

Influence of Method of Residue Application and Moisture Content on Water Soluble Nitrogen in a Rhodic Kandiustalf Amended with Different Fallow Plant Materials

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Abstract

Use of plant residues as nutrient sources presents a viable option to resource poor farmers who sparsely use mineral fertilizer in crop production. A study was conducted to gain an insight into how different application methods of residues from different fallow management systems under two moisture regimes would affect soluble N release in a Rhodic Kandiustalf. Three residue types viz, elephant grass from a natural fallow (T1) and another as a fallow following a previously fertilized maize (T2) and a fallow legume (T3) were surface applied and incorporated in a Rhodic Kandiustalf at both field capacity (FC) and 60% field capacity over a sixteen-week period. Incorporation of mucuna residues and elephant grass from previously fertilized maize fallow released similar soluble N levels which were higher than levels from the natural elephant grass amendments. At 60% FC, both mucuna and elephant grass from the fertilized maize fields that were surface applied had slower N releases than the grass from the natural fallow, suggesting the elephant grass from the natural fallow field could be used as an N source amidst light watering to avoid leaching in the dry season.

Introduction

The age old practice of slash and burning of bush and crop residue as methods of land clearing for farming in West Africa and particularly Ghana has led to low levels of organic matter and consequently nitrogen in soils (SRID, 2007; Obiri-Nyarko, 2012). To obtain appreciable crop yields therefore, the application of external nutrient sources has become imperative. Application of inorganic fertilizers at recommended crop rates has not been feasible for most of the poorly resourced small scale farmers in Ghana due to a myriad of reasons, chief of which is the high cost of fertilizers. Majority of these farmers are in the rural areas where fertilizer products are also not readily available. Consequently, average fertilizer use on cropped lands in Ghana is less than 5 kg ha⁻¹ (FAO/IFA, 2005).

To help alleviate the problem of soil fertility decline, the use of organic nutrient sources such as animal manure has been suggested

as a very important option (Kumar and Goh, 2000). On a larger scale however, the use of animal manures particularly from ruminants may not be feasible due to very low stocking densities and the extensive system of animal management which does not allow for large volume of animal waste concentration at a single location in most parts of Ghana. Additionally, high haulage costs and labour requirements involved in the application of animal manure at crops' nitrogen recommended rates make its use unattractive to many Ghanaian farmers whose farms are more often than not far removed from the livestock housing units. Weed infestation of farms upon application of cow dung has also been a major disincentive.

When returned to the soil and properly managed, crop residues are important sources of N for succeeding crops. Crop residues are very cheap and readily available especially in all the agro-ecological zones except the

Guinea and Sudan Savannas which have the uni-modal rainfall pattern. When used as inputs in cropping systems, crop residues are known to improve the physico-chemical properties of the soil (Dowuona et al., 2011; Kumar and Goh, 2000). Soil management systems based on the application of crop residues either solely, or in combination with inorganic fertilizers have been demonstrated as a viable means of soil fertility maintenance and improvement in aggregate stability of soils in low input agricultural systems (Dowuona et al., 2011; Isaac et al., 2000). Farmers can therefore, make good use of crop residue after harvest for the benefit of ensuing crops or fallow crops. When the nutrient enriched residues are applied to the soil, the captured nutrients are released upon decomposition.

Ironically, most Ghanaian farmers resort to burning of crop residues as the predominant and cost effective method of disposal, especially, during land preparation (Dowuona et al., 2011). Disposal of crop residue by burning is often criticized for accelerating losses of soil organic matter (SOM) and nutrients, particularly nitrogen as well as reducing soil microbial activity with attendant losses in soil productivity (Kumar and Goh, 2000). To help address these concerns, some studies have been conducted on crop residue management in some soils in Ghana (Dowuona et al., 2011; Adiku et al., 2008). The focus of these studies however, has been on carbon storage in soils.

There are concerns however that cropping systems in which organic materials are used as the main source of nutrients may increase the risk of N losses to the plant (Stockdale et al., 2002). This is based on the assertion that when crop residues are applied, soil microbial

activity may lead to N release that is not in synchrony with plant nutrient demand and may therefore lead to N losses to the targeted crop. Processes that influence nitrogen release from organic materials are affected partly by the quality of the organic material itself and by other factors such as soil moisture, soil type, residue and the amount of inorganic fertilizer N applied (Mohammed et al., 2014; Adiku et al., 2008; Morecroft et al., 1998). The magnitude of N release from crop residues and the opportunities for managing soils to maintain soil productivity whilst minimizing the negative effects on the environment from N losses in Ghanaian soils have not been adequately investigated. Soluble nitrogen may be prone to major losses from soils, mainly through erosion and leaching if residue materials are not managed properly. These losses may result in eutrophication of surface water bodies and pollution of groundwater sources. An understanding of the dynamics of N release from applied crop residues is a pre-requisite to maximizing plant uptake and consequently minimizing N losses from soils.

In the determination of available nitrogen in soils, the convention has been to extract with KCl. Extraction of soil N with KCl targets NH_4^+ and NO_3^- - nitrogen at the soil exchange sites in addition to the ions in soil solution. It must be noted that in most studies on the nitrogen content of soils, not much attention has been given to water soluble nitrogen levels in soil which is the most readily available to plants. Additionally, information on residue type and application method in relation to solubility of NH_4^+ and NO_3^- in soils is scanty. This study therefore seeks to determine how soil moisture and the method of application of different residue types influence water soluble

nitrogen levels in a Rhodic Kandistalf.

Materials and method

A decomposition study was conducted using a Rhodic Kandistalf (Eze, 2008), one of the most widely cultivated soils in the Coastal Savanna zone of Ghana. The plough layer (0 – 20 cm) of the Rhodic Kandistalf, was sampled, air-dried and passed through a 2 mm sieve to obtain the fine earth fraction for some physico-chemical properties determination of the soil which are presented in Table 1.

The residues were chopped to an average length of 5 cm and part oven dried at 60 °C for some chemical property determinations. A residue application rate equivalent to 3.02 tonnes per hectare based on the estimated average yield of the fallow crop in an earlier field experiment was applied to each pot. For each residue type, there were two application methods, viz. surface application (SA) and incorporation (inc.). The soils with their respective amendments were then subjected to two different moisture regimes of field capacity (FC) and 60% field capacity (60% FC). Each

TABLE 1
Some physico-chemical properties of the soil used for the study*

| Sand | Silt | Clay | Bulk Density | pH | OC | TN | Av. P | CEC |
|-------------|------|------|--------------------|-------------------------|--------------------------|--------------------------|-----------------------------|------|
| -----%----- | | | Mg m ⁻³ | (H ₂ O: 1:1) | ----- g kg ⁻¹ | -----mg kg ⁻¹ | -----cmolc kg ⁻¹ | |
| 74.4 | 19.4 | 6.2 | 1.3 | 5.7 | 8.0 | 0.7 | 5.96 | 5.62 |

* TN = total nitrogen; Av. P = Available Phosphorus; OC = organic carbon; CEC = Cation Exchange Capacity

Decomposition study

A PVC pipe of approximately 18 cm internal diameter and height 20 cm formed a pot into which air dried bulk soil was packed to attain the 1.3 Mg m⁻³ field bulk density of the soil. Elephant grass (*Pennisetum purpureum*) harvested from two different soil management systems and mucuna (*Mucuna pruriens*) harvested from a third soil management system of an earlier study were used as three residue types for the mineralization study. Elephant grasses (T1) were harvested from a natural fallow field. Another elephant grass (T2) was harvested as a minor season fallow grass from a preceding fertilized maize plot. The mucuna, (T3) was harvested from a minor season mucuna fallow following maize as a major season crop. The control for the whole set-up was a no residue amendment.

treatment combination was in triplicate giving a 4 x 2 x 2 x 3 factorial experiment which was completely randomized to give a total of 48 experimental units. There were six of such arrangements to facilitate six-time destructive sampling. Thus in all, there were 288 pots. Six extra experimental pots were filled with the same quantity of soil as in the others but with no residue application. Three of the pots each were brought to the moisture levels of FC and 60% FC and their respective average daily loss in weight which was a reflection of daily loss of water was used as the basis for water additions to all the treatment pots to maintain their respective moisture contents. The pots were kept in a screen house at temperatures between 28 and 32 °C for incubation.

Sampling

A PVC pipe of internal diameter 2.54 cm

and length 18 cm was used as a borer for soil sampling from the pots. This was driven into the soil in the bigger PVC pots to collect soil samples for laboratory analyses. The soils were sampled at 1, 3, 5, 8, 12 and 16 weeks after amendment for laboratory determinations. On each sampling day, the sampled soil from each pot was homogenised and 20g taken for analyses. Deionised water was then added to the homogenized sampled soils to form a paste and the soil solution extracted with a vacuum pump. The NH_4^+ and the NO_3^- -N concentrations in the solution was determined using an Elit ion analyzer and the concentration of the nutrients per kilogramme of soil estimated.

Model fitting and statistical analysis

To describe the pattern of N release from the residues, a first order kinetic model was fitted to the cumulative N mineralized as;

$$y = a(1 - e^{-bx}) \quad [1]$$

where;

y = cumulative water soluble N released (mg kg^{-1});

b = observed first order rate constant of N release

x = time (week)

a = decomposable N fraction.

The soluble N release rates were then obtained by differentiating Eq. 1 with respect to x to yield

$$\frac{dy}{dx} = bae^{-bx} \quad [2]$$

Total water soluble N release over the sixteen-week period of the various treatment combinations and their respective rate constants obtained from the model were subjected to analysis of variance using Genstat 9. The means were then separated using the Tukey's test

Results

Some of the physico-chemical properties of the soil used for the study are shown in Table 1. The soil is a sandy loam with a bulk density of 1.3 Mg m^{-3} and a pH value of 5.7. The soil has a low organic carbon content of 5.8 g kg^{-1} , typical of Ghanaian soils. Consequently, total N and P are also very low with values of 0.7 g kg^{-1} and 5.96 mg kg^{-1} , respectively. The CEC of $5.62 \text{ cmol kg}^{-1}$ is low and characteristic of highly weathered tropical soil with low activity clay.

The chemical composition of the residue types used in the study are presented in Table 2. The organic matter content was higher in the grasses than in the legume and was in the order of $T2 > T1 > T3$ whilst the total nitrogen content was in the order $T3 > T2 > T1$. It is worthy of note that though the grasses T1 and T2 are of the same species, the T2 grass has almost 71 g kg^{-1} more C than its T1 counterpart and approximately 70% and 2.1 times more total N and P, respectively. The C:N ratios of the various residue types were respectively, 8.95, 16.82 and 24.30 for T3, T2 and T1 thus

TABLE 2
Some chemical properties of the residues used for the study*

| Residue type | OC (g kg^{-1}) | TN (g kg^{-1}) | Total P (mg kg^{-1}) | C:N |
|---------------------------|------------------------------|------------------------------|------------------------------------|-------|
| Pennisetum purpureum (T1) | 407.9 | 16.80 | 1520.0 | 24.30 |
| Pennisetum purpureum (T2) | 478.8 | 28.47 | 3250.1 | 16.82 |
| Mucuna pruriens (T3) | 359.0 | 40.13 | 2640.4 | 8.95 |

* OC = organic carbon; TN = total nitrogen; Total P = Total Phosphorus; C:N = Carbon: Nitrogen ratio

giving a reflection of the respective carbon and total nitrogen levels of the residues. The highest C:N ratio which was observed in the T1 grass was slightly above the critical value of 20 for net N mineralization with the others below. The water soluble nitrogen levels and

nitrogen release pattern was relatively slow pattern of release from the various treatment combinations are presented in Figures 1 and 2. For all treatment combinations, the pattern of release was very rapid within the first 8 weeks, accounting for about 70% of the total release within the study period. After week 8, the nitrogen release pattern was relatively slow

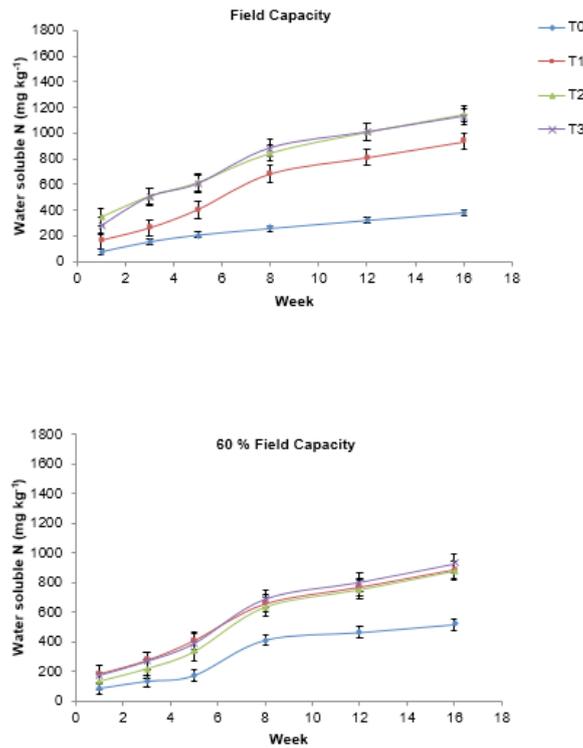


Fig. 1. Weekly water soluble nitrogen release for surface applied residues at the two moisture levels

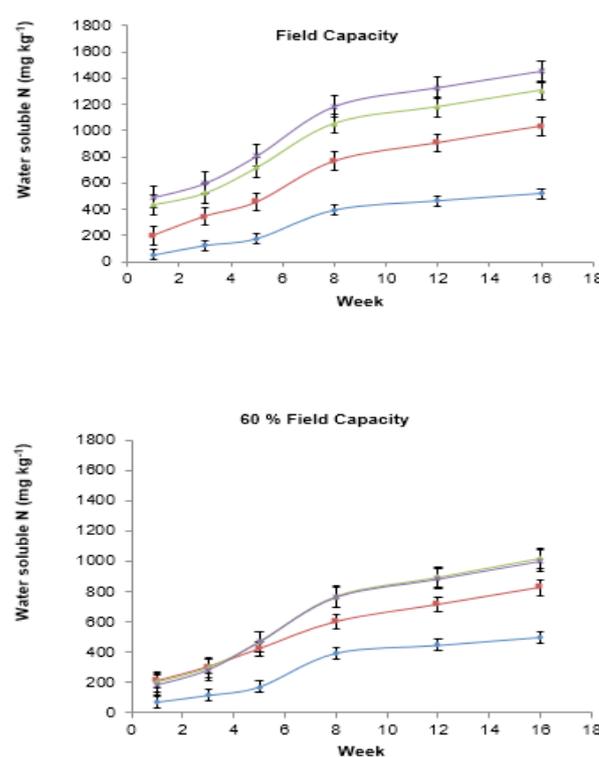


Fig. 2. Weekly soluble nitrogen release for incorporated residues at the two moisture levels

and accounted for the remaining 30% of total soluble N released.

Differences in water soluble nitrogen release from the various treatment combinations are indicated in Tables 3 and 4. The soluble N released to the soil from the elephant grass of the natural fallow, irrespective of the method of application at field capacity were statistically the same with values between 552 and 616 mg kg⁻¹ after 16 weeks of incubation. When the elephant grass from the field with history of

when the two plant residues were incorporated into the soil at field capacity. The levels of water soluble N released by the various treatment combinations at field capacity was in the order $T3_{Inc.} > T2_{Inc.} > T2_{SA} = T3_{SA} > T1_{Inc.} = T1_{SA}$.

At 60% FC, the incorporated elephant grass from the natural fallow T1 released 325.2 mg kg⁻¹ soluble N which was almost half the concentration released at FC. This concentration of soluble N released was also

TABLE 3

Effect of residue type and placement method on water soluble nitrogen concentrations for the various treatments combinations at field capacity

| Method of Application | Treatments (mg N kg ⁻¹) | | |
|-----------------------|--|--------------------|---------------------|
| | T1 | T2 | T3 |
| Incorporated | 616.1 _d | 889.7 _b | 1033.7 _a |
| Surface Applied | 552.3 _d | 766.6 _c | 747.0 _c |

TABLE 4

Effect of residue type and placement method on water soluble nitrogen release (mg N kg⁻¹) for treatment combinations at 60 % field capacity

| Method of Application | Treatments | | |
|-----------------------|--------------------|--------------------|--------------------|
| | T1 | T2 | T3 |
| Incorporated | 325.2 _b | 517.5 _a | 503.0 _a |
| Surface Applied | 370.6 _b | 359.3 _b | 408.0 _b |

fertilized maize production was incorporated into the soil at field capacity (FC), soluble N released was almost 890 mg kg⁻¹ and this was significantly 16% more than when it was surface applied to the soil. When the legume was incorporated into the soil at field capacity, soluble N which was almost 145 mg kg⁻¹ higher than in the incorporated T2, was 38% more than when it was surface applied. It is clear from Table 3 that when the three residues were incorporated into the soil at field capacity, soluble N released was in the order of $T3 > T2 > T1$. When the residues were surface applied, however, pattern of soluble release was $T3 = T2 > T1$. Even though the mucuna had a much lower C:N ratio (8.95) than the T2 elephant grass (16.82), there seemed to be no significant difference in soluble N release

37% lower than when T2 at the same moisture content was incorporated into the soil. There was, however, no significant difference in concentration of soluble N released when T2 and T3 were incorporated into the soil at 60% FC as the two treatments had soluble N concentrations between 503 and 517.5 g kg⁻¹. When the three plant residues were surface applied to the soil at 60% FC, however, there was no significant difference in soluble N released as values ranged between 359 and 408 g kg⁻¹. When treatment combinations were subjected to a moisture regime equivalent to 60% field capacity, water soluble N release levels assumed the order $T2_{Inc.} = T3_{Inc.} > T3_{SA} = T1_{SA} = T2_{SA} = T1_{Inc.}$.

It is worthy of note that at the two soil moisture contents of FC and 60% FC, whereas

T1 showed no difference in soluble N released into the soil for both methods of residue applications, there were significantly higher concentrations of the nutrient released when T2 and T3 were incorporated as opposed to when they were surface applied. Both methods of application of the three plant residues released much higher concentrations of soluble N at FC than at 60% FC. Incorporation of T1, T2 and T3 released 325.2 g kg⁻¹, 517.5 g kg and 503 g kg⁻¹, respectively at 60% FC. These concentrations increased almost 1.9, 1.7 and 2.1 fold respectively when moisture content was increased to FC. When the same residues were surface applied at 60% FC, T1, T2 and T3 respectively released 370.6 g kg⁻¹, 359 g kg⁻¹ and 408 g kg⁻¹. Increasing soil moisture content to FC increased the respective soluble

kg⁻¹wk⁻¹ when the elephant grass with history of fertilization, T2, was surface amended to the soil. The rate of N release in the soil from the surface amended fertilized grass, T2, was statistically similar to that when the legume was also surface amended to the soil at FC.

On incorporation of T1 at FC, the rate increased almost 1.2 fold from when it was surface applied to 0.1055 mgkg⁻¹wk⁻¹. Incorporation of the mucuna and the elephant grass from the soil with history of fertilization at FC did not significantly affect the rate of soluble N release as values were similar to those when the residues were surface applied albeit significantly higher values than T1. The rate of soluble N release for the various treatment combinations at FC were of the order $T3_{INC} = T2_{INC} = T3_{SA} = T2_{SA} > T1_{INC} > T1_{SA}$.

TABLE 5

Interactive effect of residue type and placement method on first order rate constants for water soluble nitrogen release (mg/kg /wk-1) for the various treatment combinations

| SURFACE APPLIED | | | FC | | INCORPORATED | |
|------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--|
| T1 | T2 | T3 | T1 | T2 | T3 | |
| rate (b) 0.0897 _c | 0.1824 _a | 0.1654 _a | 0.1055 _b | 0.1747 _a | 0.1835 _a | |

| SURFACE APPLIED | | | 60% FC | | INCORPORATED | |
|------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--|
| T1 | T2 | T3 | T1 | T2 | T3 | |
| rate (b) 0.1028 _b | 0.0690 _c | 0.0929 _c | 0.1400 _b | 0.1043 _b | 0.1046 _b | |

rate (b) = rate constant

N concentrations released 1.5, 2.1 and 1.8 folds.

The observed rate constant, b, generated after fitting the data of the cumulative water soluble N release of the various treatment combinations to equation 1 are indicated in Table 5. When the three residues were surface applied to the soil at field capacity, the rate at which water soluble N was being released was lowest in the natural elephant grass fallow treatment, T1 with a value of 0.0897 mg kg⁻¹wk⁻¹. The rate, however, doubled to 0.182 mg

When the elephant grass from the natural fallow, T1 was surface applied at 60% FC, the rate of release was 0.1028 (mg kg⁻¹wk⁻¹) slightly higher than when it was surface applied at FC. This rate of release from the T1 amended soil was significantly higher than those from the T2 and T3 amended soils at the same moisture content of 60% FC. Incorporating the natural fallow elephant grass, T1, also gave a faster rate of decomposition of 0.14 mg kg⁻¹wk⁻¹ of water soluble N than the 0.1055 mg kg⁻¹wk⁻¹ when it was incorporated at FC. Unlike at

FC where T2 and T3 amended soils had faster soluble N releases than their T1 amended counterpart, the converse was true at 60% FC. At 60% FC, water soluble N releases were significantly slower in T2 and T3 than in the T1 amended soil. The T2 and T3 amended soils had similar soluble N release rates of 0.104

coupled with the high sand content of 74% would lead to high leaching rates of nitrates and therefore calls for external input of organic material and or chemical fertilizers to improve on the productivity of the soil.

The higher level of organic carbon obtained in the elephant grass from the fertilized maize

TABLE 6
The $\text{NH}_4^+:\text{NO}_3^-$ ratios of the various treatments

| Residue Type | Field Capacity | | 60 % Field Capacity | |
|--------------------|-----------------|------|---------------------|------|
| | Surface Applied | Inc. | Surface Applied | Inc. |
| Control | 0.05 | 0.06 | 0.07 | 0.06 |
| Nat. Fallow | 0.05 | 0.05 | 0.05 | 0.06 |
| Fert. Maize Fallow | 0.04 | 0.06 | 0.05 | 0.05 |
| Mucuna | 0.06 | 0.06 | 0.05 | 0.06 |

*Inc. = Incorporated

$\text{mg kg}^{-1} \text{wk}^{-1}$ at 60% FC and these were slower by .0.07 and 0.08 $\text{mg kg}^{-1}\text{wk}^{-1}$, respectively, compared to the rates at FC. Table 6 gives the $\text{NH}_4^+:\text{NO}_3^-$ ratios of the various residue amended treatment combinations at the end of the 16-week incubation period. The ratios observed indicate that approximately 94% and 96% of the water soluble nitrogen obtained in the residue amended soils was in the nitrate form.

Discussion

Soil and residue characteristics

The low levels of organic carbon and consequently low total nitrogen and available phosphorus levels of the soil are indicative of low organic matter return to the soil and poor inherent soil fertility. The low clay content of the soil with a mineralogy which has been found to be dominated by low activity clays specifically kaolinite (Eze, 2008) may, in part, explain the very low cation exchange capacity of 5.62 cmol kg^{-1} . Cationic nutrient such as NH_4^+ retention would, therefore, be very low in the soil. The poor fertility status of the soil

field relative to that from the natural fallow field may be due to the residual nutrients harnessed from the fertilized maize field. The available residual fertilizer material may have also resulted in the respectively 70% more and 2.1 times higher total nitrogen and P levels in T2 relative to T1. Additionally, the residual fertilizer material may have also led to a lower C:N ratio in T2 relative to T1. Being a legume, the mucuna fallow had the lowest C:N ratio among the residue types. At optimum soil conditions, it is expected that decomposition for water soluble N release would be in consonance with the C:N ratios of the residues i.e. $T3 > T2 > T1$.

Water soluble nitrogen

It is indicated that the amount of N released from a decomposing residue material is related to the C:N ratio and that a break-even point between net N mineralization and N immobilization can be found between C:N ratios of 20 and 40 (Van Kessel et al, 2000; Qian and Schoenau, 2002). The fact that the residue with the highest C:N ratio had a value (24) in close proximity to the critical values

of 20 may account for the fast release of water soluble available N such that by the 8th week on amendment, irrespective of method of application, 70% of the nutrient had been released. This has implication for farmers. Application of these residues could be done two months before planting of crops especially in the dry season where with watering between 60% FC and FC, the mineralized water soluble N would be made available for crop uptake. In Ghana where the onset of the major rainy season is in April, residue application could be done in February for plant uptake in April/May.

Moisture content at FC, provided the ideal condition for microbial proliferation. This condition facilitated faster release of water soluble N from residues accounting for between 1.7 and 2.1 fold increases when incorporated and between 1.5 and 1.8 fold increases when the same residues were surface applied over releases at 60% FC. The 0.18 mg kg⁻¹ wk⁻¹ release rate from the elephant grass from the fertilized maize plots and the mucuna though higher than their natural grass fallow counterpart are far below the 20 -25 mg kg⁻¹ required for growth of maize (Gelderman and Beegle, 1998; Lindquist *et al.*, 2010). For a typical 90-day maize crop, there is likely to be released a total of approximately 2.32 mg/kg N during the growing period of the crop. Use of these residues, therefore, would not be able to sustain the crop. It is, therefore, imperative to augment the N requirement of the crop with inorganic fertilizer.

Most organic residues have components with different susceptibility to decomposition during the degradation process (Cabrera *et al.*, 2005). As decomposition progressed, variations in the C:N ratio resulting from the decomposition of the easily mineralizable

residue fractions at the early stages of incubation may have accounted for the gentle release of soluble N during the second half of the study. Considering the fact that the nutrient demand of most arable crops, particularly, in the first three weeks when roots are not extensive and well developed enough would be very minimal, most of the soluble N may not be utilized by crops if planting is done just after incorporation of the residue as is the practice by most farmers in West Africa. For such practices where incorporation of residue is synchronized with planting, the three residues should be used as amendment for the cultivation of short duration and fast growing crops like spinach, cowpea and okra. Where the residues are to be surface applied as mulch after transplanting, the choice of crop could be lettuce especially in the dry season for efficient utilization of the nutrient.

The similar concentration of mineralized water soluble N from the natural elephant grass fallow, irrespective of method of application at FC has implications for residue management on these soils. The T1 residue should be surface applied on these soils during both rainy and dry seasons to minimize production cost. The plant grows in the wild and could therefore be easily slashed and spread over the surface of the soil in the two seasons just before planting. The natural elephant grass residue whilst providing nutrients in the rainy season may minimize erosion. Conversely, it would serve as a mulch in the dry season whilst providing N.

The results suggest that at optimum moisture conditions *i.e.* field capacity, water soluble N released was controlled by the C:N ratios of the residues when incorporated as evident in the T3 > T2 > T1 increasing order of the C:N ratios of the residues. Incorporating the

mucuna in the raining season may lead to high losses of soluble N through leaching especially in this sandy soil. A better option will be to incorporate the mucuna in the dry season amidst light watering. This is corroborated by the much slower releases of N at 60% FC by the mucuna and elephant grass from the fertilized maize plot. The fact that when surface applied, the mucuna and elephant grass from the fertilized maize field released similar levels of N into solution suggests that either could be used by farmers in the dry season. However, the elephant grass from the fertilized maize fallow will have the added advantage of serving as mulch to provide extra agronomic benefits because, some of the residues still remained undecomposed as against the mucuna residues at the end of the 16-week study period. Additionally, there is cost incurred in buying and seeding mucuna as against the elephant grass that grows naturally. The higher release rates of soluble N from the natural fallow elephant grass (T1) than its T2 and T3 counterparts at 60% FC suggest that T1 will be a better residue for amendment to soils in the dry season. The natural fallow elephant grass which is likely to be abundant in the rainy seasons could be exploited for use in the dry season for crop cultivation.

One of the indices that is used to access the extent to which soluble N is prone to losses in soil is the $\text{NH}_4^+:\text{NO}_3^-$ ratio. A ratio of 1 indicates that ammonium and nitrate abound in equal proportions in solution. Since ammonium is mostly held at the soil exchange sites and is therefore not very mobile in soil, a ratio greater than 1 is desirable. When the ratio is less than 1, it indicates the abundance of nitrate relative to ammonium in solution. Considering the fact that the soil used for the study is a sandy loam and moisture regime was between 60%

FC and FC, it was not surprising that nitrate was the dominant form of soluble N as there was no leaching. This indicates the tendency for most of the soluble nitrogen to be lost through leaching should moisture content go beyond field capacity. Thus in the use of these residues for amending the soil, the watering regime must be monitored to avoid exceeding field capacity.

Conclusion

Observations made in the study indicate that water soluble N release was rapid within the first eight weeks and assumed a gentle release pattern thereafter. On the average, water soluble N release up to week 8 formed about 70 % of the total release for nearly all the treatment combinations. The study found significant differences in soluble N release between incorporated residues and that of the surface applied counterparts in all the treatment combinations. It was also established that soil moisture has significant influence on soluble N release in all the treatment combinations. At field capacity, residue N content played a significant role in soluble N release when residues were either surface applied or incorporated. Application of elephant grass either from previously fertilized fields or from the wild or mucuna to Rhodic Kandiustalf in the coastal savanna zone of Ghana would not sustain crop N requirement and should be supplemented with inorganic N sources. Application of the elephant grass is recommended for use in the dry season to serve as mulch while also providing N for plant use. Application of elephant grass as an N source should be incorporated into the soil at least eight weeks prior to the commencement of the rainy season for judicious use of water

soluble N.

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