CONTROL OF NITROGEN MINERALIZATION FROM DECOMPOSING *GLIRICIDIA SEPIUM* LEAVES TO OPTIMIZE NITROGEN UPTAKE BY MAIZE CROP

BY

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ABSTRACT

Decomposition (mass loss) and Mineralization studies were conducted at Kitete Village, Kilosa District, Tanzania during the 1995/96 cropping season. The aim was to control the rates of decomposition and nitrogen release from *Gliricidia sepium (Jacq.) Walp.* leaves through widening their C/N ratios using *Sawdust*.

Litter bags containing a fixed amount of *Gliricidia* leaves (150g/bag) and variable amounts of *Sawdust* (0, 25, 50, 75, 100% of fixed *Gliricidia*) were used in the decomposition experiment. Different *Gliricidia* leaf rates (1.5, 1.15, 0.76 and 0.38 kg dry leaves/plot or 60, 45, 30 and 15 kg N/ha respectively) and various *Gliricidia* and *Sawdust* mixtures containing a fixed amount of *Gliricidia* leaves (1.5 kg/plot) and variable amounts of *Sawdust* were used in the mineralization experiment conducted within a maize farm.

The decomposition and mineralization studies revealed that, treatments with *Gliricidia* alone had significantly (P=0.002) higher mass loss percentage and nitrogen release but decreased with increasing C/N ratio in *Gliricidia-Sawdust* mixtures. Rates of mass loss were influenced by placement depth. Most of the nitrogen from the *Gliricidia*

alone treatments was released within six weeks. In the mineralization experiment nitrate nitrogen was found to dominate the mineral nitrogen ranging from 67 to 81 percent. The nitrogen uptake by maize plants, maize height increment and maize crop yields were significantly higher in plots with correspondingly higher C/N ratios with a positive correlation between nitrogen uptake and maize growth (r= 0.762) and maize yield (r= 0.858). A 3-8 weeks period is a critical period of high nutrients demand by the maize crop in the study area. It was, therefore, concluded that the *Gliricidia (1.5 kg)-Sawdust (1.0 and 1.25 kg)* mixtures or 21:1 and 23:1 C/N ratios should be adopted in the study area for effective control of the rates of decomposition and nitrogen release and hence availability of nitrogen for crop growth and yield.

DECLARATION

I, **JEAN BAPTISTE NDUWAYEZU**, do hereby declare to the Senate of Sokoine University of Agriculture that, this dissertation has not been submitted for a degree award to any other University and it is my original work.

Signature.....

Date.....23/6/97....

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LIST OF ABBREVIATIONS

1. a.s.l: Above sea level
2. C:N: Carbon:Nitrogen ratio
3. CEC: Cation exchange capacity
4. EC: Exchangeable cations
5. eg. : For example
6. FAO : Food and Agriculture Organization of the United Nations
7. Fig. : Figure
8. ie. : That is
9. meq. : milliequivalents
10. OC: Organic carbon
11. pH : Hydrogen ion concentration
12. p.p.m: Parts per million
13. r: Correlation coefficient
14. SE: Southeast
15. sp. : Species (singular)
16. spp.: Species (plural)
17. Tshs: Tanzanian shillings

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CHAPTER 1

1.0 INTRODUCTION

The synchronization of nutrients release from mulch and green manure with nutrients uptake by crops is considered as a vital point for improving the efficiency of nutrients utilization by crops (Swift, 1987; Lehmann *et al.* 1995).

The decline in yield of maize which is the leading food grain in Tanzania, is a major problem resulting from fertility depletions and especially irregular nitrogen supply throughout the crop growing stages. To increase crop production on a sustainable basis therefore, there is a need of supplying nutrients to the soil. Although nutrients supply can be enhanced through application of fertilizers, the use of industrial fertilizers can be limited by high prices, unavailability in many developing countries, their associated pollution problems, and inefficiency of use caused by erosion, volatilization, leaching and denitrification (Colbourn, 1988; Palada *et al.*, 1992). Thus, alternative ways for supplying nutrients to the soil using safe locally available low cost external inputs are needed.

Green manuring and/or mulching have been reported to improve and maintain soil fertility, since they can assure the slow and continuous release of nutrients (Budelman, 1988; Oglesby and Fownes, 1992; Nair, 1993). They also increase phosphorus availability (Haggar *et al.*, 1991), conserve soil moisture (Budelman, 1989; Tomar *et al.*, 1992), reduce soil temperature fluctuations (Budelman, 1989), prevent weed seed germination (Yamoah *et al.*, 1986; Tomar *et al.*, 1992) and decrease soil erosion (Young, 1989). In their efforts to maintain soil fertility using low cost external inputs, farmers in tropical areas incorporate trees in their farming systems in an agroforestry setting. They also widely use crop residues, compost, green manure, sawdust, chicken manure and other animal wastes, or practice crop rotation (Sperow and Keefer, 1975; Nair, 1993). Despite all these tropical farmers' efforts, failures to restore soil fertility have been observed due to poor choice of appropriate agroforestry species, poor timing of green manure application, poor quality or insufficient quantity of materials, and inappropriate way of application.

Agricultural crops have well defined critical periods of high nutrients demand (eg. 4-6 weeks for maize crop) (Nikokwe, 1992; Nair, 1993; Lehmann *et al.*, 1995).

If nutrients could be made available to the crops during the period of high nutrient demand, therefore, the released nutrients would be used efficiently, leaching losses minimized and crop productivity increased. The effective use of organic fertilizers/green manures so as to meet the demand of agricultural crops, requires an understanding of controls on nutrient release from these sources (Szott and Kass, 1993). Climate, soil texture, soil microorganisms, quantity and chemical composition and placement of plant materials, are among other controls that regulate the decomposition and nutrient release from organic residues and soil organic matter (Haynes,1986; Palm and Sanchez, 1990; Oglesby and Fownes, 1992). However, Meentemeyer (1978) suggested that in tropical areas, the rates of decomposition and mineralization are controlled more by the quality of litter than by climate. The initial N content or C/N ratio has been considered to be the most important plant factor governing decomposition and nitrogen release from plant materials. *Gliricidia sepium (Jacq.) Walp.* with a low C/N ratio therefore, may be a good source of nitrogen due to its high quality attributes.

In trying to address soil fertility problems using plant materials, many workers have focused on mass loss and nutrients release patterns during the decomposition process (Van Cleve, 1974; Haynes, 1986; Yamoah *et al.*, 1986;

Budelman, 1988; Palm and Sanchez, 1990; Nikokwe, 1992; Lehman *et al.*, 1995), very few on N mineralization (Frankenberger and Abdelmagid, 1985; Fox *et al.*,1990; Oglesby and Fownes, 1992; Constantinides and Fownes, 1993; Piccolo *et al.*,1994). The knowledge about the proper ways of minimizing N losses by regulating the rates of decomposition and nutrients release (especially N which is highly demanded by plants and soil microorganisms) so that they can be released and made available regularly throughout the critical stages of the crop growth is, however, inadequate. Only information about minimizing nitrogen losses from inorganic fertilizers using nitrification inhibitors (eg. nitrapyrin, halophenols, nitroanilines) is readily available (Alexander, 1961; Tisdale *et al.*, 1990). This forces farmers to apply any plant material of any quantity and quality at any time during crop development which in most cases result in poor crop yield because the released nutrients were available when unwanted, and when they were needed, they were no longer available, or the applied materials were not enough to supply the required nutrients. Controlling N mineralization from plant materials, therefore, requires more investigation if the costs of inorganic fertilizers are to be minimized and crop yields, especially food crops, are to be improved and produced sustainably.

The main objective of this study was, therefore, to control nitrogen mineralization from decomposing *Gliricidia sepium* leaves through widening their C:N ratio using *Sawdust*, so as to slow down the rates of decomposition and mineralization and thus maximizing nitrogen-uptake by maize crop. The specific objectives were:

(i) To assess the effect of *Sawdust* on the decomposition rate (mass loss) of *Gliricidia* leaves.

(ii) To determine the effect of different application rates of *Gliricidia sepium* on mineral nitrogen changes and net nitrogen mineralization and nitrification.

(iii) To assess the effectiveness of *Sawdust* in controlling the rate of nitrogen release from *Gliricidia* leaves.

(iv) To investigate the treatment effects on nitrogen uptake by maize crop and on both maize growth and grain yield.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1. Decomposition and nutrients release

The decay of litter or tree mulch to humus, with concomitant release of nutrients (eg. 95% of N in the surface soil and 15-80% of phosphorus), is a major process in all terrestrial ecosystems because it controls the availability of nitrogen, the nutrient most frequently limiting to plant growth (Allison, 1973; Pastor *et al.*, 1987). Ammonium and nitrate nitrogen are the sources of nitrogen for higher plants, except for those species which host symbiotic and dinitrogen-fixing organisms in their roots (Armson, 1977). Tripathi and Hazra (1986) found a close link between nutrients uptake by the crop plants and their productivity. In their study, the Oats had much higher dry foliage yields than Barley and removed higher N for its growth and development. In addition, they also found that the available nitrogen content of soils increased with increase in nitrogen application, because the highest values were associated with the highest level of nitrogen.

2.1.1 Controls on decomposition and mineralization rates

As already seen in Chapter 1, the initial nitrogen content or C/N ratio of plant materials (litter quality) is a convenient tool for predicting the rates of decomposition and nutrients release (*nitrogen mineralization*). But also the population of nitrifying organisms, soil aeration and soil moisture may have an important role in nitrate formation (*nitrification)* and thus in *nitrogen mineralization* (Alexander, 1961; Tisdale *et al.*, 1990).

2.1.1.1. Litter quality

a) General chemical composition of plant materials

The effect of mulches on the amount of nutrients that are available to plants growing on the soil depends primarily on the composition of the mulches, and secondarily on the rate at which the mulches are decomposed (Rippin *et al.* 1994). Correlations between chemical properties and N release of green manures could be used to screen candidate species for agroforestry systems or to optimize management practices, as well as to gain some insight into ecosystem functioning (Oglesby and Fownes, 1992). The major constituents of plant material comprise cellulose (the most abundant chemical constituent: 15-60% of the dry weight),

hemicelluloses (10-30% of the weight), water solubles including simple sugars, amino acids and aliphatic acids (5-30% of the tissue weight), ether and alcohol solubles containing fats, oils, waxes, resins and a number of pigments and proteins having in their structure much of the plant nitrogen and sulphur (Alexander, 1961). The decomposition of these compounds vary from one group to another but protein-rich materials were reported to decompose at a fast rate as compared to protein-poor materials.

b) Effect of litter quality (C/N ratio) on decomposition and mineralization rates.

Nitrogen is a key nutrient substance for microbial growth and hence for organic matter breakdown (Alexander, 1961; Tisdale *et al.* 1990). Microbial action can either mineralize or immobilize nitrogen, and the principal factor determining which occurs is the C/N ratio (Thompson and Troeh, 1979). Tisdale *et al.* (1990), Frankenberger and Abdelmagid (1985) and Handayanto *et al.* (1994) pointed out that, a C/N ratio of approximately 20:1 was the dividing line between immobilization and release of nitrogen, and that when organic substances with C/N ratios wider than 30:1 are added to soil, there is immobilization of soil nitrogen during the initial decomposition process.

The initial total nitrogen concentrations of between 1.5 and 1.7% (Tisdale *et al.* (1990) or 1.73% (Frankenberger and Abdelmagid, 1985; Handayanto *et al.*, 1994) were reported to be sufficient to minimize immobilization of soil nitrogen. Nikokwe (1992) pointed out that, the application of poor and slow decomposing plant materials with a C/N ratio wider than 30:1 requires supplemental nitrogen so as to meet the demands of microorganisms involved in the decomposition process.

The term *litter quality* refers to nutrient content and comparative rate of decomposition of plant residues (Anderson and Swift, 1983; Nair, 1993). Traditionally, *high quality litter* is one with high nitrogen and low carbon content (eg. succulent materials rich in protein with narrow C/N ratio) and fast decomposing, whereas woody residues and other lignified materials (eg. cereal straw) or plant materials with high fats and wax contents which decompose slowly due to wider C/N ratio, are of low quality (Buckman and Brady, 1969; Constantinides and Fownes, 1993; Nair, 1993). This shows that the wider the C/N ratio the longer the period of net mineralization (Thompson and Troeh, 1979) or the slower the decay rate and vice versa. From his study under field conditions in Côte d'Ivoire, Budelman (1988) showed an example of such close relation between decomposition rate and C/N ratio of different plant

species. He reported that, half-life values of the fresh leaf biomass of *Leucaena leucocephala, Gliricidia sepium* and *Flemingia microphylla* with C/N ratios of 12:1, 12:1, and 21:1 were 31, 22, and 53 days, respectively. Handayanto *et al.* (1994) on the other hand, observed a rapid decrease in dry matter for *Gliricidia* and *Leucaena* prunings with losses up to 40 % over a 2 months period. Additionally, they also found that the rate of dry weight loss of all pruning materials was considerably slower after 16 days due to inadequate moisture availability, and that nitrogen released followed the same order as between *Gliricidia* and *Leuceana* as the loss of dry weight (the greatest amount of nitrogen was given by *Gliricidia*). In their research in Central Togo, Lehmann *et al.* (1995) found that *Gliricidia* alone decomposed considerably faster in the first 18 days with 75% mass loss compared to *Senna* with 30%.

If the C/N ratio of the applied materials is low, they decompose rapidly and release large amount of nitrogen, while those with wide C/N ratio (eg. cereal straw) provide a source of energy (C) for the microbes; the microbes subsequently multiply rapidly and draw upon nitrogen reserves from the soil (Alexander, 1961; Tisdale *et al.*, 1990; Nair, 1993). They further reported that as decay proceeds, and since the added material is poor in nitrogen, this causes a temporary *nitrogen immobilization* resulting

in a marked depression of nitrogen uptake by the plant and a consequent decrease in yield. When the C (energy) source is depleted, the microbial population declines and the N that had been temporarily incorporated in microbial tissues would once again be released to the soil (increase in level of mineral nitrogen) and available for plant uptake. This therefore, is how the addition of large quantities of a low quality litter to crop may result in nitrogen deficiency or unavailability for the crop, and conversely, how the addition of a high quality litter benefits the crop. From his joint study with a local farmer, at Kitete Village, Nduwayezu and Kauta (1996) found that maize grain yield was significantly higher under plots treated with *Gliricidia* leaves alone (C/N:13:1), but interestingly, the maize yield under plots treated with *Sawdust* alone (C/N: 297:1), was even lower than that from untreated (control) plots probably due to high soil nitrogen immobilization by microorganisms. Alexander (1961) indicated that, during decomposition of nitrogen-poor materials, the C/N ratio tends to decrease with time, and, this results from the gaseous loss of carbon while the nitrogen remains in organic combination for as long as the C/N ratio is wide. Therefore, the nitrogen percentage in the residual substance continuously rises as decomposition progresses. Sperow and Keefer (1975) reported that any organic residue added to the soil will eventually be decomposed and result

in a C/N ratio of about 10:1 which is the level in soil humus.

It can be noted however that, apart from the C/N ratio concept, to adequately describe the pattern of decomposition of plants and nutrient release, nitrogen, phosphorus and calcium contents (Nikokwe, 1992), (lignin + polyphenol): N and/or polyphenol: N ratios (Van Cleve, 1974; Fox *et al.*, 1990; Palm and Sanchez, 1990; Oglesby and Fownes, 1992) have to be considered, since substrate with similar C/N ratios may differ in lignin, polyphenol or tannin contents. This therefore, suggests that many leguminous plants used in agroforestry systems may not be good sources of available N, despite their high N contents, due to high polyphenol: N or (lignin + polyphenol): N ratios (Fox *et al.*, 1990). From the above definition of litter quality therefore, *Gliricidia sepium* qualifies to be a high quality material, due to its high content in protein (low C/N) and its low contents of lignin, while *Sawdust* on the other hand, qualifies to be a poor quality material associated with its high C/N ratio and high lignin contents. These high quality attributes of *Gliricidia* material ensure its high decomposition rate while the poor quality of *Sawdust* ensures its slow decomposition.

According to Garrity and Mercado (1994), *Gliricidia sepium* is a multipurpose tree legume which is very commonly used in tropical farming systems. It is also a nitrogen-fixing legume in which atmospheric N-fixation may account for 30% to 60% of the plants' nitrogen-uptake. It has wide range of environmental adaptability, and provides large amounts of foliage. *Gliricidia sepium* was reported to decompose and release nutrients at a faster rate than most other legumes used in agroforestry trials (Yamoah *et al.*, 1986; Budelman, 1988). It has high N content, readily decomposable compounds, and low contents of lignin and polyphenols compared to other agroforestry species (Maliondo, S.M.S. personal communication, 1995). Similarly, Lehmann *et al.*(1995), reported that *Gliricidia sepium* leaves were chemically composed of nitrogen (31.8 g/kg), phosphorus (1.7 g/kg), potassium (13.9 g/kg), calcium (13.1 g/kg), magnesium (6.62 g/kg), polyphenols (4.1%), lignin (9.8%), cellulose (17.8%) and lipid (6.1%) with 14, 1.31 and 3.1 carbon:nitrogen, polyphenol:nitrogen and lignin:nitrogen ratios respectively.

Among other materials commonly added to East African soils including maize stalks (C/N: 60), straw (C/N:80) and coffee husks (C/N: 25-30), *Sawdust* is the only material reported to have a higher C/N ratio of 400 (Sperow and Keefer, 1975). Similarly, Tisdale *et al.* (1990), reported that the

C/N ratio of *Sawdust* is generally 400. Alexander (1961) indicated that, natural materials rich in lignin are less readily utilized by microorganisms than lignin-poor products. The resistance of wood and *sawdust* to microbial attack is probably linked not only to C/N ratio but also to the abundance of lignin in such materials. The abundance of termites however, can accelerate the decomposition rate of lignified and nitrogen-poor materials (Lehmann *et al.*, 1995). Constantinides and Fownes (1993) reported that, the net nitrogen immobilization in the leguminous leaf-twig mixture was largely caused by the presence of twigs (ie. high lignin:nitrogen ratio), and that nitrogen immobilization during decomposition tends to increase with increasing lignin and decreasing nitrogen content of plant tissue.

2.1.1.2 Other controls of decomposition and nitrogen mineralization rates.

a) Population of nitrifying organisms

The presence of different-sized populations of nitrifiers would probably result in lag time between the addition of ammonium source and the build up of nitrate nitrogen in the soil (Tisdale *et al.* 1990). In addition to this, the microbial populations normally, have a tendency to multiply

rapidly in the presence of an adequate supply of substrate (Nair, 1993).

b) Soil aeration : Since the nitrobacteria are obligate autotrophic aerobes (Alexander, 1961; Tisdale *et al.*, 1990; Nikokwe, 1992; Nair, 1993), adequate aeration is of great importance. Where the oxygen supply is inadequate for microorganisms, there will be little ammonium oxidation, and the reactions aiming at nitrates production ceases in the total absence of oxygen (Alexander, 1961; Tisdale *et al.*, 1990). More decomposition was reported to occur in the upper soil layers because more organic matter is added there, and furthermore, aeration is more adequate there than it is below (Thompson and Troeh, 1979).

c) Soil moisture : Because moisture affects the aeration regime of soil (Alexander, 1961), the water status of the microbial habitat has a marked influence on nitrate production. Nitrogen mineralization tends to be impeded in wet soils exceeding 1/3 bar or field capacity (Tisdale *et al.*, 1990) since waterlogging limits the diffusion of oxygen (Alexander,1961).

2.1.2 Nitrogen cycle

According to Alexander (1961), among the major plant nutrients derived from the soil (ie. N, P, K), nitrogen stands out as the most susceptible to microbial transformations. Alexander (1961), and, Devlin and Witham (1983) pointed out that, nitrogen, is a key building block of protein molecule upon which all life is based, and it is thus an indispensable component of the protoplasm of plants, animals, and microorganisms. Alexander (1961) further urged that, because of the critical position of the nitrogen supply in crop production and soil fertility, a deficiency markedly reduces yield as well as quality of crops; and because this is one of the few soil nutrients that are lost by volatilization, as well as by leaching , it requires continued conservation and maintenance. Nitrogen passes repeatedly through its various forms (nitrogen cycle) as it moves from the soil into the bodies of living organisms and back again (Alexander, 1961; Thompson and Troeh, 1979). It is an open cycle because nitrogen go around and around and can enter or leave the cycle in various ways (Thompson and Troeh, 1979). In trying to explain nitrogen cycle, Alexander (1961) indicated that, a small part of the large reservoir of N_2 in the atmosphere is converted to organic compounds by certain free-living microorganisms or by microbial-plant association that makes

the element directly available to the plant. The nitrogen present in the proteins or nucleic acids of plant tissues is used by animals. In the animal body, the nitrogen is converted to other simple or complex compounds. When animals and plants are subjected to microbial decay, the organic nitrogen is released as ammonium, which in turn is utilized by the vegetation or is oxidized to nitrate. The nitrate ion may be lost by leaching, it may serve as plant nutrient or, alternatively, it may be reduced to ammonium or to gaseous N_2, which escapes to the atmosphere, thereby completing the cycle. Nitrogen *mineralization* and *immobilization* are the portions of the nitrogen cycle governed by microbial metabolism in which organic matter is decomposed and inorganic ions released (*mineralization*), or in which inorganic ions are converted to organic forms (*immobilization*) (Alexander, 1961; Thompson and Troeh, 1979). In addition to these two definitions, Alexander (1961) reported that, the mineralization of organic nitrogen and the microbial assimilation of inorganic ions proceed simultaneously.

2.1.2.1 Nitrogen mineralization

Uriyo and Singh (1974) and Tisdale *et al.* (1990) reported that, nitrogen in soil is mainly in organic forms, and a smaller fraction in inorganic forms such as ammonium

($NH4^+$), nitrate (NO_3^-), nitrite (NO_2^-), nitrous oxide (N_2O^-), nitric oxide (NO), and elemental nitrogen (N_2), and that most of the cultivated soils have total N content ranging from 0.06 to 5% . From the standpoint of soil fertility, the NH_4^+, NO_3^-, and NO_2^- forms are very important, while N_2O and NO are also important but in negative way because they are lost through denitrification. The conversion (mineralization) of organic compounds to the above available forms takes place in three steps known as *aminization* (formation of amines and amino acids under activity of heterotrophs), *ammonification* (formation of ammoniacal compounds from amines and amino acids) and *nitrification* (biological oxidation of ammonia to nitrate) (Tisdale *et al.*, 1990). Rates of conversion of organic nitrogen (N) to biologically available ammonium (NH_4^+) and nitrate (NO_3^-) (*mineralization* rate) and the total quantity of N in tropical soils are indicators of soil fertility and affect the ability of these soils to retain N following disturbance such as deforestation (Piccolo *et al.* 1994). Net *nitrogen mineralization* and *nitrification* is often equated with nitrogen availability (Anderson and Ingram, 1993). Alexander (1961) pointed out that the rate at which organic nitrogen is converted to ammonium and nitrate (mineralization), and the velocity of such release in environments receiving nitrogen rich crop residues ranges from less than 1.0 to 20 ppm per day. He also added that

this rate is closely correlated with the total nitrogen content of the soil, implying that sites rich in nitrogen liberates more of the inorganic ions than deficient areas in a given time interval. Nitrate ions however, were reported to be the dominant form of mineral nitrogen since they are in soil solution (ie. readily available and easily removed) which make them to be much more susceptible to leaching loss than ammonium (Alexander, 1961; Meentmeyer, 1978; Tisdale *et al.*, 1990). Oglesby and Fownes (1992) found that, in general, nitrate plus nitrite constituted over 95% of the extractable inorganic nitrogen. In connection with the dominance and the high mobility of nitrate in the soil solution, Meentemeyer (1978) also suggests that, under high rainfall conditions, *nitrification* may result in loss of N from soil whereas NH_4^+ ion is adsorbed to soil colloids. Similarly, Angle (1990) reported that, increased infiltration of water could enhance the leaching of nitrate. The presence of K^+ ion however, will often restrict NH_4^+ fixation since this ion can also fill fixation sites because the mechanism of NH_4^+ fixation is similar to that of K^+ fixation (Tisdale *et al.*, 1990).

2.1.2.2 Nitrogen immobilization

Decomposition of organic matter requires contact between decomposers and substrate so that enzymatic processes can occur (Noorrallah and McGill, 1986). Alexander (1961) reported that during decomposition of the applied substrate, the soil inhabitants capture energy for growth and carbon (50%) for cell synthesis, and, the process of converting substrate to protoplasmic carbon is known as *assimilation*. At the same time as carbon is assimilated for the generation of new protoplasm, there is a concomitant uptake of nitrogen, phosphorus, potassium and sulphur. Agronomically, *assimilation* of inorganic substances can be of great practical significance because nutrient assimilation is an important means of *immobilization*, that is, a mechanism by which microorganisms reduce the quantity of plant available nutrients in the soil (Alexander, 1961). Tisdale *et al.* (1990) indicated that, under equilibrium conditions the soil microbial population remains about the same, a consistent amount of organic residues is returned to the soil, depending on the vegetative cover, and there is a fairly fixed and usually low rate of nitrogen mineralization. They further suggested that, if the soil is disturbed, as in ploughing, there is an immediate and rapid increase in mineralization, and that continued

cultivation without the return of adequate crop residues with sufficient nitrogen lead to a decline in the humus content of soils. In connection with the equilibrium state of the soil, Thompson and Troeh (1979) reported that decomposition with neither net *mineralization* nor *immobilization* from decomposing organic matter is equal to nitrogen use by microorganisms. Additionally, they further indicated that, mineralization nearly stops when the A horizon is dry because most of the organic matter is in the A horizon (top soil).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1. Site description

3.1.1 Study site location

The study was carried out in Kitete Village at a site about 2 km Southeast of the Dumila-Kilosa road in Kilosa District, Morogoro Region, Tanzania within the Mkata plain (37°8'SE, 6°30'SE; 375m a.s.l). The Village is nearly 20 km South of Dumila Village which is approximately 80 km from the Morogoro Municipality on the Morogoro-Dodoma Highway.

3.1.2 Rainfall

The major part of Morogoro Region shows a bimodal rainfall pattern. The short rain season starts from November or December up to January while the long rain season starts from February or March up to May. Rainfall is generally unevenly distributed from one place to another, and varies from year to year. The data available for Morogoro Region during 1991/1992 cropping season, however, shows that rainfall in Kilosa District was more or less continuous as follows: November (143 mm /7 days), December (114 mm /11

days), January (98 mm/9 days), February (67 mm/5 days), March (180 mm/9 days), April (367 mm/ 26 days), May (45 mm /3 days), June (3 mm/1 day) (Kilimo/FAO Project, 1994).

3.1.3. Soils

The soils of maize producing areas of Kilosa District are moderately to well drained , deep, brownish fine sands to sandy loams with high textural variability over short distances (Kilimo/FAO Project, 1994). The initial soil physical (Table 1) and chemical (Table 2) properties determination, showed that soils in Kitete are sandy clay loams containing moderate nitrogen, high carbon, medium phosphorus, medium pH, high magnesium, medium potassium and medium CEC. However, it has been noted that the top soil horizon (0-20cm) contained more total nitrogen and potassium than the sub-soil horizon (20-40cm).

Table 1: The Kitete experimental site soil physical properties .

Parameter	Content
Soil particle size	
Sand	64.4%
Clay	23.4%
Coarse silt	10%
Fine silt	2.2%
Bulk density	1.45g / cm^3

Table 2: Initial soil chemical properties within 0-20cm and 20-40cm depths before treatments application

Soil properties	Sampling depths		Overall mean
	0-20cm	20-40cm	
OC (%)	3.92	3.84	3.88
N (%)	0.235*	0.178*	0.207
P (ppm)	44.0	41.37	42.70
pH	6.78	6.72	6.75
Exchangeable cations (meq./100g soil)			
Ca	8.57	8.77	8.67
Mg	3.70	3.52	3.61
K	0.86*	0.53*	0.70
Na	0.55	0.50	0.53
CEC	14.81	15.70	15.3

Note: Only values in the same row that are followed by * differ significantly (**P=0.05**), and the t-tabulated at **5 %** with **52** degrees of freedom is **2.025** while t-calculated for N and K is **5.65** and **4.023** respectively.

3.1.4 Vegetation types

The area is dominated by *Acacia sp.* (locally known as *Mtalula* and *Mkololo*) (*Mimosaceae*), *Kigelia africana* (*Mlegea*) (*Bignoniaceae*), *Piliostigma thonningii* (*Msegese*) (*Caesalpinaceae*), *Vitex sp.* (*Mfulu*) (*Verbenaceae*), *Ficus sp.* (*Mkuyu*) (*Moraceae*) and *Sterculia appendiculata* (*Mgude*) (*Sterculiaceae*). Other species are locally known as *Mfumbili* and *Mng'ongo*. The grass layer is dominated by tall grasses including *Panicum maximum* (locally known as *Sinde*) and *Mbayaya* (*wild sorghum*).

3.1.5 Land use

Since 1970, after establishing small demonstration plots on cotton,the Ilonga Research Institute motivated farmers in Kitete village to cultivate cotton by providing cotton seeds free of charge and by providing tractors for cultivation at 45 Tshs per acre and insecticides (eg. DDT) at 3 Tshs per acre. This money was paid back after harvesting and selling cotton product (Personal communication with local farmers).

In 1975, the Institute stopped its support to farmers since they were already familiar with cotton cultivation. Then, from 1975-1978, the study area was taken by a local farmer known as Kauta, who after one year of cultivation, allowed

the soil to rest for 2 years (1979-1980). The area was cultivated again for 4 years (1981-1984) after which it was allowed to rest for 6 years (1985-1991). Since 1991, the Sokoine University of Agriculture was given an area of 20 acres for research purposes and only a quarter of an acre was used to establish an alley agroforestry trial, leaving aside the rest of the land for other research activities. The present trial, however, was established on a portion on which maize and beans had been grown for one season during 1991/92. The remaining portion of the area is under fallow.

3.2 Plant materials (*Gliricidia* and *Sawdust*) used.

Gliricidia leaves of 4 months old were collected during the period of September to October 1995 from the Sokoine University Horticultural Unit. To avoid decomposition before their application, *Gliricidia* leaves were air dried, packed in sisal sacks and stored in a dry, clean, well aerated and well covered space. *Sawdust* materials on the other hand, were collected from local saw mills where local chicken keepers use to collect *Sawdust* for chicken bed making. Such a mixture of *Sawdust* and chicken manure is then used for improving soil fertility. After the collection of *Gliricidia* and *Sawdust* materials their C and N contents and C/N ratios were determined (Table 3). Similarly, the C, N and C/N ratios for the various

Gliricidia + *Sawdust* mixtures used in the study were determined.

Basing on nitrogen content in *Gliricidia* and on the recommended rate of fertilization (60 kg N/ha) in Kilosa District, the amounts of air dried *Gliricidia* leaves required per hectare or per plot ($9m^2$) to provide 60 kg N/ha or 0.054 kg N/$9m^2$ were estimated at about 1.7t/ha or 1.5 kg/plot respectively.

Table 3: Initial chemical composition of *Gliricidia* and *Sawdust* material applied

Plant material	Characteristics		
	Total nitrogen (% N)	Organic carbon (OC%)	C:N ratio
Gliricidia sepium leaves	3.66	47.44	13:1
Sawdust	0.168	49.85	297:1

3.3. Experimental procedures

3.3.1. Decomposition study

3.3.1.1 Experimental design

Land was ploughed and harrowed using a tractor. After land preparation and soil sampling the site was divided into 2 portions, one portion was for decomposition and the other portion for nitrogen mineralization studies. The two field experiments were established on the same day (29/12/1995) and had the same sampling or retrieval periods of 2 weeks.

Six treatments of *Gliricidia* + *Sawdust* mixtures were tested as follows :

T1: 150g/plot *Gliricidia* alone (C/N:13:1)
T2: 150g/plot *Gliricidia* + 37.5g (25%) *Sawdust* (C/N:16:1)
T3: 150g/plot *Gliricidia* + 75g (50%) *Sawdust* (C/N:19:1)
T4: 150g/plot *Gliricidia* + 112.5g (75%) *Sawdust* (C/N:22:1)
T5: 150g/plot *Gliricidia* + 150g (100%) *Sawdust* (C/N:25:1)
T6: 150g/plot *Sawdust* alone (C/N:297:1)

The experiment was a completely randomized block design with six *Gliricidia* + *Sawdust* mixture treatments replicated three times. There were two placement depths (0-20 cm and 20-40cm) and four sampling/retrieval periods (2, 4, 6 and

8 weeks after incubation). Plot size was 2m x 4m with inter-plots and inter-block spacing of 1m.

Before making the mixtures and subsequent incubations, *Sawdust* was first sieved using a 2mm sieve, then the various *Gliricidia* and *Sawdust* mixtures were loosely packed in the fine net bags which were buried in the soil at either 20cm or 40cm depth and left to incubate at field conditions for the prescribed sampling/ retrieval intervals. The quantity of *Gliricidia* used in the various mixtures was kept constant (ie. 150 g) and that of *Sawdust* varied from 0 to 100% of applied *Gliricidia* material resulting in the subsequent C/N ratios of the mixtures varying from 13:1 to C/N: 25:1.

To each treatment plot, 4 positions (representing the 4 retrieval periods) were randomly located. At each location 2 sampling depths (ie. 20 and 40 cm) were established. Eight litter bags of each mixture treatment were randomly assigned to each sampling depth (4 litter bags to 20 cm and 40 cm depths) by tossing 8 papers corresponding to 8 litter bags. These papers were carrying numbers of either 20 or 40 to represent soil depths 20 cm and 40 cm. After being buried in the soil, each litter bag location was marked with a special label, and additionally, a guide map also showing the litter bag's location was prepared.

3.3.1.2 Sampling procedure

After every two weeks, and following the guide map and litter bags location labels where they were still visible, 2 litter bags (one litter bag from 20 cm and 40 cm depths respectively) in each plot of each block, were removed from the soil by digging around each location using a knife, packed in paper bags then transported for further analysis.

3.3.1.3 Sample analysis

a) Mass loss determination

After each sampling period, all debris and large soil particles on the net bags were wiped out. Samples were then oven dried at 60°C to constant weight (ie.48 hours) and allowed to cool. After cooling and before taking residual weight measurements, the net bags and their contents were air dried as was the case for initially incubated materials (ie. before incubation). The total dry weights were recorded and the net bag contents were sieved on 1mm sieve assuming that any material passing through this sieve was decomposed. The residues were reweighed and the remaining weight recorded which allowed to calculate mass loss percentage by subtracting the residual mass from the initially applied weight of plant material. It can be noted

however that, instead of washing samples before oven drying followed by weighing of residual mass, sieving oven dried samples was preferred for fear of loosing sawdust material and other small particles in water.

3.3.2 Nitrogen mineralization study

3.3.2.1 Experimental design

The recommended fertilization rate for Kilosa's soils to support a good maize yield (STAHA variety), is 60 kg N/ha (Kilimo/FAO Plant Nutrition Project, 1994). Therefore, the quantity of *Gliricidia* leaves required to provide 60 kg N/ha (ie about 1.7t dry leaves per hectare) or 0.054 kg N/plot ($9m^2$) (1.5kg dry leaves per plot) was kept constant and that of *Sawdust* varied so as to vary the C/N ratio of the mixture from 13:1 to 23:1.

Nine treatments were applied in this study as follows :

T1: 1.5 kg/plot *Gliricidia* leaves (60 kg N/ha) **(C/N:13:1)**

T2: 1.15 kg/plot *Gliricidia* leaves (45 kg N/ha)

T3: 0.76 kg/plot *Gliricidia* leaves (30 kg N/ha)

T4: 0.38 kg/plot *Gliricidia* (15 kg N/ha)

T5: 1.5 kg *Gliricidia* + 0.50 kg *Sawdust* **(C/N: 17:1)**

T6: 1.5 kg *Gliricidia* + 0.75 kg *Sawdust* **(C/N: 19:1)**

T7: 1.5 kg *Gliricidia* + 1.00 kg *Sawdust* **(C/N: 21:1)**

T8: 1.5 kg *Gliricidia* + 1.25 kg Sawdust (**C/N: 23:1**)

T9: **Control treatment (no *Sawdust*, no *Gliricidia*)**

The experiment was a completely randomized block design (CRBD) with nine treatments replicated three times. The plot size was 3m x 3m and maize spacing was 90cm x 30cm (ie. between-row x within-row spacing respectively). Both inter-blocks and inter-plots spacings were 4m and 1m respectively. The whole experimental unit was surrounded by two border lines of maize crop so as to minimize/remove boundary effects.

Gliricidia leaves alone and *Gliricidia* + *Sawdust* mixtures were applied first, by evenly distributing the materials over the treatment plots, then well mixing with the soil by hand hoes and maize sowing immediately followed the same day on 29/12/95.

3.3.2.2 Sampling procedure

a) Nitrogen mineralization

Soil samples for initial soil physical and chemical properties determination and for mineral nitrogen changes during different sampling periods (0, 2, 4, 6, 8, 10 and 18 weeks) were collected from both the top (0-20cm) and sub-

soil (20-40cm) horizons using an auger. For each plot and each depth, four soil samples were collected randomly and pooled into two composite samples (ie. one composite sample for 0-20 cm depth and one for 20-40 cm) making a total of 54 samples (ie. 27 samples from 0-20cm and 27 samples from 20-40cm: samples of equal size). These composite soil samples were packed in clean plastic bags and transported in a cool box so as to maintain the field conditions. To avoid the mixing up of samples, a piece of paper indicating the sampling date, treatment and block numbers and sampling depth was put in each plastic bag. The 27 samples collected from each depth (0-20cm and 20-40cm), were also used to compare the two sampling depths (0-20cm and 20-40cm), in terms of their initial chemical properties.

Before sampling for bulk density determination, the soil surface was cleaned by removing the top surface soil. Then a 5cm diameter and 5cm height sampling core was inserted into the soil surface. The soil from around the core was excavated and the excess soil from the core ends was removed using a sharp knife.

b) Nitrogen uptake by maize crop

To determine the amount of nitrogen nutrient uptaken by the maize crop, 2 maize plants from each treatment in each

block (6 maize per treatment) were selected randomly and carefully up-rooted after measuring their above ground height. The total fresh weight (in the field) of each up-rooted maize was recorded, and, to know at which depth maize roots were concentrated, the roots of carefully uprooted maize plants for nitrogen uptake analysis were counted and their lengths measured. The maize plants up-rooting exercise was carried out by digging around each maize plant so as to get all roots out of the soil.

c) Maize crop development and yield

To monitor maize growth, maize height measurements were recorded at different periods (3, 8 and 10 weeks after maize sowing, and, *Gliricidia* and *Gliricidia + Sawdust* mixtures application). Ten maize plants per each treatment in each block/replication, were initially selected randomly and marked. A total of 270 maize plants for the whole experiment were involved in this exercise (ie. 30 maize plants per treatment).

After maize harvesting (120 days after maize sowing and *Gliricidia*, *Gliricidia + Sawdust* mixtures application), the total maize grain yield from each plot/treatment and each block was weighed.

3.3.2.3 Sample analysis

a) Soil condition and nitrogen mineralization

Since the initial soil condition can have high influence on mineral nitrogen changes and nitrogen mineralization potentials, both soil physical and chemical properties were determined. The soil physical properties of texture and bulk density and soil chemical properties of pH, total nitrogen, available nitrogen, available phosphorus, organic carbon, exchangeable cations and cations exchange capacity were determined. The soil texture (particle size : % sand, % clay, % silt) was determined using Hydrometer Method (Ministry of Agriculture and Livestock Development, 1990). Soil bulk density (g/cm3) was determined according to Anderson and Ingram (1993). The soil pH was determined by pH-meter (Uriyo and Singh, 1974; Anderson and Ingram, 1993). The total N was determined using the semi-micro Kjeldahl procedure as described by Page *et al.*(1982). To measure the changes in available nitrate (NO_3^-) and ammonium (NH_4^+) at different sampling or field incubation periods (0, 2, 4, 6, 8, 10, and 18 weeks after *Gliricidia* and *Gliricidia* + *Sawdust* mixtures application), the soil sub-samples from the two composite soil samples collected from both 0-20cm and 20-40cm depths respectively, were weighed, and the concentrations of both nitrate and ammonium were

immediately determined using the distillation and colorimetric method as described by Anderson and Ingram (1993). The difference in mineral nitrogen between the two consecutive sampling periods (Time 1 - Time 0 : Final - initial) divided by the number of incubation days between these periods, allowed the estimation of net nitrogen mineralization and nitrification per day under field conditions, while the difference between the total mineral nitrogen level during a given period of time and the initial mineral nitrogen level before green manuring (equilibrium state where no mineral nitrogen was added to and removed from the soil due to initially dry soil) allowed the estimation of cumulative mineral nitrogen added to or removed from the soil during that particular period of time. At every sampling period, moisture content was determined and results were expressed basing on oven dry weight. Available phosphorus was determined using both Bray No.1 Method during extraction process (Page *et al.*, 1982) and colorimetrically using Ascorbic Acid Method as described by International Institute of Tropical Agriculture (1979). The soil organic carbon was determined colorimetrically (Anderson and Ingram, 1993). Both exchangeable cations (Na+, K+, Ca2+ and Mg2+) and cation exchange capacity (CEC) were determined using flame emission or atomic absorption photometer, distillation and titration (Uriyo and Singh, 1974).

b) Analysis for nitrogen uptake by maize

In the laboratory, both shoots and roots of maize carefully up-rooted 8 weeks after sowing and green manuring were separated, washed with distilled water and oven dried to constant weight at 60°C. The dry weights for both shoots and roots were recorded and then ground separately. Using these powders, the total nitrogen was determined using the standard semi-micro Kijeldhal procedure as described by Page *et al*. (1982).

3.3.2.4 Statistical analysis

Data on the mass loss percentages, daily net nitrogen mineralization and nitrification following field conditions, nitrogen-uptake by maize crop, maize growth and yield were analyzed for variance using the CRBD model. The differing means between treatments were separated using the Duncan's Multiple Range test. Regression analysis, was carried out to seek for the existence of correlation between the maize height growth, nitrogen uptake by maize crop, and maize grain yield.

A paired t-test was again used on the soil chemical properties data from the two sampling depths (0-20cm and 20-40cm depths).

CHAPTER 4

4.0 RESULTS

4.1 The effect of adding *Sawdust* and placement depth on decomposition rate (mass loss) of *Gliricidia* leaves.

The results of mass loss percentage under two placement depths (0-20cm and 20-40cm) at different sample retrieval periods are given in Tables 4 and 5 respectively. In both placement depths, mass loss percentages increased with the length of incubation time but decreased with increasing C/N ratio of *Gliricidia* + *Sawdust* mixtures. *Gliricidia* alone showed the highest mass loss percentage while *Sawdust* alone showed the lowest ($P<0.002$).

Overall, neither the placement depths ($P=0.65$) nor interactions between the placement depths and the C/N ratios ($P=0.08$) had significant influence on the decomposition rate of *Gliricidia* + *Sawdust* mixtures except at the 6^{th} week the decomposition was significantly influenced by the placement depths ($P=0.01$). The mass loss percentage of *Sawdust* alone in the sub-soil horizon (20-40cm), was about twice that observed in top soil horizon (0-20cm). However, at the end of incubation (8 weeks), mass loss was higher in the top soil horizon (0-20cm) than in the sub-soil horizon (20-40cm).

Table 4: Mass loss percentage at 0-20cm soil depth under different C/N ratios at different periods of field incubation

Sampling weeks	*Gliricidia* + *Sawdust* mixtures (C/N ratios)					
	13:1	16:1	19:1	22:1	25:1	297:1
2	31.7±1.7a	24.5±4.4a	23.5±3.8a	24.2±2.5a	23.5±3.0a	6.9±1.1b
4	45.6±5.5a	38.1±4.5ab	41.5±1.0a	37.8±1.4ab	32.2±2.0b	10.7±0.7c
6	51.1±1.6a	45.6±0.6b	41.5±1.6b	41.3±2.3b	35.9±1.7c	12.0±1.2d
8	60.0±3.8a	54.3±2.1ab	51.8±5.3ab	50.7±2.6ab	46.4±4.2b	13.7±1.0c

Note: Values in the same row that are followed by the same letter, do not differ significantly (P=0.05).

Table 5: Mass loss percentage at 20-40cm soil depth under different C/N ratios at different periods of field incubation.

Sampling weeks	*Gliricidia* + *Sawdust* mixtures (C/N ratios)					
	13:1	16:1	19:1	22:1	25:1	297:1
2	32.0±1.9a	26.8±3.7ab	25.2±2.6ab	24.7±0.9ab	23.0±2.9b	8.8±1.0c
4	40.4±4.5a	34.4±7.6a	33.6±6.2a	38.5±2.2a	33.2±1.1a	19.3±1.8b
6	54.4±2.3a	42.8±2.1bc	44.6±1.2b	43.2±2.1bc	37.7±2.4c	21.0±1.5d
8	57.1±2.6a	50.7±1.0a	49.0±2.7a	48.8±2.9a	54.7±7.1a	22.8±0.1b

Note: Values in the same row that are followed by the same letter, do not differ significantly (P=0.05).

4.2 The effect of *Gliricidia* application rates and *Gliricidia* + *Sawdust* mixtures (C/N ratios) on mineral nitrogen changes and daily net nitrogen mineralization and nitrification.

The results for cumulative mineral nitrogen changes (ie. total mineral nitrogen after time n - initial mineral nitrogen level before *Gliricidia* and *Gliricidia* + *Sawdust* mixtures application) within 0-20cm and 20-40cm depths under different *Gliricidia* application rates and various C/N ratios, at the various time intervals, are shown in Figures 1, 2, 3 and 4 respectively. These figures, however, are based on the assumption that initially, neither mineral nitrogen was added to nor removed (ie. equilibrium state) from the soil because the soil was very dry for quite a long period of time implying that even microbial activity was negligible.

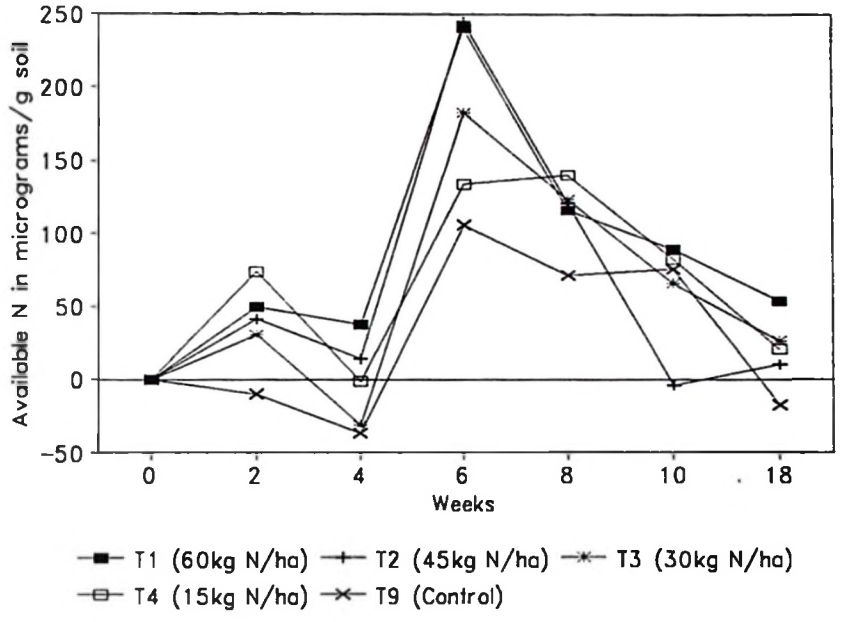

Figure 1: Mineral nitrogen changes within 0-20cm soil depth under various rates of *Gliricidia* application at different periods of field incubation at Kitete.

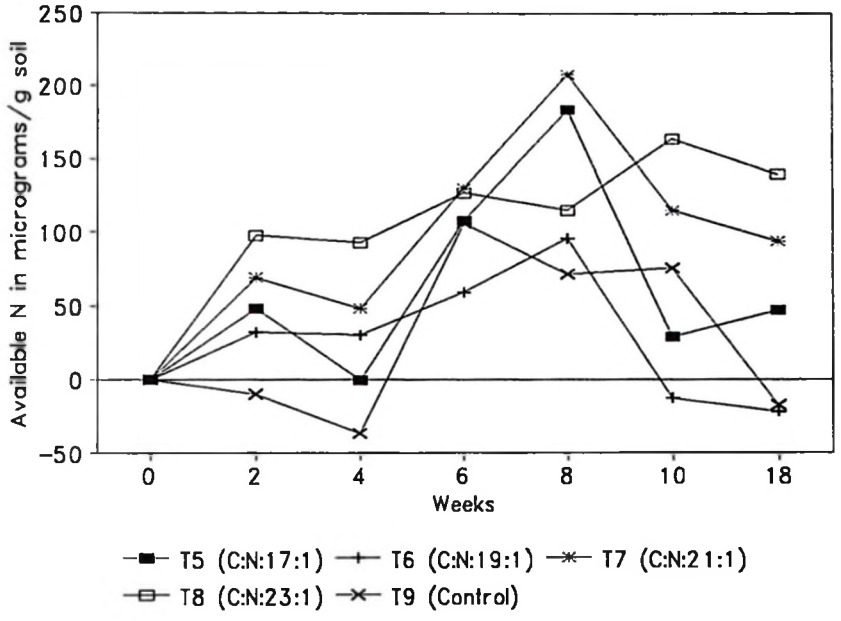

Figure 2:Mineral nitrogen changes within 0-20cm soil depth under various C/N ratios at different periods of field incubation at Kitete.

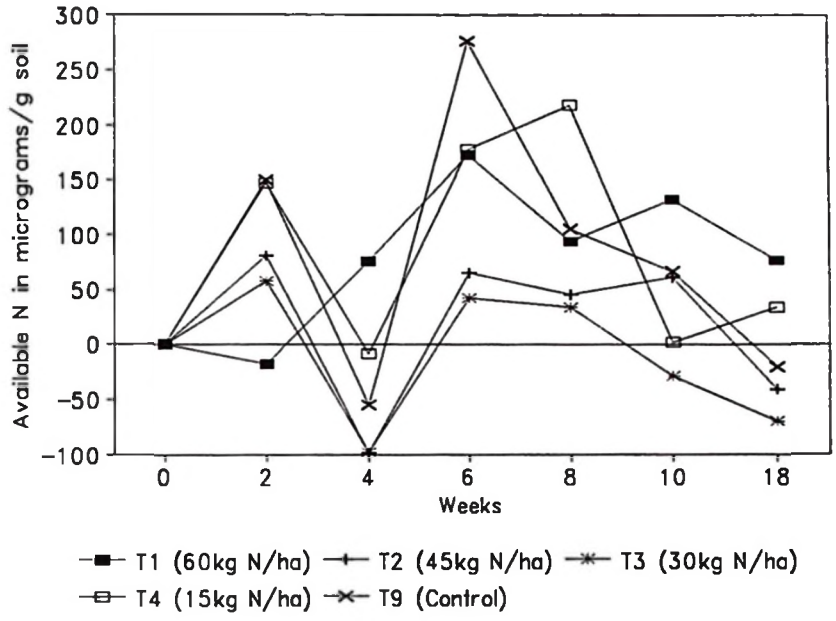

Figure 3:Mineral nitrogen changes within 20-40cm soil depth under various rates of *Gliricidia* application at different periods of field incubation at Kitete.

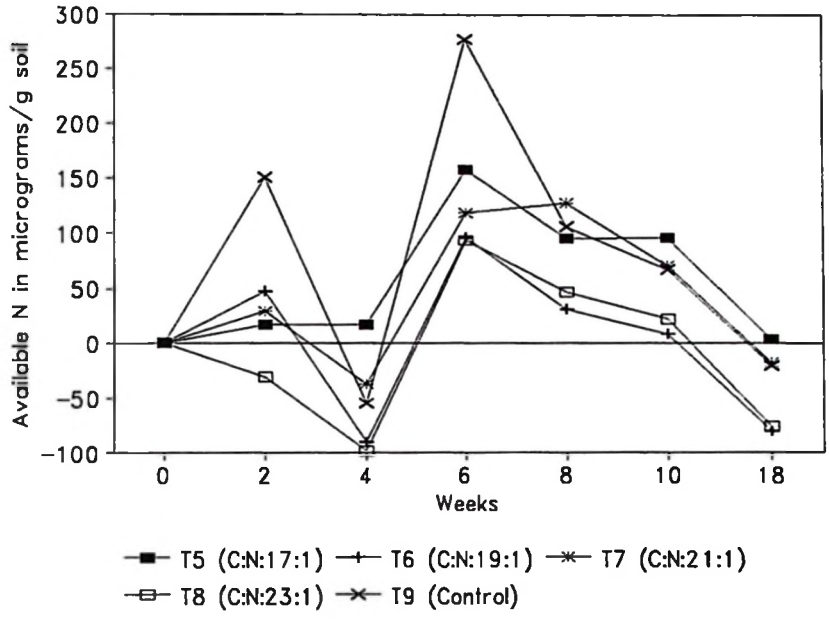

Figure 4:Mineral nitrogen changes within 20-40cm soil depth under various C/N ratios at different periods of field incubation at Kitete.

The results for mineral nitrogen changes over time showed that, during the whole period of field incubation (2, 4, 6, 8, 10 and 18 sampling weeks), nitrate nitrogen was found to be the dominant form of the total extractable mineral nitrogen (nitrate + ammonium), on average ranging between 67-81% of the total mineral nitrogen (Fig. 1, 2, 3 and 4). Throughout the maize crop developmental stages, mineral nitrogen in top soils (0-20cm), where most of maize roots were found to concentrate, was released gradually under plots treated with *Gliricidia* + *Sawdust* mixtures of higher C/N ratios (21:1 and 23:1). Plots treated with higher rates of *Gliricidia* material (60 and 45 kg N/ha) however, showed the highest rates of nitrogen mineralization within the first 6 weeks, after which, these rates declined rapidly (Fig. 1). The untreated (control) plots, showed the highest mineral nitrogen decline in the top soil horizon (0-20cm) and highest mineral nitrogen accumulation in the sub-soil horizon (20-40cm) throughout the maize crop development. This can be attributed to leaching of nitrogen from the top soil horizon to deeper horizon. Neither *Gliricidia* rates nor *Gliricidia* + *Sawdust* mixtures showed such a high accumulation of nitrogen in sub-soils.

The results for the daily net nitrogen mineralization and nitrification within the two sampling depths (0-20cm and 20-40cm) are summarized in Tables 6, 7, 8 and 9. The daily net nitrogen mineralization and nitrification followed the same trend as that of the cumulative mineral nitrogen changes within a specified period of time.

The Table 6 and 7 for net nitrogen mineralization, and Table 8 and 9 for net nitrification within 0-20cm and 20-40cm sampling depths indicate that, initially, all plots treated with either *Gliricidia* or *Gliricidia* + *Sawdust* mixtures showed a positive daily net nitrogen mineralization and nitrification in the top soil (0-20cm). Higher values were obtained from plots having high initial total nitrogen, but the control plots on the other hand, had significantly lower and negative values ($P<0.0001$). This initial mineralization was followed by immobilization, after which, the nitrogen mineralization and nitrification rates started to increase in plots treated with *Gliricidia* alone, in direct proportion to the rates of application (60 and 45 kg N/ha), and decreased with increasing C/N ratio, while the control treatment showed the lowest values ($P<0.0001$). But with time, the rate of mineral nitrogen formation per day increased gradually in *Gliricidia* + *Sawdust* mixtures plots having higher C/N ratio (23:1 C/N ratio) and inversely decreased with *Gliricidia* alone.

The control treatment showed the lowest and negative rate of mineral nitrogen formation in the top soil horizon ($P<0.0001$). In general, within the 20-40cm depth, the rate of mineral nitrogen formation was significantly higher ($P<0.0001$) under control plots due to high leaching losses of nitrogen from the upper soil layer and accumulation in the deeper soil horizon.

Table 6: Daily net nitrogen mineralization (μg/g soil) at 0-20cm soil depth under different rates of *Gliricidia* application and C/N ratios at different periods of field incubation.

Sampling weeks	Gliricidia application rates (kg N/ha)				Gliricidia + Sawdust mixture (C/N ratios)				Control
	60	45	30	15	17:1	19:1	21:1	23:1	
2	3.6±0.8 cd	3.0±0.5 d	2.2±0.4 d	5.3±0.8 b	3.4±0.3 cd	2.3±0.6 d	4.9±0.2 bc	7.0±0.3 a	-0.8±0.4 e
4	-0.9±0.6 ab	-1.9±0.3 bc	-4.4 e	-5.4±1.0 e	-3.5±0.5 cd	-0.1±0.5 a	-1.5±0.6 ab	-0.3±0.4 ab	-1.9±0.4 bc
6	14.5±0.3 a	16.5±0.9 a	15.3±1.3 a	9.7±1.2 b	7.7±0.6 bc	2.1±0.9 c	5.7±0.1 c	2.4±0.7 d	10.2±0.2 b
8	-8.9±0.8 e	-8.8±1.1 e	-4.3±1.6 d	0.5±0.9 b	5.4±0.4 a	3.5±1.0 a	5.6±1.2 a	-0.8±0.7 bc	-2.5±0.5 cd
10	-1.9±1.3 bc	-8.9±0.7 de	-4.1±0.9 c	-4.1±0.7 c	-11±0.6 e	-7.7±1.0 d	-6.6±1.1 d	3.5±1.0 a	-0.1±0.7 b
18	-0.6±0.2 bc	0.3±0.2 a	-0.7±0.3 bc	-1.1±0.1 cd	0.3±0.2 a	-0.2±0.5 ab	-0.4±0.4 abc	-0.4±0.1 abc	-1.7±0.1 d

Note: Values in the same row that are followed by the same letter, do not differ significantly (P=0.05).

Table 7: Daily net nitrogen mineralization (μg/g soil) at 20-40cm soil depth under different rates of *Gliricidia* application and C/N ratios at different periods of field incubation.

Sampling weeks	*Gliricidia* application rates (kg N/ha)				*Gliricidia* + *Sawdust* mixtures (C/N ratios)				Control
	60	45	30	15	17:1	19:1	21:1	23:1	
2	-1.3±0.1 f	5.8±0.9 b	4.1±0.9 bc	10.6±0.4 a	1.3±1.0 e	3.4±0.2 cd	2.1±0.3 de	-2.2±0.6 f	10.7±1.1 a
4	6.8±1.6 a	-12.9±1.1 ef	-11.1±0.4 de	-11.3±0.2 de	-0.02±0.4 b	-9.9±0.1 d	-4.8±0.3 c	-4.8±0.3 c	-14.7±1.0 f
6	6.9±1.4 d	11.7±0.4 bc	10.0±0.8 c	13.4±0.4 b	10.1±0.2 c	13.3±0.2 b	11.1±0.3 c	13.7±0.8 b	23.7±0.7 a
8	-5.7±0.9 a	-1.4±0.5 bc	-0.6±1.0 b	2.6±0.6 a	-4.5±0.6 d	-4.7±0.5 d	0.7±0.8 ab	-3.3±0.9 cd	-12.2±0.6 e
10	2.8±1.0 a	0.6±0.6 b	-4.5±0.6 e	-15.3±0.3 f	0.1±0.4 d	-1.6±0.5 cd	-4.1±0.9 e	-1.8±0.2 cd	-2.8±0.6 de
18	-1.0±0.4 bc	-1.8±0.3 d	-0.7±0.1 b	0.6±0.2 a	-1.7±0.2 cd	-1.6±0.1 cd	-1.6±0.1 cd	-1.7±0.1 d	-1.6±0.1 cd

Note: Values in the same row that are followed by the same letter, do not differ significantly (P=0.05).

Table 8: Daily net nitrification (μg/g soil) at 0-20cm soil depth under different rates of *Gliricidia* application and C/N ratios at different periods of field incubation.

Sampling weeks	*Gliricidia* application rates (kg N/ha)				*Gliricidia* + *Sawdust* mixtures (C/N ratios)				Control
	60	45	30	15	17:1	19:1	21:1	23:1	
2	2.8±0.3 bc	1.0±0.5 de	-0.2±0.4 e	3.4±0.5 ab	1.5±0.3 cd	0.9±0.8 de	2.3±0.3 bcd	4.9±0.4 a	-2.0±0.2 f
4	1.1±0.1 bc	1.0±0.1 bc	-0.5±0.1 d	-1.9±0.4 e	0.04±0.5 cd	3.1±.0.7 a	2.0±0.5 ab	3.1±0.4 a	0.9±0.3 bcd
6	12.3±0.4 b	15.0±0.8 a	13.9±1.2 ab	8.1±1.3 cd	6.2±0.5 d	0.7±0.8 f	3.5±0.01 e	1.0±0.8 f	9.0±0.2 c
8	-7.6±0.8 e	-7.6±1.1 e	-4.8±1.5 d	0.7±0.9 bc	5.8±0.5 a	2.5±0.4 b	5.0±1.0 a	-0.4±0.6 c	-1.4±0.4 c
10	-2.1±1.3 bc	-9.7±0.7 ef	-4.7±0.8 d	-4.3±0.4 cd	-11.1±0.5 f	-7.8±1.3 e	-5.3±1.3 d	2.4±1.0 a	-0.7±0.5 b
18	-0.7±0.2 bcd	0.5±0.2 a	-0.2±0.3 abc	-1.0±0.1 cd	0.3±0.3 a	0.1±0.5 ab	-0.3±0.3 abc	-0.01±0.1 ab	-1.4±0.1 d

Note: Values in the same row that are followed by the same letter, do not differ significantly (P=0.05).

Table 9: Daily net nitrification (μg/g soil) at 20-40cm soil depth under different rates of *Gliricidia* application and C/N ratios at different periods of field incubation.

Sampling weeks	*Gliricidia* application rates (kg N/ha)				*Gliricidia* + *Sawdust* mixtures (C/N ratios)				Control
	60	45	30	15	17:1	19:1	21:1	23:1	
2	-2.3±0.03 d	3.7±0.9 b	3.3±0.2 b	8.7±0.2 a	0.1±1.0 c	2.0±0.3 b	0.2±0.2 c	-4.0±0.4 d	9.0±1.3 a
4	9.3±1.6 a	-9.3±1.0 de	-8.6±0.2 d	-8.3±0.2 d	2.3±0.5 b	-7.0±0.2 d	-1.8±0.2 c	-1.9±0.4 c	-11.1±1.1 e
6	5.0±1.4 e	9.8±0.4 cd	9.2±0.8 d	12.1±0.3 b	8.5±0.1 d	11.2±0.2 bc	9.4±0.2 cd	11.8±0.7 b	21.8±0.6 a
8	-4.7±0.7 d	-1.6±0.5 bc	-0.6±0.9 b	3.3±0.4 a	-3.5±0.5 cd	-3.6±0.4 cd	2.2±0.7 a	-1.9±0.7 bc	-10.6±0.7 e
10	1.5±1.0 a	1.2±0.5 a	-4.7±0.5 d	-15.4±0.1 e	-0.7±0.3 b	-2.5±0.5 bc	-5.1±1.0 d	-2.6±0.1 bc	-4.2±0.7 cd
18	-0.7±0.4 b	-1.6±0.3 c	-0.6±0.1 b	0.6±0.2 a	-1.4±0.2 c	-1.2±0.1 bc	-1.4±0.1 c	-1.5±0.03 c	-1.4±0.01 c

Note: Values in the same row that are followed by the same letter, do not differ significantly (P=0.05).

4.3 Maize growth, yield and nitrogen uptake

The results of maize roots data showed that on average, root length was 18.5 cm, indicating that maize roots were generally concentrated in the top soil horizon (0-20cm depth). The results of nitrogen uptake by maize crop are summarized in Table 10. They indicate that nitrogen uptake by maize crop decreased with decreasing rate of *Gliricidia* application, and significantly (P=0.002) increased with widening C/N ratio. The C/N ratio of 23:1 showed the highest values, and the control treatment showed the lowest nitrogen uptake. This suggests that under lower application rates of *Gliricidia*, nitrogen was not readily available to maize crop, due to immobilization by soil microorganisms, weeds or leaching. Widening the C/N ratio allowed the gradual release of nitrogen and its efficient use by maize crop.

Table 10: Nitrogen uptaken by maize crop (g/9m²) under different treatments 8 weeks after green manuring and maize sowing

Treatments	N-uptake by maize plants (in grams)
Gliricidia application rates	
1.5 kg dry leaves/plot (60 kg N/ha)	66.3 ± 8.3 abc
1.15 kg dry leaves/plot (45kg N/ha)	58.9 ± 15.0 bc
0.76 kg dry leaves/plot (30kg N/ha)	51.6 ± 12.0 c
0.38 kg dry leaves/plot (15kg N/ha)	44.5 ± 5.4 c
Gliricidia + *Sawdust* mixtures (C/N ratio)	
1.5 kg *Gliricidia* + 0.5kg *Sawdust* (17:1 C/N)	83.2 ± 3.0 ab
1.5 kg *Gliricidia* + 0.75kg *Sawdust* (19:1 C/N)	54.1 ± 6.5 c
1.5 kg *Gliricidia* + 1.0kg *Sawdust* (21:1 C/N)	90.7 ± 9.0 a
1.5 kg *Gliricidia* + 1.25kg *Sawdust* (23:1 C/N)	93.8 ± 9.2 a
Control	40.4 ± 8.5 c

Note: Values in the same column that are followed by the same letter, do not differ significantly (P= 0.05).

Table 10: Nitrogen uptaken by maize crop (g/9m²) under different treatments 8 weeks after green manuring and maize sowing

Treatments	N-uptake by maize plants (in grams)
Gliricidia application rates	
1.5 kg dry leaves/plot (60 kg N/ha)	66.3 ± 8.3 abc
1.15 kg dry leaves/plot (45kg N/ha)	58.9 ± 15.0 bc
0.76 kg dry leaves/plot (30kg N/ha)	51.6 ± 12.0 c
0.38 kg dry leaves/plot (15kg N/ha)	44.5 ± 5.4 c
Gliricidia + *Sawdust* mixtures (C/N ratio)	
1.5 kg *Gliricidia* + 0.5kg *Sawdust* (17:1 C/N)	83.2 ± 3.0 ab
1.5 kg *Gliricidia* + 0.75kg *Sawdust* (19:1 C/N)	54.1 ± 6.5 c
1.5 kg *Gliricidia* + 1.0kg *Sawdust* (21:1 C/N)	90.7 ± 9.0 a
1.5 kg *Gliricidia* + 1.25kg *Sawdust* (23:1 C/N)	93.8 ± 9.2 a
Control	40.4 ± 8.5 c

Note: Values in the same column that are followed by the same letter, do not differ significantly (P= 0.05).

The results of maize growth are given in Table 11. Maize height was positively and highly correlated to nitrogen uptake (r= 0.762). This implied that an increase of one unit of nitrogen uptake increased maize growth by 0.81502 cm in height.

Table 11: Effect of nitrogen uptake on maize height 8 weeks after sowing

Predictor variable	Coefficient
Constant	92.7645
Nitrogen	0.81502

Regression equation :

$$H = 92.7645 + 0.81502\ N$$

Coefficient of correlation: r= 0.762

Coefficient of determination : r^2= 0.5806

P ⟨ 0.00001.

Note: H represents maize height growth in centimetres;
N indicates nitrogen uptaken by maize crop in grams;
P shows the probability level.

The results of daily maize height increment and maize grain yield under different rates of *Gliricidia* and *Gliricidia + Sawdust* mixtures applications at different periods after maize sowing are presented in Tables 12 and 13 respectively. There were no significant differences in maize plants height between different *Gliricidia* rates and C/N ratios during the first (P=0.832) and last (P=0.474) weeks. Overall the rate of daily maize plant height increment increased from a mean of 1.1 cm for the period of 0-3 weeks to a maximum mean of 4.4 cm during 3-8 weeks and falling to a mean of 3.6 cm as the crop matured (8-10 weeks). The daily maize plant height increment observed within 3-8 weeks, was significantly higher in plots treated with *Gliricidia + Sawdust* mixtures (P(0.0001).

Table 12: Daily maize height increment (cm) under different rates of *Gliricidia* application and C/N ratio at the different periods after sowing

Treatments	Maize plant height (cm)		
	Weeks		
	3	8	10
Gliricidia application rates (kg N/ha)			
60	1.13 ± 0.3 a	4.4 ± 0.1 bc	3.7 ± 0.1 a
45	1.0 ± 0.1 a	4.4 ±0.1 bc	3.7 ± 0.4 a
30	1.1 ± 0.1 a	4.1 ± 0.1 d	3.5 ± 0.1 a
15	1.1 ± 0.1 a	4.1 ± 0.03 d	3.9 ± 0.1 a
Gliricidia + *Sawdust* mixtures (C/N ratios)			
17:1	1.0 ± 0.2 a	4.3 ± 0.1 cd	3.4 ± 0.5 a
19:1	1.25 ± 0.03 a	4.7 ± 0.2 a	3.4 ± 0.3 a
21:1	1.0 ± 0.1 a	4.8 ± 0.1 a	3.8 ± 0.1 a
23:1	1.1 ± 0.1 a	4.6 ± 0.1 a	3.7 ± 0.3 a
Control	1.2 ± 0.1 a	4.3 ± 0.02 cd	3.0 ± 0.3 a
Overall mean	1.10	4.40	3.60

Note: Figures in the same column that are followed by the same letter do not differ significantly (P=0.05).

The results of maize grain yield are summarized in Table 13. The maize grain yields decreased with decreasing rates

of *Gliricidia* application, and significantly (P=0.03) increased with increasing C/N ratio. The highest yields from the 21:1 and 23:1 C/N ratio treatments were 3 times higher than that of control treatment. The higher yields observed in the higher C/N ratio treatments can be partially attributed to gradual release of nitrogen and efficient use by maize crop. The maize grain yields from different *Gliricidia* application rates were highly correlated (r= 0.858) to nitrogen uptake by the maize plants.

Table 13: Maize grain yield (kg/ha) under different rates of *Gliricidia* application and C/N ratios 18 weeks after sowing

Treatments	Maize grain yield (kg/ha)
Gliricidia application rates (kg N/ha)	
60	1463.0 ± 66.8 ab
45	1481.5 ± 370.4 ab
30	1370.5 ± 196.1 abc
15	1111.1 ± 0.0 bc
Gliricidia + *Sawdust* mixtures (C/N ratios)	
17:1	1073.1 ± 74.0 bc
19:1	1185.3 ± 243.0 abc
21:1	1888.9 ± 390.2 a
23:1	1889.1 ± 169.6 a
Control	629.7 ± 74.1 c

Note: Values in the same column that are followed by the same letter do not differ significantly (P=0.05).

CHAPTER 5

5.0 DISCUSSION

5.1 The effect of adding *Sawdust* and placement depth on decomposition rate of *Gliricidia* leaves.

The results for the effect of adding *Sawdust* and placement depth are presented in Tables 4 and 5. It was noted that, mass loss percentage increased with time, but decreased with increasing C/N ratio of *Gliricidia* + *Sawdust* mixtures, with *Gliricidia* alone treatment showing the highest mass loss percentage, while *Sawdust* alone showing the lowest. Since the decay rate and nutrients release patterns are controlled more by litter chemical properties (Oglesby and Fownes, 1992; Nair, 1993; Rippin *et al.*, 1994), these high and slow decomposition rates observed in *Gliricidia* alone, and in *Gliricidia* + *Sawdust* mixtures respectively were expected because the initial total nitrogen was higher and the C/N ratio of *Gliricidia* alone material was lower than the reported critical total nitrogen of 1.7 % N and C/N of 20 respectively (Yamoah *et al.*, 1986; Frankenberger and Abdelmagid, 1985; Budelman, 1988; Tisdale *et al.*, 1990; Handayanto *et al.*, 1994; Lehmann *et al.*, 1995). The decomposition of organic matter and nitrogen mineralization are closely linked because nitrogen is covalently bounded

directly to carbon in soil organic matter, implying that the rapid the rate of decomposition the rapid will be the release of nitrogen (Thompson and Troeh, 1979; McGill *et al.*, 1881). The slow decomposition of *Gliricidia* + *Sawdust* mixtures and *Sawdust* alone is attributed to the poor quality (ie. higher C/N ratio and higher lignin contents) of *Sawdust* (Alexander, 1961; Buckman and Brady, 1969; Sperow and Keefer, 1975; Tisdale *et a.*, 1990; Constantinides and Fownes, 1993; Nair, 1993). This therefore clearly shows that widening the C/N ratio of the rapidly decomposing *Gliricidia* material using *Sawdust* is a convenient way of controlling (ie. slowing down) both the rate of decomposition and thus nutrients release. The highly significant mass loss percentage observed at 6 weeks under different *Gliricidia* + *Sawdust* mixtures placed at 20-40cm depth, can probably be attributed to possible termites activity as confirmed by the residual big termite holes observed on the litter bags. This is in agreement with findings reported by Lehmann *et al.* (1995) that mass loss of twigs and roots (ie. materials resisting microbial attack) can be attributed to termites activity.

5.2 The effect of different *Gliricidia* and *Gliricidia* + *Sawdust* mixtures (C/N ratios) on cumulative mineral nitrogen changes and net nitrogen mineralization and nitrification at Kitete.

The results of cumulative mineral nitrogen (Fig. 1, 2, 3 and 4) and those of daily net nitrogen mineralization and nitrification (Table 6, 7, 8 and 9) in the present study, indicate that nitrate is the dominant form of mineral nitrogen, ranging between 67- 81 percent, and that the level of mineral nitrogen in the soil at a given period of time, depends upon the daily mineral nitrogen added to or removed from the soil during that period. These results confirm earlier findings that nitrate ions are the dominant form of mineral nitrogen which are readily available and easily removed from the soil as compared with ammonium ions (Alexander, 1961; Meentemeyer, 1978; Tisdale *et al.*, 1990), and that the rates of mineralization and nitrification are indicators of soil fertility (Allison, 1973; Pastor *et al.*, 1987; Piccolo *et al.*, 1994). The assumption on the initial soil equilibrium state and the results from this study, are also in conformity with findings reported by Tisdale *et al.* (1990) that, under equilibrium conditions, microbial populations remained constant, and there is a fairly and usually low rate of nitrogen mineralization, and that any addition of organic materials improves the level of

available nitrogen in the soil (Nair, 1993).

The plots that had high initial total nitrogen showed high levels of mineral nitrogen. This high rate of mineral nitrogen formation associated with high initial total nitrogen in this study, is in agreement with earlier findings by Alexander (1961). During the first two weeks, the mineral nitrogen was probably coming from the already existing nitrogen in the soil, thus creating favourable conditions for decomposition and mineralization of the added *Gliricidia* and *Sawdust* materials.

The high rates of *Gliricidia* application (60 and 45 kg N/ha) showed high cumulative mineral nitrogen and daily net nitrogen mineralization and nitrification during the first 6 weeks after green manuring. Probably this was due to the high quality attributes of *Gliricidia* that ensured its fast rate of decomposition as reported by Yamoah *et al.* (1986), Budelman (1988) and Lehmann *et al.*(1995). After the 6 weeks, however, the level of mineral nitrogen declined rapidly, due not only to weeds and maize crop uptake, but also due to the completion of the decomposition of the incorporated *Gliricidia* leaves. The later is in line with earlier findings reported by Budelman (1988) in which half of the applied fresh leaves of *Gliricidia sepium* was decomposed within 22 days. Similarly Lehmann *et al.* (1995)

found that *Gliricidia* decomposed considerably faster in the first 18 days with 75 % mass loss compared to *Senna* with 30 %. The fast decomposition of *Gliricidia* manures was associated with rapid nitrogen release, and was in line with reports by Thompson and Troeh (1979). Decomposition and mineralization rates are closely linked and, the rapid decomposition rate leads to rapid nitrogen mineralization. McGill *et al.* (1981), concluded that the observed rapid mineralization in lowland tropical soils, was associated with decomposition rate.

The observed highest decline in the cumulative mineral nitrogen and daily net nitrogen mineralization and nitrification in the top soil horizon (0-20cm), and the highest mineral nitrogen formation below the maize rooting zone (20-40cm) in the control plots can be attributed to leaching of nitrogen from the upper soil horizons (0-20cm) and accumulation in the deeper soil horizons (20-40cm). Neither the plots incorporated with *Gliricidia* alone nor with *Gliricidia* + *Sawdust* mixtures showed similar high nitrogen losses by leaching, probably due to soil conditions amelioration and protection afforded by the organic matter. This is due to the fact that, organic materials added to the soil do not only improve and maintain soil fertility (Budelman, 1988; Oglesby and Fownes, 1992; Nair, 1993), but they also conserve soil

moisture (Budelman, 1989), and decrease soil erosion (Young, 1989). All these benefits from organic manures were missing in the control plots, and thus, the marked negative influence on nitrogen availability, its uptake by the maize crop, maize plant growth and maize grain yield.

Interestingly, throughout the maize crop development, treatments with high C/N ratios (21:1 and 23:1 respectively) showed the gradual release of mineral nitrogen within the maize rooting zone (0-20cm). This gradual release of mineral nitrogen can be attributed to the efficient control exercised by the *Sawdust* on the decomposition rates and nitrogen release from *Gliricidia* leaves. These mass loss and mineralization results show that mixing *Sawdust* with the fast decomposing green manures is a convenient way of controlling both the decomposition and nitrogen mineralization rates. Constantinides and Fownes (1993) indicated that the net nitrogen immobilization in the leguminous leaf-twig mixtures was largely caused by the presence of twigs (resistant material to microbial attack), and that nitrogen immobilization during decomposition tended to increase with increasing lignin and decreasing nitrogen of plant tissue. It is important that fast decomposing leguminous materials should be applied in combination with slow decomposing materials (having either higher C/N or lignin : nitrogen ratios) to

ensure an even release of nutrients for crops use over the entire period of crop growth and development.

It should be noted from these results that the daily net nitrification can be used to predict the net nitrogen mineralization, not only because nitrate is the dominant form of mineral nitrogen but also it is a governing factor of mineralization (ie. the last step of mineralization). The higher the release of nitrate the higher will be the rate of nitrogen mineralization. The higher the nitrate immobilization or losses the lower will be the level of mineral nitrogen in the soil.

5.3 The effect of nitrogen uptake by maize crop on its growth and yield.

The results for maize root counts and root length measurements indicated high concentration within the 0-20cm depth, implying that maintenance of nitrogen availability in this zone would optimize its uptake by agricultural crops. The nitrogen uptaken by the maize plants (Table 10), mean height increment (Table 12) and grain yield of the maize crop (Table 13) varied in direct proportion with both the *Gliricidia* leaves application and C/N ratio with the 21:1 and 23:1 C/N ratios showing the highest uptake of nitrogen. These results imply that the soils deficient in

organic matter rapidly loose their fertility, mainly due to leaching, while the application of fast decomposing manures alone only temporarily improves nitrogen availability. Possibly this may benefit short duration crops such as some varieties of legumes. Improvements in the yields of long duration crops like maize, however, would depend on the effective regulation of the decomposition rates of these high quality manures. They will require a gradual but sustained nutrient release pattern that would ensure that sufficient nitrogen is available throughout the crops' developmental stages, and maximize its overall uptake. These findings are in agreement with the major aims of maintaining and improving soil fertility reported by a number of workers on organic fertilizers (Alexander, 1961; Yamoah *et al.*, 1986; Budelman, 1988; Tisdale *et al.*, 1990; Oglesby and Fownes, 1992). They are also in line with the suggestions of efficiently managing nutrients and, especially nitrogen, in order to improve crop yields (Nikokwe, 1992; Nair, 1993; Lehmann *et al.* 1995). The strongly positive correlations between nitrogen uptaken by the maize crop and the crops subsequent growth and yield performance in the present study are in conformity with the general linkage patterns between nutrient uptake by the crop plants and their subsequent productivities reported by Tripathi and Hazra (1986). If we consider the period of maximum height increment (3-8 weeks) observed in the

present study to reflect the critical period of high nutrients demand by the Staha maize crop in Kitete, then the nutrient release patterns afforded by the *Gliricidia* + *Sawdust* mixtures with 21:1 and 23:1 C/N ratios provide the most efficient use of released nitrogen (Alexander, 1961; Allison, 1973; Pastor *et al.*, 1987). Such period is, however, wider than that of 4-6 weeks reported by Lehman *et al.* (1995) from Central Togo, probably reflecting maize varietal differences or differences in the environmental conditions or differences in height measurement intervals.

It should be remembered however, that, although combining *Sawdust* with *Gliricidia* is a convenient way of controlling nitrogen release from *Gliricidia* manures, very high quantities of material with high C/N ratio should be avoided, since as reported by Nair (1993), additions of high quantity of poor materials to the soil, reduces crop productivity due to high soil nitrogen immobilization by soil microorganisms. Similarly, from his joint study with a local farmer at Kitete Village, Nduwayezu and Kauta (1996) found that, maize grain yield was significantly higher under plots treated with high quality organic material (*Gliricidia* leaves alone), while the maize grain yield from plots treated with *Sawdust* alone (poor quality), was even below that of the control treatment plots. Since the critical *Gliricidia* + *Sawdust* mixture proportion above

which result in negative influence has not been established in the present study, further research in that direction is required.

CHAPTER 6

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the preceding decomposition and mineralization results and discussion the following conclusions have been reached:

(i) The rate of dry weight loss of *Gliricidia* leaves alone was considerably faster within 8 weeks but it decreased with increasing C/N ratio of *Gliricidia* + *Sawdust* mixtures.

(ii) The *Gliricidia* leaves alone decomposed rapidly to release most of their nitrogen during the first six weeks, while the higher C/N ratios (21:1 and 23:1 C/N) *Gliricidia* + *Sawdust* mixtures released the nitrogen gradually extending over the entire period of the maize crop growth and development.

(iii) Nutrients, especially nitrogen, leached out rapidly from the top to the sub-soil horizons in organic matter deficient treatment plots (control).

(iv) Nitrate nitrogen was found to be the dominant form of the available mineral nitrogen, ranging from 67 to 81 percent.

(v) Overall, the amount of available nitrogen depended upon the daily net nitrogen mineralization and nitrification.

(vi) Most of maize crop roots were concentrated within the 0-20cm soil horizon. Maintaining nitrogen availability in this zone, therefore, significantly increased its uptake by maize crop.

(vii) The higher C/N ratios of *Gliricidia + Sawdust* mixtures (21: and 23:1 C/N) resulted in highest nitrogen uptake, growth rate and higher grain yields of the maize crop.

(viii) The nitrogen uptaken by maize plants was found to be positively correlated with the maize growth and yield.

(ix) The first 3-8 weeks constituted a critical period of high nutrients demand by maize crop in Kitete Village, and only the C/N ratios of 21:1 and 23:1 (*Gliricidia + Sawdust* mixtures) sufficiently met this requirement due to the extended gradual nutrient release.

6.2 RECOMMENDATIONS

From the preceding conclusions the following recommendations can be made :

(i) To optimize nutrients uptake by agricultural crops and improve their yields on a sustainable basis, green manures should be properly added to the soil, but their application should be well timed.

(ii) Fast decomposing plant material such as *Gliricidia* leaves should be applied where crops grow very fast and mature early in order to benefit optimally from nutrients supplied by decomposing plant materials.

(iii) When the slow growing crops are involved plant material with a gradual release of nutrients either by widening the C/N ratio of the organic manures up to 21:1 and 23:1 C/N ratios by the incorporation of materials such as *Sawdust*, should be adopted in order to optimize nitrogen uptake by the crops, and thus increase their yields.

(iv) A critical C/N ratio in the *Gliricidia* + *Sawdust* mixtures which optimizes sustained nitrogen nutrient availability and uptake by the maize crop and, thus, maximizing its grain yield, has not been established in the present study. It is recommended that future research should address this problem.

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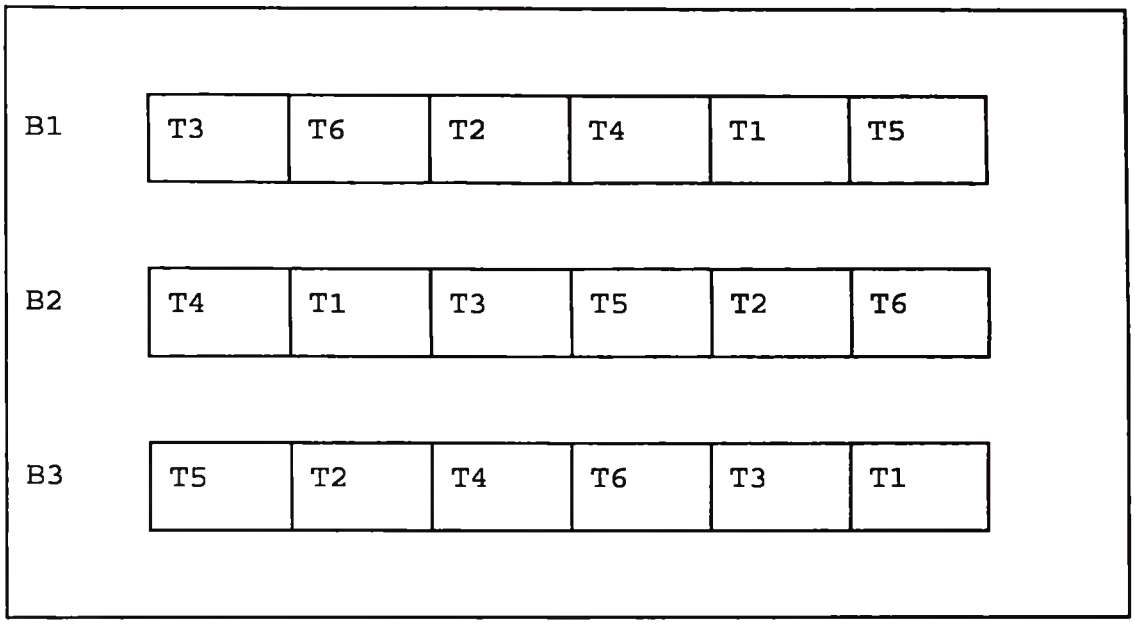
Appendix 1. The Experimental Design and Field Layout of the Decomposition Study at Kitete (1995/96).



Treatments mixtures in each litter bag:

T1:150 g/plot *Gliricidia* alone (C/N:13:1)

T2:150 g/plot *Gliricdia* + 37.5 g *Sawdust* (C/N:16:1)

T3:150 g/plot *Gliricidia* + 75 g *Sawdust* (C/N:19:1)

T4:150 g/plot *Gliricidia* + 112.5 g *Sawdust* (C/N:22:1)

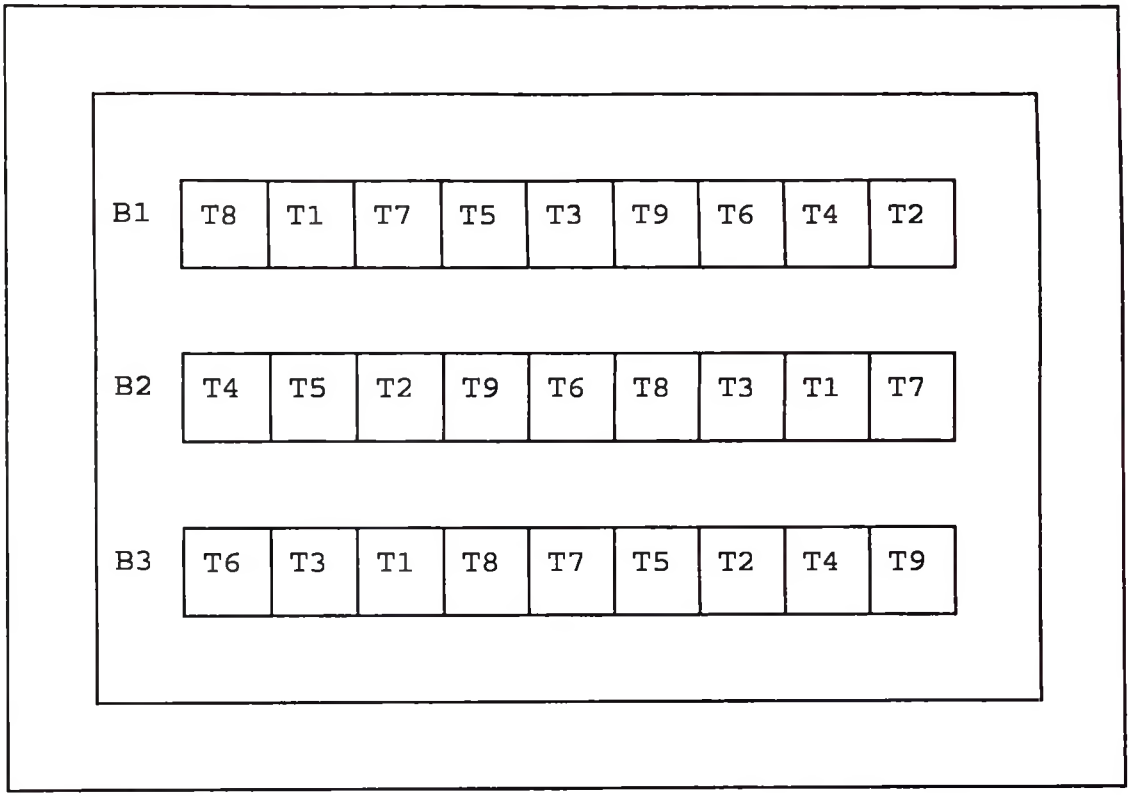
T5:150 g/plot *Gliricidia* + 150 g *Sawdust* (C/N:25:1)

T6:150 g/plot *Sawdust* alone (C/N:297:1)

Note: - Plot size: 2m x 4m

- Inter-block and inter-plot spacings:1m
- After every two weeks two litter bags (one from 20cm and one from 40cm placement depths) per treatment in each block were retrieved.
- Sample retrieval period: 2 weeks.

Appendix 2. The Experimental Design and Field Layout of the nitrogen mineralization study at Kitete (1995/96).



Treatments:

T1: 1.5 kg/plot *Gliricidia* leaves (60 kg N/ha)

T2: 1.15 kg/plot *Gliricidia* (45 kg N/ha)

T3: 0.76 kg/plot *Gliricidia* (30 kg N/ha)

T4: 0.38 kg/plot *Gliricidia* (15 kg N/ha)

T5: 1.5 kg/plot *Gliricidia* + 0.5 kg *Sawdust* (C/N:17:1)

T6: 1.5 kg/plot *Gliricidia* + 0.75 kg *Sawdust* (C/N:19:1)

T7: 1.5 kg/plot *Gliricidia* + 1.0 kg *Sawdust* (C/N: 21:1)

T8: 1.5 kg/plot *Gliricidia* + 1.25 kg *Sawdust* (C/N: 23:1)

T9: Control (neither *Gliricidia* nor *Sawdust* application).

Note:- These treatments mixtures are based on the recommended fertilization rate of 60 kg N/ha for Kilosa's soils that's why the quantity of *Gliricidia* leaves required to produce this rate was kept constant (1.5 kg/plot *Gliricidia* leaves) while that of Sawdust varied. Maize was used as a test crop.

- Plot size: 3m x 3m
- Maize (STAHA variety) spacing: between line (90cm) x within line (30cm) spacing
- Inter-blocks and plots spacings: 4m and 1m respectively.
- The whole Experiment was surrounded by two border lines of maize so as to minimize the border effect.