéral A de prélèvements de sol étaient mésurés par l'exraction du sol avec 2 *M* KCl, filtrés et les filtrats étaient ensuite distillés à vapeur. Le minéral A dégagé augmentait avec la prolongation de la période de l'incubation. Les T1, T2 et T3 avaient les valeurs cumulatives de NH_4^+-N de 5, 5 et 8 kg ha^{-1}, respectivement, après la période de 90 jours d'incubation. Le traitement d'incorporation avait la quantité élevée de NO_3-N (66 kg ha^{-1}) suivi par le traitement d'application superficielle (54 kg ha^{-1}). Le traitement de contrôle avait la moindre (10 kg ha^{-1}). Le sol dans lequel *M. pruriens* était incorporé (T3) avait la quantité cumulative plus élevée *du minéral* A (74 kg ha^{-1}) que le T2 (59 kg ha^{-1}). L'efficacité de dégagement de minéral A de *M. pruriens* était 45% pour T2 et 61% pour T3. Les résultats indiquent que *M. pruriens* var. *utilis* lorsque appliquée au sol, pourrait être une source potentielle de minéral A pour la production culturale.

Introduction

The traditional slash-and-burn agriculture, which was successful in the past because of its characteristic long fallow periods, can no longer sustain the productivity of soils in Ghana (Agyenim-Boateng, 1997). It is not possible in many parts of the country to maintain the long fallow periods crucial for the regeneration of the

soil's inherent fertility (Kang & Mulongoy, 1992) owing to the increasing demand for land resulting from rapid population growth and the changing socio-economic structures (Kombiok, Rudat & Frey, 1995).

The slow natural regrowth is ineffective in restoring the productivity of the soil (Agboola, 1980), and this has resulted in a breakdown of the natural system for replenishing soil fertility and a subsequent decline in crop yields (Ofori, 1980). The use of high-energy inputs such as inorganic fertilizers offers a possible solution to the problems of low soil fertility and consequent poor crop yields (Quarshie-Sam, 1995). However, in Ghana the removal of agricultural subsidies and the decline in imports of mineral fertilizer have made prices of inorganic fertilizers unaffordable, resulting in a decline in fertilizer use (Ofori & Fianu, 1996). The resource-poor or smallholder farmer cannot, therefore, adopt high chemical-input agriculture because of the economics of using inorganic fertilizers (Mulongoy & Akobundu, 1992).

The need is to consider alternative nutrient management systems and adopting low-input technologies such as managing leguminous cover crops that are not only sustainable, but also economically viable (Mulongoy & Akobundu, 1992). The soil restorative and protective value of leguminous cover crops such as *Mucuna pruriens* are well known (Akobundu & Okigbo, 1984).

Mucuna pruriens can produce 11 kg ha^{-1} of dry matter and accumulate 206 kg N ha^{-1} within a period of 135 days after establishment (Ahmed, 2001). The rate of release of mineral N has been extensively measured for most species, but that for mucuna is limited.

The study aimed to determine the release of mineral N (NH_4^+ and NO_3^-) in the soil that could be subsequently made available for crop use over a 3-month period under different methods of applying *M. pruriens* var. *utilis*.

Materials and methods

Soil

The soil used for the study belongs to the Benya series (Asamoah, 1973). It is classified as Savanna Ochrosol in the Ghana soil classification system (Brammer, 1962) and as Acrisol in the FAO-UNESCO world soil map legend (FAO-UNESCO, 1988). Table 1 presents some physico-chemical properties of the soil.

TABLE 1

Some Physico-chemical Properties of the Soil

Soil property	Value
Texture - Bouyoucos hydrometer method (Anderson & Ingram, 1993)	
Sand (%)	71
Silt (%)	11
Clay (%)	18
Total porosity (%) (Anderson & Ingram, 1993)	45
Organic carbon (%) - Wet oxidation method (Walkley & Black, 1934)	0.7
Total N (%) - Micro-Kjeldahl method (Anderson & Ingram, 1993)	0.07
(NH_4^+ + NO_3^-) (mg kg^{-1} soil) - Double distillation (Rowell, 1994)	1.8
Extractable P (mg kg^{-1} soil) - Bray-1 (Anderson & Ingram, 1993)	16.3
*p*H (1: 2.5 - soil : water) (Anderson & Ingram, 1993)	5.7
Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) (cmol$_c$ kg^{-1} soil) - ammonium acetate (at *p*H 7) method (Rowell, 1994)	3.11
Effective CEC (cmol$_c$ kg^{-1} soil) (Anderson & Ingram, 1993)	3.63

Incubation experiment

The soil used for the incubation study was a composite soil sample of 40 cores taken from the field at a depth of 20 cm. The field moist soil sample was passed through a 2-mm sieve. Three treatments were applied to three sets of soil samples: control (150 g of field moist soil only) (T1), 0.3 g of *M. pruriens* var. *utilis* surface-applied to 150 g of field moist soil (T2), and 0.3 g of *M. pruriens* incorporated into 150 g of field moist soil (T3). Each of the treated samples was kept in a 250-ml conical flask and incubated at room temperature for a period ranging from 0 to 90 days. The soil samples were kept at 60 per cent water holding capacity during incubation by determining the gravimetric moisture content of the soil at field capacity and at room temperature in laboratory at the beginning of incubation. The gravimetric moisture of the latter was 60 per cent of the former.

Distilled water was sprayed into each soil sample in the conical flasks daily to maintain its initial weight. The above-ground parts of *M. pruriens* were oven-dried at 60 °C until the weight was almost constant and, thereafter, milled and applied to the soil. The rate of 0.3 g per 150 g field moist soil was equal to the dry matter yield of 5421 kg ha^{-1} recorded at 75 days after planting (Ahmed, 2001). *Mucuna pruriens* was chosen because of its high rate of accumulation of biomass.

At the end of the appropriate incubation periods, 50 ml of 2.0 *M* KCI were added to 40-g soil samples and shaken for 1 h. The suspension was filtered through Whatman No. 42 filter paper, and the NH_4^+-N and also NO_3^+-N contents of the extract were determined by steam distillation (Rowell, 1994). The aliquot of the extract was steam-distilled into 10 ml of 2 per cent boric acid after adding 0.5 g of ignited magnesium (II) oxide (MgO). The distillate was titrated against 0.01 *M* hydrochloric acid (HCI) to determine NH_4^+ -N. After adding 0.5 g of Devarda's alloy, a second distillation was done and NO_3^+-N determined by titration with 0.01 *M* HCI (Rowell, 1994). The total mineral N was then calculated by the summation of the values determined for NH_4^+-N and NO_3^+-N.

The percent mineral N release efficiency (% MNRE) was determined using the formula: % MNRE = [(Nx - N1)/QN] × 100, where Nx = mineral (N) released in treatment X (kg ha^{-1}), N1 = mineral (N) released in control treatment (kg ha^{-1}), and QN = quantity of mineral (N) in the managed above-ground parts of *M. pruriens* var. *utilis* in kg ha^{-1}, determined to be 97 kg ha^{-1}.

Results and discussion

NH_4^+-N release

Table 2 presents the amounts of NH_4^+-N released over the incubation period. The ammonium-N release in *M. pruriens* var. *utilis*-incorporated soil samples (T2) was the highest and peaked earliest at 30 days after incubation (DAI), but declined thereafter (Table 2). The treatment effect on the amount of NH_4^+ released was significant ($P < 0.01$) over the incubation period, with the NH_4^+-N

TABLE 2

Cumulative NH_4^+-N Released (kg ha^{-1}) under Different M. pruriens *var.* utilis *Management Practices*

Management practice*	Days after incubation						
	0	*15*	*30*	*45*	*60*	*75*	*90*
T 1	5	6	10	7	6	6	5
T 2	5	11	15	22	19	15	5
T 3	5	29	36	28	23	20	8
LSD (0.05)	0.9	1.1	1.5	2.8	1.3	0.6	0.4

* T1 = soil only
  T2 = soil + surface-applied mucuna
  T3 = soil + incorporated mucuna

released being higher in T3 than in the other treatments. The activities of soil micro flora and fauna, which are important in the mineralization process, are enhanced with incorporation compared to non-incorporation, and this could explain the higher NH_4^+-N values in T3. Incorporating green manure helps to improve the pore volume of soil, which is conducive to the activity of soil microbes (Balasubramanian & Nnadi, 1980) such as saprophytic and heterophytic bateria, fungi and protozoa involved in ammonification process (Harris, 1988).

The cumulative NH_4^+-N was higher from the 15th to the 75th DAI for surface-applied mucuna (T2) than the control treatment (T1) because of the ammonification process in T2. Generally, there was a decrease in the amount of NH_4^+-N released after 45 days of incubation for T1, T2 and T3. This could be due to the process of nitrification, mainly by autotrophic bacteria involved in oxidising ammonium to nitrate (Alexander, 1977). Losses through volatilisation of ammonia (NH_3) might have contributed to the amount of NH_4^+-N released (Harris, 1988), because the set-up was not air-tight.

NO_3^- -N release

The release of NO_3^--N was markedly higher for T2 and T3 than T1 (Table 3). This could be ascribed to the conversion of NH_4^+ -N derived from milled *M. pruriens* in T2 and T3. If external environmental factors such as oxygen supply, temperature and moisture are not limiting, autotrophic bacteria will transform NH_4^+ into NO_3^- *via* NO_2^- (Alexander, 1977).

The amount of NO_3^- -N released from *M. pruriens* -incorporated soils (T3) was significantly greater than the values for T1 and T2. Improvement in the physical properties of the soil (Davies, Eagle & Finney, 1975; Dalzell *et al.*, 1987) and greater rate of oxidation of NH_4^+-N to NO_3^- -N through increased soil microbial activity could have accounted for the difference (Balasubramanian & Nnadi, 1980). Alexander (1977) observed that adequate oxygen supply and aeration stimulated the activities of bacteria, and the release of NO_3^- -N was more rapid.

Because in acidic soil environments nitrification proceeds slowly even in adequate supply of substrate (Alexander, 1977), the acid condition (*p*H 5.7) of the incubated soil might have, therefore, limited the release of NO_3^--N within the first 30 DAI for all the treatments.

Mineral N release

Fig. 1 shows the amounts of total mineral N ($NH_4^+ + NO_3^-$). The total N mineralization was very rapid in T3 within 15 days of incubation but, thereafter, decreased markedly. The total mineral N was significantly greater in T3 than in T1 and T2. For T2, the rapid phase of mineral N release lasted for 30 DAI, after which it slowed down till the 90th day. The pattern of N mineralization of *M. pruriens* was, therefore, one of an initial fast rate followed by a relatively slow phase. This agrees

TABLE 3

Cumulative NO_3^--N Released (kg ha^{-1}) under Different M. pruriens *var.* utilis *Management Practices*

Management practice*	Days after incubation						
	0	15	30	45	60	75	90
T 1	2	2	5	8	9	9	10
T 2	2	7	15	19	29	39	54
T 3	2	13	20	36	47	53	66
LSD (0.05)	0.4	0.5	1.1	0.6	0.4	0.2	0.4

* T1 = soil only
  T2 = soil + surface-applied mucuna
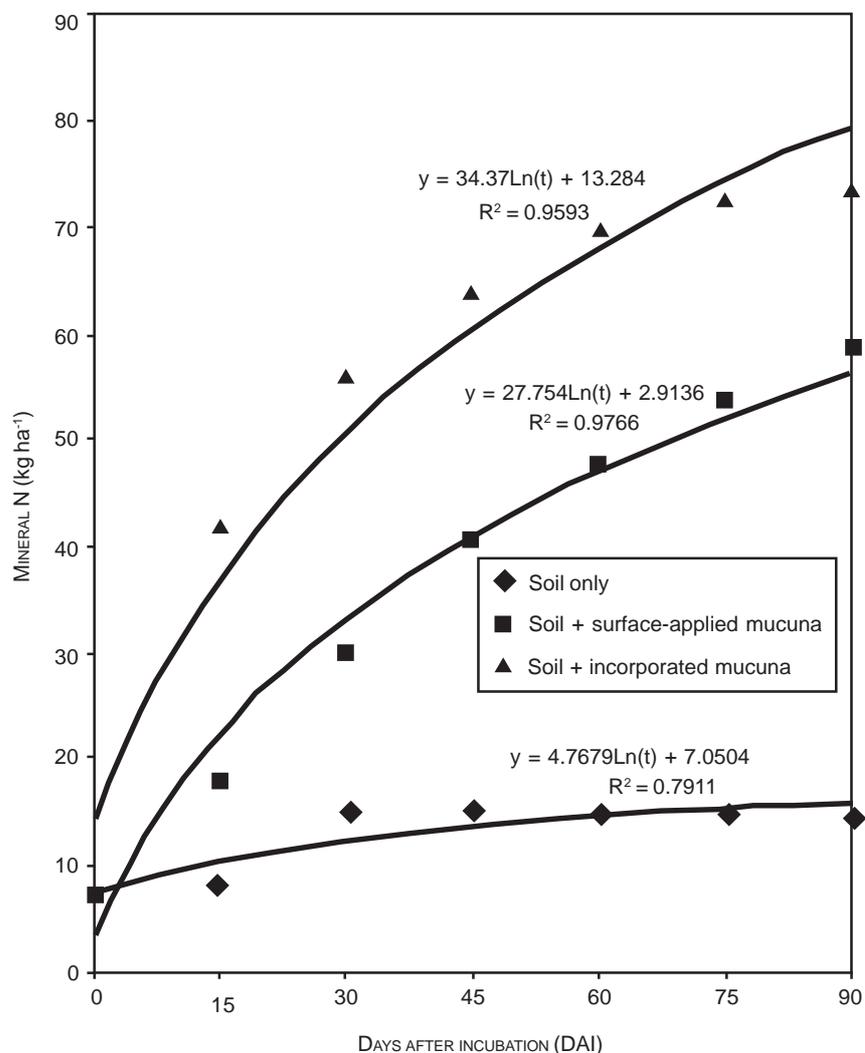 T3 = soil + incorporated mucuna

Fig. 1. Mineral N release in mucuna-treated soils as affected by period of incubation.

with the observation by Bhardwaj & Dev (1985) that nitrogen mineralization kinetics of leguminous plants under aerobic conditions can be modelled by two simultaneous first-order reactions–an initial fast reaction followed by a slow release of inorganic N.

Substrate quality, especially its N content, pH and microbial activity are important in influencing the two-phase reaction of the mineralization process (Yadvinder-Singh *et al*., 1988). Mahmoud & El-Sawy (1982) expressed a similar view with their work on soil samples incubated with different legume species. They concluded that the growth of microorganisms during the first 60 days of incubation exhausted the supply of nutrients from the substrate, resulting in a subsequent decrease in their numbers. The availability of N in the substrate (substrate quality) and extent of microbial activity are, hence, factors that may be directly related to the rate of N mineralization.

The total mineral N released over the 90-day incubation period ranged from 15 to 74 kg ha^{-1} for the different treatments (Table 4). The total mineral N released over the incubation period was greater for T3 than the other treatments. This might be due to an expected increased pore volume during incorporation and increased microbial activity in the ammonification and nitrification process for the incorporated treatment. Groffman *et al.* (1987) reported that the release of nutrients from incorporated legumes was twice as fast as that from the surface-applied ones. The amount of mineral N contributed by mucuna in amended soils ranged from 44 to 59 kg ha^{-1} (Table 4). There was a higher and more efficient release of mineral N from *M. pruriens* in mucuna-incorporated soils compared with the surface-applied mucuna soils (Table 4). The amounts of mineral N released from mucuna (44 to 59 kg ha^{-1}) could meet the nutritional demand of some crops (NARP/CSIR), 1988).

Conclusion

The incorporation of *M. pruriens* var. *utilis* in soil produced the highest amount of inorganic N compared with the other treatments. It can, therefore, be inferred that within the limits of the experimental conditions, it would be preferable to incorporate *M. pruriens* for maximum release of available N. Appreciable quantities of mineral N that could meet the N requirement of some food crops were released from soils treated with mucuna.

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TABLE 4

Percent Mineral N Release Efficiency (%)

Management practice	Total mineral N released (kg ha^{-1})	Increase in mineral N over control (kg ha^{-1})	Efficiency of mineral N release (% MNRE)*
Soil only (control)	15	-	-
Soil + surface-applied mucuna	59	44	45
Soil + incorporated mucuna	74	59	61

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