THE EFFECT OF SOIL TYPE, MANURE APPLICATION RATE AND PLACEMENT METHOD ON THE DECOMPOSITION OF, AND NITROGEN RELEASE FROM, *SENNA SIAMEA* GREEN MANURE

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ABSTRACT

The decomposition and nitrogen release of *Senna siamea* green manure was studied under glasshouse and field conditions. The effects of two soil types, two manure application rates and two methods of manure placement on the decomposition rate were monitored by use of three parameters, namely residual dry matter, organic carbon and total nitrogen. These parameters were measured at the 1st, 3rd, 6th, 9th and 12th week of manure incubation in the glasshouse while in the field, measurements were made at the 3rd, 6th and 9th week.

The glasshouse study revealed that there was no significant ($p=0.05$) difference between the decomposition rates, at 10 cm depth, in a Rhodustult (soil 1) and Dystropept (soil 2) as indicated by the three parameters. The manure decomposed faster at a lower application rate (60 kg manure-N/ha) than at a higher rate (150 kg manure-N/ha). Under field conditions, buried manure decomposed faster in soil 2 than in soil 1 while for the surface-placed manure the opposite was observed. In soil 1, where termite activity was appreciable, the surface-applied manure decomposed faster than the buried material while in soil 2 the decomposition rate was faster for the buried manure.

The trends of manure decomposition were similar under the two incubation conditions but the decomposition rate after the third week was significantly higher in the field than in the glasshouse.

The results of the present study indicated that in the glasshouse, the decomposition rate of green manure was not affected by the soil types used. But the decomposition varied with soil type, manure application rate as well as the mode of placement in the field. Therefore these factors should be considered when conclusions are to be made with respect to nutrient release from this manure.

DECLARATION

I, RUTH WATIRI HARU, do hereby declare to the SENATE of Sokoine University of Agriculture that this dissertation is the result of my own original work and has not been submitted for a degree award in any other university.

Signature...Ruth Haru............

Date.....1/1/96.................

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CHAPTER ONE

1.0 INTRODUCTION

1.1 General

The use of mineral fertilizers to improve soil fertility has received the main emphasis in developing countries in recent years. This has been done as an attempt to efficiently produce food as well as cash crops in order to meet the increasing demand for food and earn foreign exchange. The attempt has worked in the case of the large scale farmers who can afford such materials, whose prices are very high at present. In Tanzania, for example, urea is presently selling at Tshs. 7 000.00 per 50 kg bag. The small scale farmers, who constitute about 75% of the farming population in these countries, have been disadvantaged. This is not only because of the prohibitive fertilizer prices but also because of the frequent unavailability of the fertilizers at the village markets at the time the farmers need them. Moreover due to the high population growth rate in these countries land subdivision, that is, larger farms being fragmented into small ones, is on the increase. These farms are cropped season after season with very little being done to maintain and/or improve their fertility and good physical conditions.

The above-mentioned constraints have necessitated or, more emphatically, dictated a change in outlook with respect to the source of plant nutrients for soil fertility improvement and to the maintenance of good physical conditions in the small scale farming systems. The supply of the nutrient element nitrogen (N) is especially important because it is a major limiting factor in most soils in the tropics. Among the essential nutrient elements, N is required by plants in the greatest quantities (Alexander, 1977).

In this regard, there is need to encourage farming systems which will make use of locally available organic N sources, either to supplement or in some cases substitute for the use of inorganic fertilizers. One such system is the use of green manures. Green manuring has a potential for maintaining high soil productivity and has proved successful in different farming systems. In alley cropping systems, for example, prunings from leguminous woody perennials such as *Leucaena leucocephala* have great potential to supply N for plant growth (Oglesby and Fownes, 1992). Field experiments carried out in southern Nigeria by Kang *et al.* (1985) have shown that under intensive pruning (five prunings per year) for six years, *Leucaena* hedgerows in alley cropping continued to produce substantial amounts of pruning and nitrogen yields. Ten tons of such prunings, dug into the soil at the time of maize seeding, increased grain yields from 1.3 to 3.1 tons per hectare (Rocheleau *et al*., 1988). This was equivalent to applying 100 kg of N fertilizer per hectare.

The use of *Senna siamea* as a source of N in alley cropping systems has been documented in East Africa (Rocheleau *et al*., 1988; Omoro and Nair, 1993). This evergreen tree species grows in humid, sub-humid, dry and arid climates. In a comparative study between the performance of *Senna siamea* and *Leuceana leucocephala* as hedgerow species for alley cropping, Jama-Adan (1993) indicated that *Senna siamea* was a better species for alley cropping under semi-arid conditions at the International Centre for Research in Agroforestry (ICRAF)research centre in Machakos, Kenya. He found that maize grain yields were higher when alley-cropped with *Senna* than with *Leuceana*.

At the Kazabona experimental station in Central Togo, *Senna siamea* and *Gliricidia sepium* formed a good combination for mulch and green manure production. This was in terms of absolute amounts of nutrients and patterns of their release (Lehmann *et al*., 1995).

1.2 Problem analysis

The potential nutrient contribution of green manure plants is important in so far as the nutrients are made available to a growing crop at the time the nutrients are most needed. This becomes critical when the nutrients made available during the decomposition of such manures added to soil is the only source of nutrients for the crops, that is when inorganic fertilizers are not used. In order to achieve the above mentioned synchrony, that is to have the N being released at the time it is most needed by the crop, there is need to know not only the nitrogen content of a specific green manure plant material but also the nitrogen release patterns upon decomposition under a particular set of environmental and crop-soil management conditions (Wilson and Hargrove, 1986; Yamoah *et al.*, 1986). Moreover, the patterns should be established for different soil types in order to be able to devise effective strategies to achieve good management of green manure N. This may be undertaken using laboratory studies but to obtain more reliable information, results from laboratory studies should be confirmed in the field. Not much has been done in this direction.

The studies reported herein were focused on *Senna siamea,* and were carried out with the following objectives:

1. To determine the rate of decomposition and extent of N release of *Senna siamea* green manure under different soil types, manure application rates and methods of application.

2. To compare the rates of decomposition of *Senna siamea* under laboratory and field conditions.

3. To determine the microbial population changes in the course of the decomposition process in the different soils and to relate these changes to the patterns of manure decomposition.

4. To explore/speculate the extent to which soil type can be a factor in determining the timing of green manure application in the field.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The potential of green manure in supplying the plant nutrient Nitrogen

When fresh plant materials containing high amounts of N are incorporated into the soil or are left on the soil surface, they decompose and serve as a source of nutrients, mainly N, for subsequent crops. Legume green manures are especially important in this respect due to the nitrogen (N_2) fixing capacity of the legume plants and their comparatively high N concentrations in their shoots. Alfalfa (*Medicago sativa)*, for example, can fix between 150 and 250 kg N/ha/year (Brady, 1984).

The importance of green manures in supplying N has been demonstrated in different cropping systems. In a green manure experiment carried out in Maseno Research Station in western Kenya, *Sesbania sesban* var *nubica* and *Leuceana leucocephala* produced 13 603 and 16 659 kg of dry matter/ha/year, equivalent to 643 and 448 kg N/ha/year, respectively (Onim *et al.*, 1990). These were cumulative values for six prunings done every two months at a height of 60 cm above the ground. In a later study at Hawaii, Rosecrance *et al.* (1992) reported that maize yields responded linearly to N applied as green manure from nine types of leguminous manures, among which *Senna siamea* was included. Two successive additions (one every cropping season) of prunings from these trees were able to support maize grain yields at about 1 800 kg/ha during those two cropping seasons while control plot yields averaged less than 600 kg/ha (Rosecrance *et al., 1992)*.

Other field trials where *Sesbania* spp was used indicated that green manures could substitute N fertilizer to the extent of 50 to 100 kg N per hectare depending on the age of the plant at the time it was used as green manure (Singh and Brat, 1989). Moreover, Palm *et al.* (1989), Prabharkar and Nair (1989) and Kang *et al.* (1985) demonstrated similar results in rice, cassava and maize production, respectively. The examples quoted above demonstrate the great potential of green manures to supply plant nutrient elements, especially N. This potential should be taken advantage of, particularly by the low-input small scale farmers whose meagre resources make inorganic fertilizers unaffordable to them. There is not much work that has been done in East Africa using *Senna siamea* in this respect. Therefore, this review addresses green manures in general, hoping that the trends exhibited by other manures would be similar to those shown by *Senna siamea*.

2.2 Influence of green manures on soil properties

Together with their important role in supplying the nutrient elements, particularly N, green manures have beneficial effects on soil physical and chemical properties. They also influence the microbiological properties.

Green manures help in improving soil organic matter levels (Kang *et al.*, 1985). The beneficial effect on soil physical properties is due in part to the action of organic matter as "gum" in binding soil particles into aggregates, leading to an improvement in soil structure with balanced distribution of pore sizes (Dalland *et al.*, 1993). Yamoah *et al.* (1986) have pointed out that good physical properties may at times be more important than the supply of nutrients; the nutrients released by the manures may become useless if physical conditions do not favour proper root development to take up the nutrients.

The effect of enhanced organic matter levels on soil chemical properties has also been documented (Brady, 1984). In an alley cropping system, use of *Leucaena* prunings resulted in higher amounts of organic matter, exchangeable K, Ca, Mg, and also resulted in a balanced nutrient supply, slow release of nutrients, protection of nutrients from leaching and an increased buffering effect against soil acidity (Dalland *et al.*, 1993).

The decomposition of green manure serves two functions for microorganisms, namely provision of energy for growth and supplying carbon for formation of new cells. As already indicated, green manuring has been shown to increase the amount of organic matter in the soil. The amount, type and availability of organic matter determine the size and composition of the heterotrophic microbial community that a soil will contain. The nature of the flora will vary with the chemical composition of the added substrate (Alexander, 1977).

2.3 Factors affecting the decomposition of plant residues and their nutrient release.

The suitability of organic materials as manures depends to a great extent on the rapidity of their decomposition, hence of liberating the nutrients they contain. Work by Azam *et al.* (1985), in which the transformations in soil and availability to plants of ^{15}N applied as inorganic fertilizer or legume residues was studied, led to the conclusion that until legume residues were completely mineralized their value as an immediate source of plant available N was doubtful. The rate of decomposition and nutrient release is dependent on soil, substrate, management, as well as environmental factors.

2.3.1 Soil factors

Factors influencing microbial growth modify the rate at which crop residues added to soil are transformed. Hence soil factors such as aeration, soil pH, soil temperature and moisture content are very important in the decomposition process (Adams *et al.*, 1989; Alexander, 1977). These factors are influenced by soil structure as well as texture, which vary with soil type.

Investigations with isotope-labelled substrates have demonstrated less-extensive decomposition and higher proportions of isotope in organic residues accumulating in microbial biomass in high-clay soils than in soils of lighter texture (Sorensen, 1975; Ladd *et al.*, 1992). Work in which the decomposition of wheat and legume straw were studied indicated that soils of higher clay contents retained higher proportions of added wheat and legume ^{14}C in organic residues (Amato *et al.*, 1987). In another study by Amato and Ladd (1992), total residual organic ^{14}C from *Medicago littoralis* decomposition was found to be directly correlated with clay content and related properties, such as CEC and total soil pore space, of neutral to alkaline soil pH. Similarly Christensen (1985) found that the overall N dynamics of maize and wheat straw decomposing under field conditions was significantly influenced by soil type. In a sandy loam soil (14% clay), both straw types showed net immobilization of N which began immediately after straw incorporation, followed by a net N release. However, in a coarse sand (3% clay), a small loss of straw N occurred during the first month after burial followed by a slow rate of N immobilization and to a less extent than in the sandy loam soil.

According to Sorensen (1975), clay influences the decomposition process up to a certain stage. He found that the rate of decay of amino acid metabolites, synthesized in seven different soils containing silt + clay in amounts varying from 8 to 15%, was higher in soils containing low amounts of silt + clay in the initial stages of decomposition. However the rate of decay was independent of the clay content in the later stages.

Jenkinson (1977) found that the rate of decomposition of labelled ryegrass tops in soils containing different amounts of organic matter was not significantly different. He concluded that the retention of added plant C in the soils was not significantly influenced by factors such as the CEC, water holding capacity, structural stability, or amounts of potentially mineralizable N, P or S, all of which depend greatly on the amount of organic matter in soil. Unlike organic matter, the clay content of the soils was found to have a significant influence on the decomposition rate. The ryegrass decomposed faster in a sandy soil with 7.6% clay than in a comparable soil with 17.5% clay.

From these studies it is apparent that the clay fraction of the soil plays a great role in the decomposition of organic residues added to soil. The reduced rate of decay of these materials in the presence of clay is assumed to be a result of adsorption of organic material between layers in expanding clays, or adsorption on the surface of silt and clay particles, or aggregate formation of some kind between cells or cell fragments and clay material. Such interaction might render the organic material less accessible to decomposition by microorganisms (Greenland, 1965a,b). Earlier studies by Bondietti *et al.* (1971) and Zunizo *et al.* (1982) on the influence of clays on microbial activity and organic residue decomposition showed that clays increased the microbial growth rate but reduced the total loss of C by increasing the efficiency of C utilization by the microbes. Clays also complexed the decomposition products and humic substances, thereby reducing their availability to microbes. The presence of clays may also affect the availability of various N compounds to the microorganisms by fixing ammonium and strongly adsorbing organic N compounds. Moreover, the sand, silt and clay particles may probably physically impede microbial movement to nutrient sources in soil, thereby serving as mechanical barriers to the contact between the particulate substrate and the potentially active microbial cell or its extracellular enzymes (Ou and Alexander, 1974).

The activity of soil fauna is believed to be a major factor contributing to the maintenance of soil physical and chemical properties (Okwalol, 1993). The feeding and burrowing activities of these animals affects the decomposition of organic matter, and alters soil physical structure and soil water relations. Biological turnover and nutrient release from residues is greatly influenced by soil fauna (Scheu and Wolters, 1991; Anderson and Ingram, 1989). These organisms fragment the residues thus enhancing microbial activity. Soil fauna also digest plant residues through symbiotic interaction with gut microorganisms (Edwards and Fletcher, 1988). A study on the effect of earthworms and millipedes on the breakdown of plant residues under humid tropical conditions revealed that earthworms and millipedes on the average accounted for the breakdown of plant residues by 10.4 and 28.4%, respectively (Tian *et al.*, 1995). Wood (1976) as cited by Gotz *et al.* (1992) pointed out that in savanna regions termites can consume considerable quantities of fresh plant materials before it is colonized by saprophytic microorganisms. This reduces the role of microbes in the early stages of decomposition. Nandwa *et al.* (1993) reported that termite activity was one of the reasons for the different decomposition rates obtained during the decomposition of maize stover at two different sites. Moreover, the dominance of the soil fauna in the decomposition process could explain why there was a rapid release of N and P from a decomposing plant residue mulch even though the C:N ratio of 20 and C:P ratio of 200, which are normally necessary for net N and P release during microbial decomposition, had not been reached (Gotz *et al.*, 1992).

2.3.2 Substrate factors

Substrate quality, particularly the chemical composition, is an important factor in determining the decomposition rate (Tian *et al.*, 1992). The chemical composition differs between plant species, plant parts and plants at different stages of maturity. Therefore they have different decomposition rates when exposed to similar conditions. Amato *et al.* (1987) observed that the tops of pasture legumes (*Medicago littoralis* and *Trifolium subterraneum*) incorporated into topsoil decomposed more extensively than did wheat straw, especially soon after incorporation. Lekasi *et al.* (1993) reported that soil-incorporated maize stover decomposed significantly faster than incorporated roots, suggesting that the regulation of decomposition by the soil microclimate interacted with the chemical characteristics of the litter material. Similarly, Constantinides and Fownes (1993) demonstrated that the presence of twigs reduced short-term net mineralization and release of available N from decomposing green manures. According to their study, twigs may immobilize higher amounts of N released during mineralization of leaf nitrogen. This could explain the complex patterns of nitrogen mineralization and immobilization in leaf and twig mixtures in a study by Oglesby and Fownes (1992). In general, the N concentration, C:N ratio, the lignin and polyphenol contents are the recognized plant factors controlling the decomposition and N mineralization rate of plant materials added to soil (Haynes, 1986 as cited by Fox *et al.*, 1990; Iratani and Arnold, 1960; Frankenberger and Abdulmagid, 1985).

Palm and Sanchez (1991) and Oglesby and Fownes (1992) confirmed that the best chemical index of N release from some tropical legumes was controlled more by polyphenols than by lignin or N content. The mechanism to explain the low rate of nutrient mineralization in materials high in polyphenols include the formation of stable polymers between polyphenolics and amino groups, and nitrosation, the chemical reaction of nitrites with polyphenolics.

2.3.3 Management factors

The manner in which plant residues are managed will also determine their rate of decomposition and nitrogen release. The plant residue particle size appears to be an important factor in the decomposition rate when such residues are added to the soil. Scheu and Wolters (1991), Amato *et al*. (1984) and Sims and Frederick (1970) suggested that fragmentation of residues facilitated microbial attack; hence small particles may decompose faster than larger ones. According to Jensen (1994), the effect of particle size on decomposition is dependent on the C:N ratio of the residue as well as the stage of decomposition. The decomposition of plant residues, microbial biomass and of matabolites formed during the early decomposition stages of materials of low C:N ratios is slower with small than with coarse residues, probably due to the better protection, from microbial attack, of the residues and biomass by clay minerals. During the initial stages of decomposition of high C:N residues the decomposition of larger-sized residues may be limited, resulting in an overall slow rate of decomposition as compared to that of smaller-sized residues.

The method of placement in the field is also an important factor to consider in green manure management. Under environmental conditions that might require soil erosion control and improvement of soil moisture retention, green manure may be applied as a surface mulch. However N_2 loss through volatilization is greater in this case than when the green manure is incorporated into the soil (Janzen and McGinn, 1991). Therefore, soil fertility improvement by the manure may be greatly reduced by the surface placement. Investigations by Varco *et al.* (1989) have demonstrated that N recovery by crops is often higher when green manure is incorporated than when retained on the soil surface. These findings suggest that optimum use of green manure residues may require a compromise between retaining a surface cover and maximizing soil fertility improvement. To reach such a compromise there is need to have the knowledge on the pattern and rate of nitrogen release from both surface- applied and soil-incorporated green manures under a given set of environmental and soil conditions. Several workers (Cogle *et al.* 1987; Lehmann *et al.* 1995; Lekasi *et al.* 1993; Msumali *et al.* 1993 and Mugendi *et al.* 1993) showed that residues applied on the soil surface decomposed at a slower rate than those incorporated into the soil. This was due to the greater positional availability of the residue carbon and nitrogen to soil organisms in the incorporated material.

Other workers (Puig-Gimenz and Chase, 1984), found that the rate of wheat straw decomposition varied inversely with the amounts applied while Ishuza (1987) reported that the amount of available N in the soil decreased with increasing rates of straw applied. Not much information is available on the effect of green manure application rate on their decomposition rate and patterns of nutrient release but a recent study suggests that the rate of decomposition varies with the manure application rate (Wangari, 1995).

2.3.4 Environmental factors

Decomposition rates are affected by climatic factors, namely temperature and rainfall. Amato *et al.* (1987) observed that for every additional mm of rainfall, the organic ^{14}C in soil-incubated legume tops declined by 0.38% during the first four weeks of incubation. However, the magnitude of the rainfall effect decreased with decomposition period. Previous work by Jenkinson and Ayanaba (1977) indicated that mean annual air temperature was of greater importance than moisture in controlling the extent of decomposition of added plant materials in (top) soils. They reported that overall rates of decomposition doubled for every 8-9 °C rise in mean annual air temperatures.

Unlike in laboratory studies where optimal soil moisture conditions for microbial activity are usually maintained, decomposition of plant residues in the field takes place under alternating wet and dry soil conditions during the rainy and dry seasons, respectively. Birch (1964) reported that intermittent drying enhanced the amount of mineral N released from four of five grass species, the effect of drying increasing as decomposition of the residue advanced. He concluded that when plant materials containing 2% N or less decomposed under constant moisture conditions for up to 33 days, there was an immobilization of soil mineral N. This process was either partly offset, or changed to a net N gain, when moist periods were alternated with dry conditions. He further concluded that where decomposition normally brought about a release of mineral N, drying increased this effect and decreased immobilization of soil mineral N where this would have been otherwise pronounced. Accordingly the immobilization effect of adding low N residues to the soil would be less under alternate wet and dry than under moist conditions.

Contrary to these findings, van Schreven (1967) reported that repeated drying at 35 °C depressed the release of carbon and N from alfalfa (*Medicago littoralis*). Similarly Franzluebbers *et al.* (1994), using cowpea (*Vigna unguiculata*) plant material, found that N mineralization was significantly reduced from 46% of initial plant N in moist soil to 29% in repeatedly dried and wetted soil at 68 days of incubation. Repeated drying and wetting of the soil increased the resistance of N compounds to microbial decomposition. These workers concluded that intermittent periods of dry and wet conditions between rainfall events could therefore lead to a long-term increase of N fertility in soils treated with legume green manure by increasing the soil organic N content. Moreover such conditions would reduce nitrate formation from ammonium released upon green manure decomposition. Also, nitrate losses would be reduced in sandy soils with low nitrifier populations as a result of reduced nitrification in such soils when subjected to short drying-wetting cycles. Hence these soils may be more nitrogen conserving than those that remain continuously moist.

2.4 Nitrogen availability from green manures

Nitrogen is assimilated by plants almost entirely in the inorganic state, NO_3^- or NH_4^+. Therefore, the organic form of this nutrient element added to soil in green manures has to be mineralized to be of use to the targeted crop. The availability of the released N to the crop will depend on the balance between the magnitude of factors and processes which influence the concentration of NH_4^+-N and NO_3^--N in the soils.

Nitrogen from plant materials decomposing in soil is believed to become rapidly and intensively involved in the process of microbial growth and decay (Amato *et al.*, 1987). Consequently, the release and availability of N from such materials is the resultant of the processes of mineralization and immobilization. According to Alexander (1977) the accumulation, in soils, of NH_4^+-N released from plant residues represents the quantity of substrate N in excess of the microbial demand. A decrease of NH_4^+-N in manured soil can be due to the utilization of this ion by soil microorganisms for growth (Iritani and Arnold, 1960; Pink *et al.*, 1946; Winsor and Polland, 1950). This decrease can also be due to the activity of nitrifying bacteria (Cornfield, 1952). A decrease in NO_3^--N is brought about by the immobilization of NH_4^+-N and denitrification of NO_3^- by the general soil microflora and denitrifiers, respectively (Alexander 1977). Generally, the amount of plant-derived N which becomes immobilized into relatively stable forms of organic residues depends not only upon the amounts of metabolizable carbon from both plant and soil organic matter sources, but also upon the availability of soil-derived nitrogen in the immobilization reaction, and the patterns of leaching in the soil profile.

Investigations carried out over a period of seven days revealed that more NH_4^+-N and NO_3^--N were released from decomposing plant residues under aerobic than under anaerobic conditions (Weeraratna, 1979). During incubation the NO_3^--N decreased due to denitrification. Patnaik and Rao (1978) reported that decomposition of added residue under anaerobic conditions gave NH_4^+-N as the end product while under aerobic conditions nitrification subsequently occurred, resulting in the formation of NO_3^--N which is prone to denitrification and leaching.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The general objective of the experiments in this study was to determine the decomposition rate and nitrogen release patterns of *Senna siamea* green manure under two soil types.

3.1 Soil Sampling

Surface (0-10 cm) samples of two soils were collected within the Sokoine University of Agriculture (SUA) farm. Msanya (1980) and Urassa (1991) classified similar soils within the farm as Typic Rhodustult (soil 1) and Fluventic Dystropept (soil 2), respectively.

Soil 1 was sampled from a cultivated site located about 100 m East of the Faculty of Forestry hostel. Soil 2 was taken from the horticultural unit within the SUA farm at an uncultivated site to the north of the orange orchard. These sites, known to be low in total N were also used to conduct a field experiment.

3.2 Soil analysis

The physical, chemical and microbiological properties of the soils were determined as follows:

3.2.1 Physical properties

(i) Soil texture

The particle size distribution was determined by the hydrometer method (Anderson and Ingram, 1993) and the textural class was arrived at by the use of the textural triangle for soil textural analysis according to the USDA classification scheme.

(ii) Bulk density

This was determined by the core method (Blake and Hartge, 1986). The soil, in cylindrical metal cores, was dried to constant weight at 105 °C. The ratio of this mass to the pre-determined volume of the cores gave the bulk density.

3.2.2 Chemical properties

(iii) Soil pH

The soil pH was determined electrochemically in a 1:1 soil:water suspension (Juo, 1979).

(iv) Total Nitrogen

The Macro-Kjeldahl digestion-distillation method (Bremner, 1982) was used to determine the total N of the soils. The soil was digested with concentrated sulphuric acid in the presence of a selenium catalyst whereby the organic nitrogen was converted into the inorganic (NH_4^+) form. The solution was made alkaline with 40% Sodium hydroxide and the liberated ammonia gas was distilled and trapped in boric acid which was finally titrated with 0.05N sulphuric acid.

(v) Extractable Phosphorus

The acid-soluble form of phosphorus was extracted by 0.025M HCL and 0.03M NH_4F as described in the Bray 1 method (Juo, 1979). Ammonium molybdate (1%) in sulphuric acid was used to form a blue coloured complex with the phosphate in the extract. The amount of phosphorus was then determined spectrophotometrically at 882 nm.

(vi) Organic carbon

The wet oxidation method as described by Juo (1979) was used in determining the organic carbon content in the soil.

(vii) Cation Exchange Capacity (CEC) and Exchangeable Bases

The soil was treated with an excess of 1M neutral ammonium acetate to saturate the colloidal complex with ammonium ions (Chapman, 1965). The excess of these ions were removed by washing with alcohol and those adsorbed were replaced by potassium, using acidified 1M potassium chloride. The ammonium in this extract was then determined by distillation in an alkaline medium of sodium hydroxide and absorbed in boric acid as for total N. The distilled ammonium was titrated with sulphuric acid and was a measure of the CEC. The exchangeable bases namely, Na^+, K^+, Mg^+, and Ca^{2+} were determined by atomic absorption spectrophotometry using the 1M neutral ammonium acetate extract.

3.2.3 Microbiological Properties

The release of N and other nutrients from organic plant residues added to soil is the result of the metabolism of a diversity of microbial types. In this study, it was found desirable to determine the initial size of the microbial population in the soil samples and the changes of these populations in the course of the decomposition of the plant material at the 1st, 3rd, 6th, 9th and 12th week of incubation. The agar-plate method for viable microbial count, as described by Clark (1965), was used. The spread plate technique, described in this method, was used to determine the viable microbial count in soil extract agar.

3.2.4 Summary of the soils' properties.

The soil characteristics determined as described above are shown in Table 3.1. These soils have low levels of total N, exchangeable bases as well as organic carbon (hence low organic matter) content. The viable microbial counts are also low. These parameters indicate that the fertility of the soils is low. Moreover soils 1 (pH 5) and 2 (pH 6) are strongly acidic and medium acidic, respectively. Therefore, N mineralisation from the organic matter in these soils may be slow (Thompson and Troeh, 1989).

3.3 Collection and analysis of the green manure material.

Succulent twigs and leaves were collected from *Senna siamea* trees growing within the University area. To ensure uniformity, the materials from different trees were collected in the same ratio as they occur on the trees; and the length of the twigs sampled, starting from the apex backwards, was approximately 30 cm.

The moisture and consequently the dry matter content were determined by weighing the wet material immediately after sampling and drying to constant weight at 60 °C. The dried material was then ground to pass through a 1 mm sieve. The total nitrogen and organic carbon contents of the material was determined using the same procedures as described for soils. The characteristic of this green manure are shown in Table 3.2.

Table 3.1 Properties of the soils used.

Characteristic	Value	
	Soil 1	Soil 2
Soil pH	5.0	6.0
Sand, %	28	58
Silt, %	14	16
Clay, %	58	25
Textural class	Clay	Sandy clay loam
Exchangeable cations, meq/100g of soil		
K+	0.88	1.56
Na+	0.31	0.37
Ca2+	1.07	0.38
Mg2+	0.93	0.86
Cation Exchange Capacity (CEC), meq/100g of soil	22	17
Organic carbon, %	0.92	1.72
Total nitrogen, %	0.07	0.08
Extractable P, ug/g	1.20	39.7
Bulk density, g/cm^3	1.01	1.23
Viable Microbial counts, CFU*/g	2.1x10^5	2.4x10^5

*CFU= Colony forming units

Table 3.2 **Characteristics of the *Senna siamea* green manure used**

Characteristic	Value
Total nitrogen, %	1.9 (twig-leaf mixture) 2.4 (leaflets)
Organic carbon, %	56
C:N ratio (twig-leaf mixture)	29.5
Moisture content, %	71

As shown in Table 3.2, the plant material was succulent and contained a substantial amount of N at the time of harvest. The C:N ratio was only slightly narrower than the critical value (30) at which N immobilisation is expected to occur upon incubation of such material with soil (Parnas, 1975).

3.4. Experimentation and statistical analysis

Two experiments, one in the glasshouse and the other in the field were carried out.

3.4.1. Experiment 1: Green manure decomposition in the glasshouse

The specific objective of this experiment was to determine the effect of the rate of manure application on the nitrogen release rate and pattern in the two soil types. It was set up in the glasshouse where controlled conditions for the decomposition process were maintained.

Seven rectangular wooden troughs measuring 450x45x20 cm were constructed. Each trough was partitioned into 10 compartments whose inside was lined with plastic material to make them leakproof. Six troughs were filled with air dry soil in such away that three of them contained soil 1 and another three soil 2. The seventh trough received both soils; five of its partitions (plots) on the same end were filled with soil 1 and the rest with soil 2.

The plant material was packed in 60 plastic litter bags, measuring (30x30) cm with a pore size of 7 mm. The bags were then incubated, in a horizontal position, at 10 cm depth, in the compartments of the first 6 troughs. Each compartment contained one litter bag. Each soil type received two rates of manure application which would supply 60 and 150 kg N/ha, respectively, upon complete decomposition. The amounts of material in each litter bag in soil 1 and 2 were 150 and 180 g, respectively, for the lower rate of manure application while for the higher rate the litter bags contained 370 and 453 g. These calculations were arrived at by taking into account the bulk density of the soils and the total N content of the plant material. For each of the two soils the two rates of manure application were randomly allocated to the plots.

Another 10 empty bags were buried in the two soils in the seventh trough to serve as control treatments for the assessment of microbial population changes as indicated in section 3.2.3. Water was added to each plot to moisten the soils to approximately field capacity. The moisture content was maintained at this level throughout the incubation period. The experiment was set up in a completely randomized design with a 2x2x6 factorial arrangement.

Sampling was done after the 1st, 3rd, 6th, 9th and the 12th week. At every sampling time three bags were retrieved from every treatment combination of soil type, rate of manure application and sampling time for the first 6 six troughs. One litter bag from each soil in the seventh trough was retrieved and three samples of soil were collected from inside the bag for total viable microbial counts.

After retrieving the litter bags the soil adhering to the undecomposed material was carefully removed by hand and representative samples were analyzed for viable microbial counts. The undecomposed material was further cleaned by removing the remaining soil particles through successive sieving and rinsing with water. This material was then sun-dried to remove the moisture on the surface and later oven dried to constant weight at 60 °C.

The following parameters were determined at every sampling time:

(a) Residual dry matter.

This was determined gravimetrically.

(b) Organic carbon and Total nitrogen

The dried plant material was ground. Organic carbon and total N were determined as described for soils in section 3.2.2.

(c) Viable microbial counts in the soils

(d) Decomposition rate constant (k)

This was calculated by use of the exponential equation, $Y=e^{-k}$, where Y is the percent remaining of the initial weight of plant material at time t in weeks (Wieder and Lang, 1982). The equation was also used to calculate the organic carbon and total N loss constants.

The statistical analysis of the data was done using the completely randomised design, as described by Snedecor and Cochran (1989) using the MSTATC computer programme. The data was subjected to ANOVA to determine the effect of soil type, manure application rate and method on the decomposition rate and N release pattern of *Senna siamea* green manure.

3.4.2. **Experiment 2: *Senna siamea* decomposition under field conditions.**

In this experiment, the effect of method of manure placement on the manure decomposition rate and N release was studied under field conditions. The sites for this work were as indicated in section 3.1. Two plots measuring 4x4m were marked out at the two sites and were cleared of weeds and so maintained up to the end of the experiment.

At each site 12 litter bags each containing 150g of freshly harvested material were randomly buried in a horizontal position at a depth of 10 cm. For surface placement, the same number of litter bags were made into cylindrical shapes and inserted into the soil to a 5 cm depth, in a vertical position. The cylinders had a diameter of 20 cm. The same weight of plant material (150 g) was placed on the surface of the soil enclosed inside the now cylindrical litter bags. To avoid contamination by external material such as dry leaves from the neighbouring fields, the open ends of the litter bags were covered with plastic mosquito-net material.

The use of litter bags made it easy to retrieve as much as possible of undecomposed buried material and also prevented the surface-placed manure from being blown away by wind. For each treatment combination of method of placement, soil type and sampling time, four bags were sampled at the 3rd, 6th and 9th week. The same parameters as in section 3.4.1 were determined except for microbial counts. The experimental design was the completely randomised design and was in a 2x2x4 factorial form.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Decomposition of *Senna siamea* under glasshouse conditions

The decomposition was studied under two soil types and at two rates of N application as green manure. The rate of decomposition was monitored by the use of three parameters namely residual dry matter, residual organic carbon and residual total nitrogen. These parameters were expressed as a percentage of the original amounts added to the soils. The decomposition rate constant, carbon and nitrogen loss constants were also used to assess the effect of soil type and manure application levels on decomposition.

4.1.1 Residual dry matter

The residual dry matter decreased with incubation time with similar trends for both soil 1 and soil 2 (Figures 4.1 and 4.2). There was an initial faster rate of decrease during the first 3 weeks of manure incubation in both soils. During this fast phase, the dry matter decreased to about half of the amounts initially added to the soils. Thereafter the decrease occurred at a comparatively slower rate.

In general there was no significant (p=0.05) difference between the decomposition rates in soil 1 and soil 2 (Figure 4.1, Table 4.1). The decomposition rate constants averaged over the manure application rates and incubation period were 0.188 and 0.194 for soil 1 and soil 2, respectively. These were not significantly (p=0.05) different.

The lower rate of manure-N application resulted in significantly (p=0.05) faster decomposition than the higher rate as revealed by the overall residual dry matter mean values, obtained by averaging over sampling times and the soil types (Table 4.1). This observation was further supported by the decomposition rate constants (k), shown in Table 4.2, in that the lower manure rates were characterised by the higher decomposition rate constants. The results further showed that the difference in decomposition rates due to the different rates of manure application was significant (p=0.05) only in soil 2 during the last six weeks of incubation (Figure 4.2). In soil 1 the effect of the manure rates was not significant.

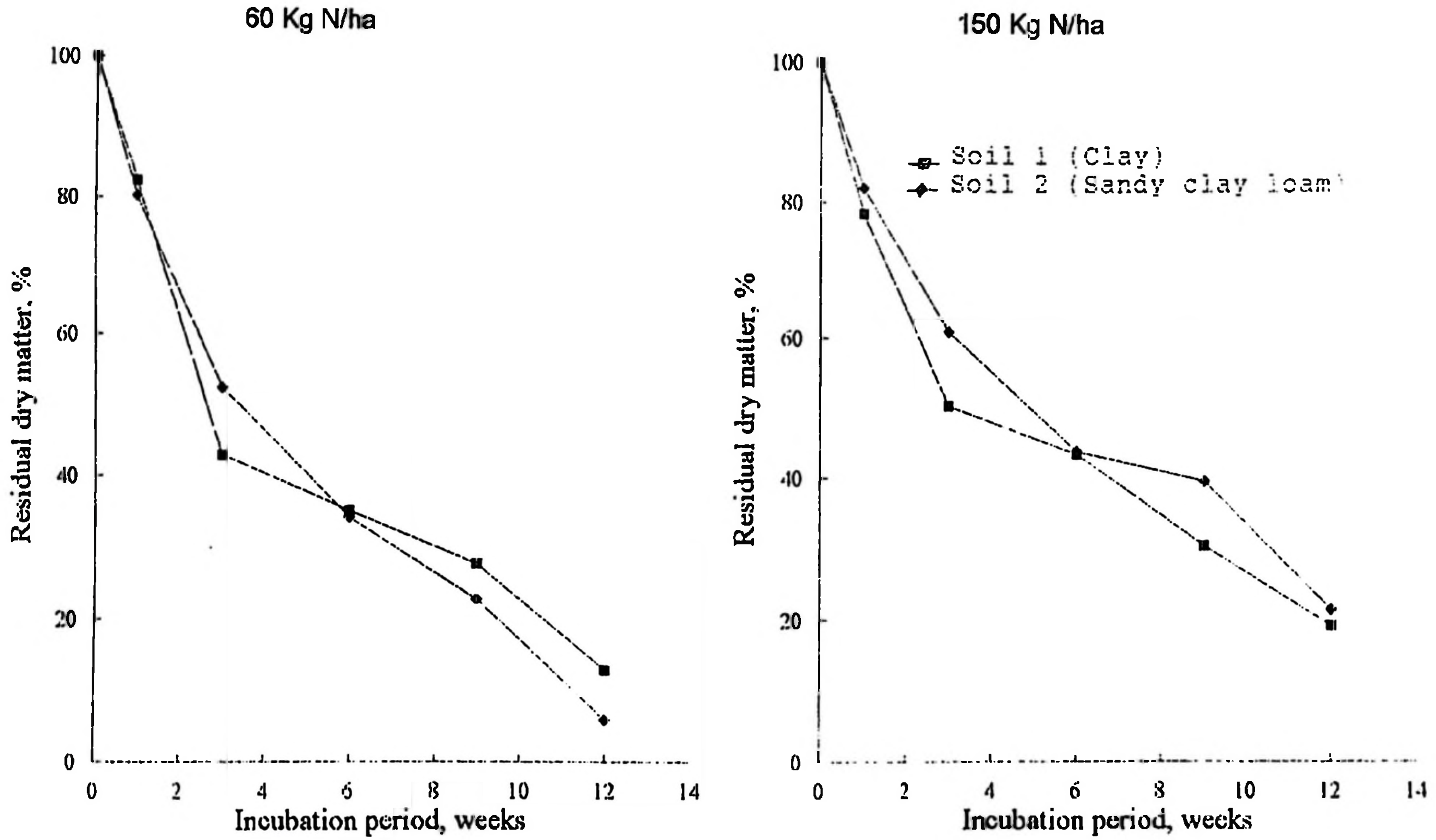

Figure 4.1. Effect of soil type on the decomposition of *Senna siamea* green manure under glasshouse conditions as indicated by residual dry matter.

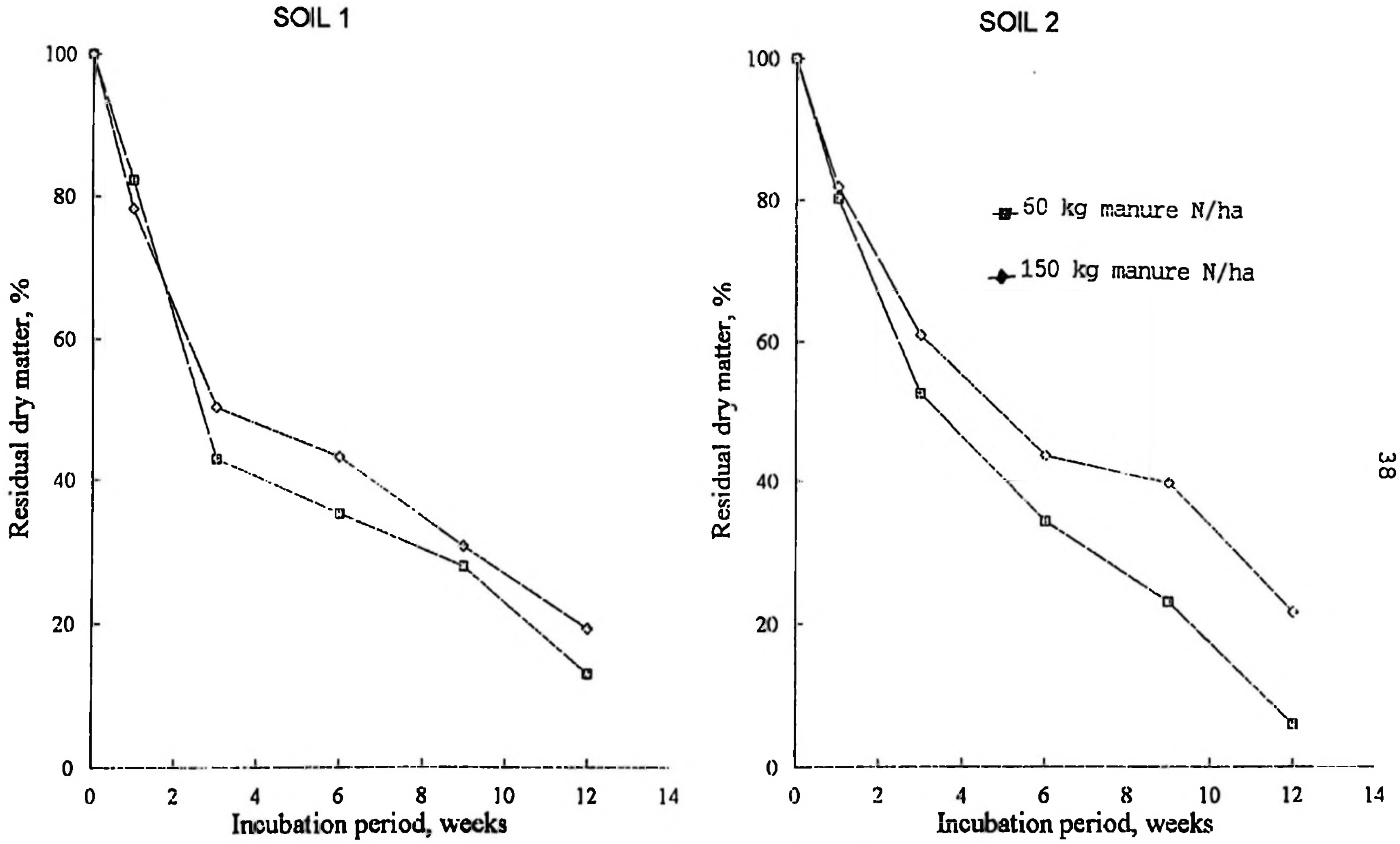

Figure 4.2. Effect of rate of application on the decomposition of *Senna siamea* green manure, as indicated by residual dry matter.

Table 4.1 Overall effect of soil type and manure application rate on the decomposition of *Senna siamea* green manure as indicated by residual dry matter averaged over the sampling periods.

Soil type	Rate of manure-N application (Kg manure-N/ha)		Soil type means	LSD (P=0.05) for soil type means
	60	150		
	--% residual dry matter---			
1 (Clay)	40.31	44.42	42.37	± 3.88
2 (SCL)	39.20	49.62	44.41	
Rate of application means	39.76	47.02		
LSD (p=0.05) for rate of application means	± 3.88			

SCL=Sandy clay loam

Table 4.2 Green manure decomposition rate constants for the two rates of manure-N application.

Treatment	Decomposition rate constant (week^{-1})
Soil 1+ 60 Kg N/ha	0.176
Soil 1+ 150 Kg N/ha	0.140
Soil 2+ 60 Kg N/ha	0.244
Soil 2+ 150 Kg N/ha	0.135

When plant residues are introduced into the soil, the soil microorganisms, through the decomposition process, utilize them as a source of energy and carbon for new cell formation (Alexander, 1977). First, the microbes act on the easily decomposable (water-soluble) components of the residues and hence their population increase rapidly. Consequently, there is an initial fast phase of decomposition. In the present study this phase occurred during the first three weeks. As the process proceeds, the water soluble fraction gets exhausted and, subsequently the rate of decomposition slows down as the microbes decompose the resistant fractions. Similar trends of residual dry matter decrease have been reported for *Crotalaria* and *Leuceana* by Nikokwe (1992) and also for cowpea by Smith and Peckenpaugh (1986).

Christensen (1985) attributed the total weight loss from barley and wheat straw, enclosed in mesh bags and incubated into the soil, to three loss components: leaching, microbial decomposition and loss of straw particles through mesh openings. He suggested that the initial stage of straw weight loss was probably dominated by leaching and microbial decomposition of readily - available substrates. In the following stage, decomposition losses dominated and particulate losses were thought to be relatively small. However, when decomposition proceeded and the straw became fragile and eventually disintegrated, losses of straw particles through the mesh openings, most likely became important while microbial decomposition slowed down as the substrate became less accessible to the decomposers. The reduced rate of decomposition may also be related to immobilisation of nutrients by the microorganisms. The fast and slow rates of decomposition may have been associated with large and small populations of microorgarnisms, respectively, in response to availability of nutrients in the decomposing material.

The relatively higher decomposition rate observed in soil 2 could be related to the better aeration in this light-textured soil compared to that of the heavy-textured soil 1, especially immediately after watering. Due to the high clay content of soil 1, water infiltration into this soil would, conceivably, be quite slow compared to that in soil 2. Therefore, temporary anaerobic conditions may be created in soil 1 following watering while in soil 2 there would be a better status of aeration due to the comparatively lighter texture. Weeraratna (1979) reported that the decomposition of some plant residues was faster under aerobic conditions (as would be attained in soil 2) than under anaerobic conditions (which would prevail in the clay soil 1). The higher proportion of clay in soil 1 may have reduced the activity of the microorganisms, thereby contributing to the lower rate of decomposition in this soil.

The fact that the lower rate of *Senna siamea* green manure resulted in a faster overall loss of residual dry matter than did the higher rate is in agreement with the findings of Puig-Gimenez and Chase (1984). These workers reported that small amounts of wheat straw decomposed more rapidly in soil than large quantities. The packing of the manure into litter bags, though done as loosely as it was possible in the present studies, would not initially allow total mixing of the material with soil and hence soil microorganisms. This was because of the physical barrier provided by the bags and the manure itself. Therefore, decomposition initially took place first in the manure layer that was in immediate contact with soil. Subsequently, better mixing of manure with the microorganisms was attained through dispersion of the soil microorganisms during watering. This was first attained in the case of the lower rate of application and hence the faster rate of decomposition.

These trends agree with those of the changes in soil microbial numbers during the decomposition process (Figure 4.3).

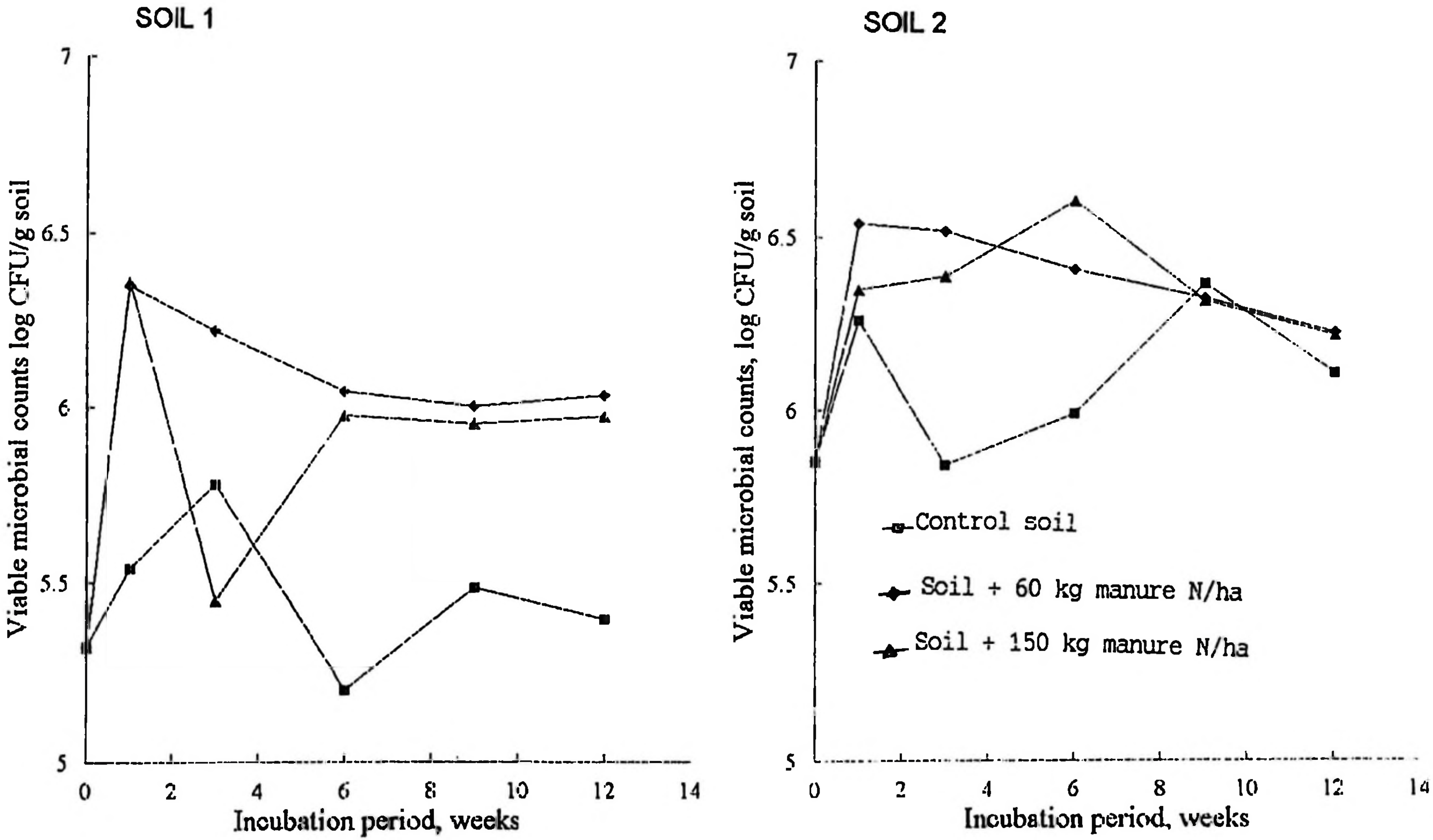

Figure 4.3. Changes in viable microbial populations in the experimental soils.

There was a rapid increase in the microbial numbers in both the manured and the control soils during the first week of incubation. Thereafter the numbers in the manured soils remained more or less constant over the incubation period. The manured soils generally had higher counts than the controls. The microbial populations were generally slightly higher in samples treated with the lower quantity of the manure.

The rapid increase in the microbial numbers on addition of the green manure may be associated with availability of easily degradable manure components to the microorganisms. This could also be partly attributed to the improved moisture conditions of the previously dry soil upon watering. The greater difference in microbial counts between control and manured samples in soil 1 may be related to this soil's lower content of organic matter. Soil 1 had 0.92% organic carbon while soil 2 had 1.72%.

The slightly higher levels of microbial populations at the lower rate of manure application is difficult to explain at present. It is probable that the smaller quantity of manure got better mixed with soil and, hence, stimulated a higher microbial population than the larger quantity.

It is also possible that some toxic decomposition product may be associated with the *Senna* spp manure, especially at the higher rate of application, thus reducing the numbers of some microbial groups, hence the observed decrease of the total population. Wangari (1995) observed lower microbial numbers in soils treated with higher quantities of *Lantana* spp but higher quantities of *Sesbania* spp stimulated higher microbial populations than the lower quantity. These observations suggest that different types of manure may influence soil microbial populations differently. In the case of *Senna siamea*, further studies are required to establish whether or not it has toxic effects on soil microorganisms. The pods of this plant were reported to be toxic to pigs (Nair, 1993).

4.1.2 Residual organic carbon

The residual organic carbon decrease followed the same trend as that shown by residual dry matter (section 4.1.1). The residual organic carbon decreased at a faster rate, to about 50% of the original level, in the first three weeks, and slowed down thereafter (Figures 4.4 and 4.5). By the end of the 12th week only about 20%, or lower, of the added carbon remained (Figure 4.4). The rates of organic carbon decrease in the two soils were not significantly ($p=0.05$) different (Figure 4.4, Table 4.3). However the rate of decrease was significantly ($p=0.05$)

higher with the lower manure application rate than with the higher rate as shown in Figure 4.5 and Tables 4.3 and 4.4.

The trends of organic carbon were similar to those of residual dry matter discussed above. Other workers (Amato *et al.*, 1987; Christensen, 1985; Franzluebbers, 1994 and Lehmann *et al.*, 1995) also have reported trends similar to those of these studies. According to Alexander (1977) simple sugars, amino acids and aliphatic acids, which constitute the water-soluble fraction of plant residues, were easily and rapidly decomposed in the first phase. The more resistant cellulose, hemicellulose and, ultimately, lignin components were involved consequently, resulting in a slower rate of decomposition in the period beyond the initial three weeks.

The observation that the rate of loss of organic carbon decreased with an increase of manure application rate is in line with that of some workers (Van Schreven, 1964; Broadbent and Bartholomew, 1948) who found that the rate of plant residue decomposition varied inversely with the amounts applied. However, in some other studies Stotzky and Mortensen (1958), Jenkinson (1965) and Jenkinson (1977) found that the proportion of added plant carbon decomposing in a given time was substantially

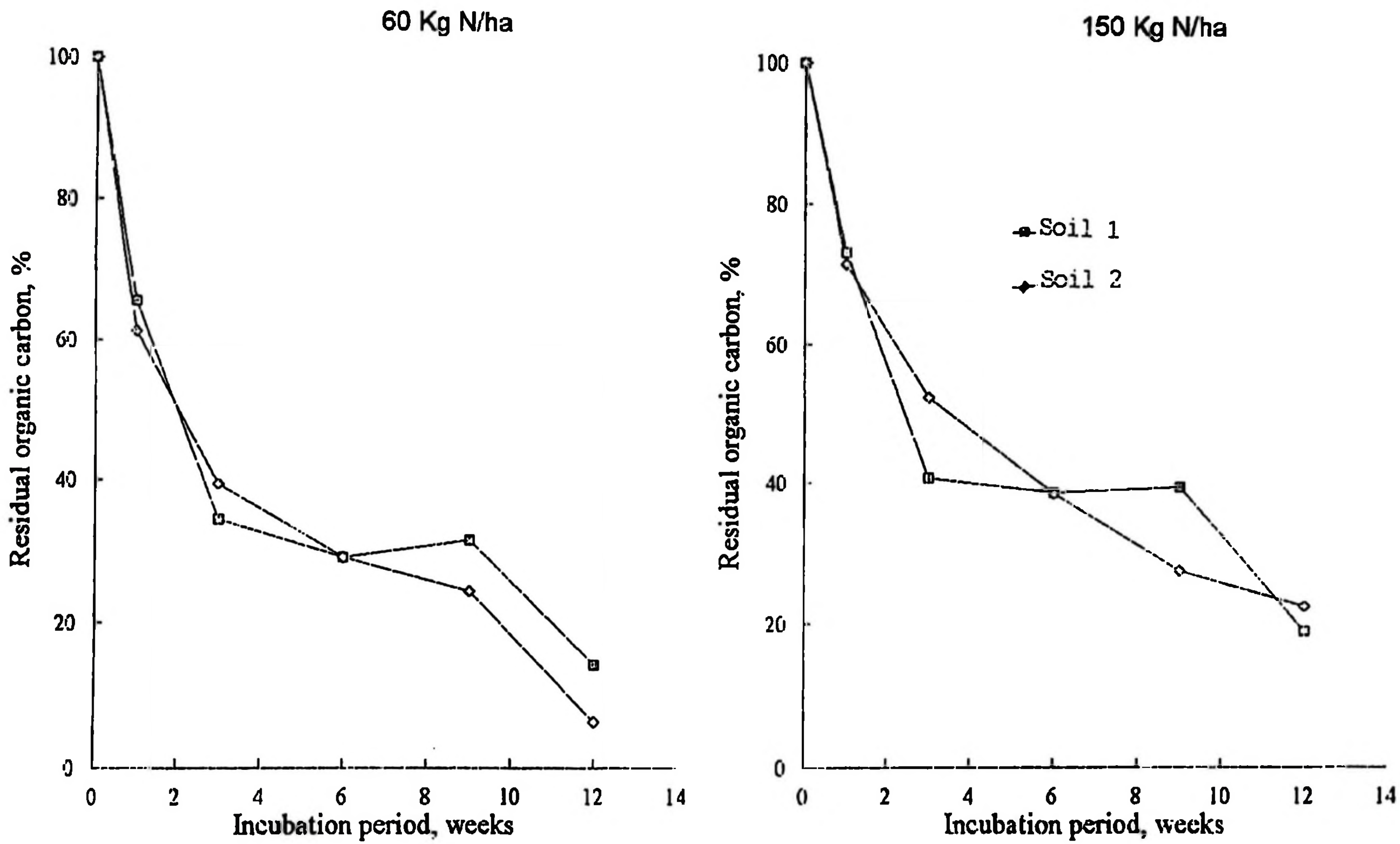

Figure 4.4. Effect of soil type on the decomposition of *Senna siamea* green manure under glasshouse conditions, as indicated by residual organic carbon.

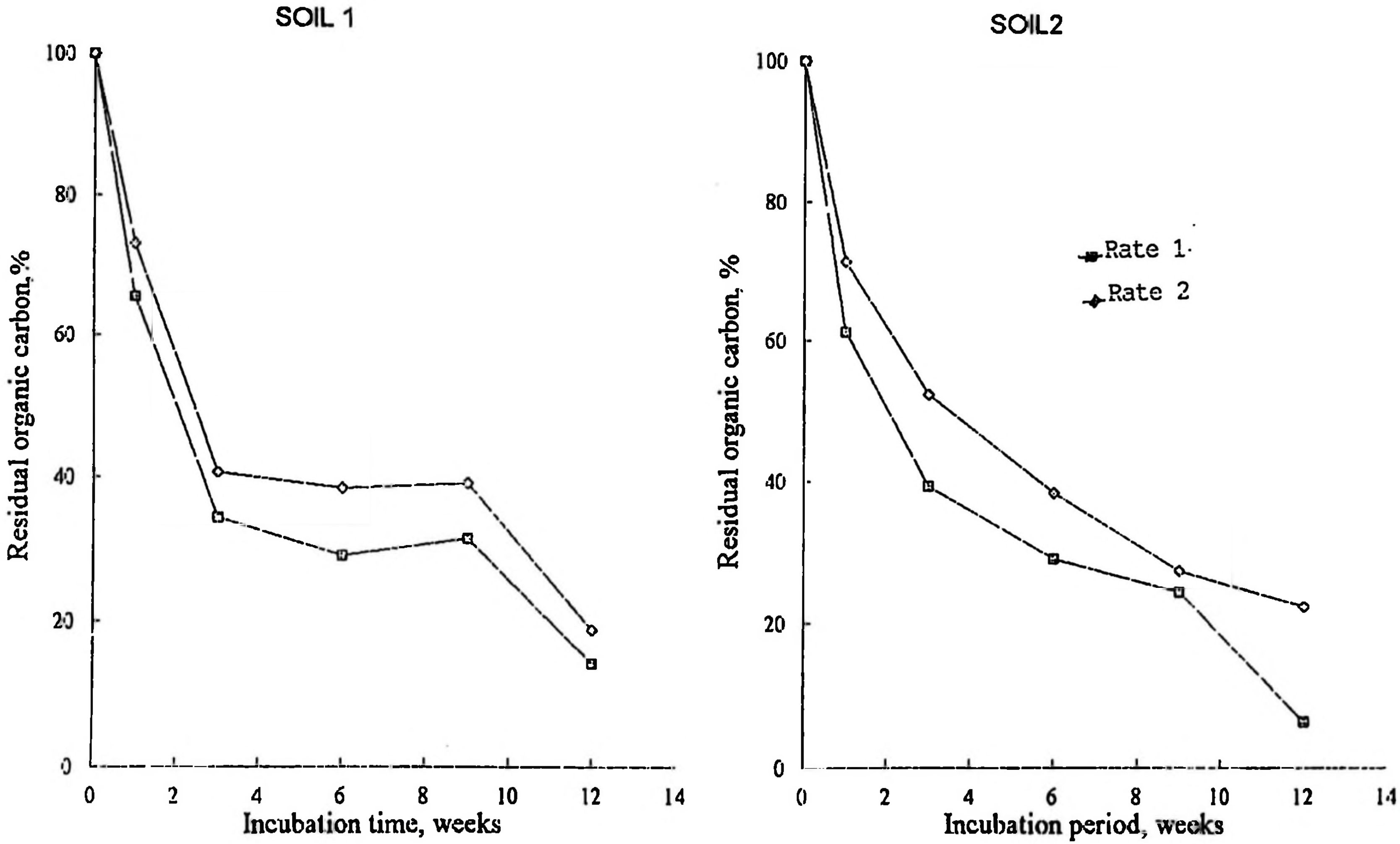

Figure 4.5 Effect of application rate on the decomposition of *Senna siamea* green manure, as indicated by residual organic carbon.

Table 4.3 Overall effect of soil type and manure application rate on the decomposition of *Senna siamea* green manure, as indicated by residual organic carbon averaged over the sampling periods.

Soil type	Rate of manure-N application (Kg manure-N/ha) 60	150	Soil type means	LSD (P=0.05) for soil type means
	--% residual organic carbon--			
1 (Clay)	35.07	42.25	38.66	± 4.64
2 (SCL)	32.22	42.54	37.38	
Rate of application means	33.65	42.40		
LSD (p=0.05) for rate of application means	± 4.64			

SCL=Sandy clay loam

Table 4.4 Organic carbon loss rate constants at the two rates of manure-N application

Treatment	Organic carbon loss rate constant ($week^{-1}$)
Soil 1+ 60 Kg N/ha	0.162
Soil 1+ 150 Kg N/ha	0.138
Soil 2+ 60 Kg N/ha	0.229
Soil 2+ 150 Kg N/ha	0.124

independent of the rate of manure addition. Pinck and Allison (1951) showed that the latter results were true only if the carbon addition did not exceed 1.5% of the dry weight of the soil. The highest rate of organic carbon addition in the present studies was 0.6 % of the dry weight of soil 2.

From the above findings it is apparent that the effect of manure application rate on carbon release rate cannot be easily defined. In the current study, however, it is postulated that the lower rate of application allowed for a greater proportion of the residue to be in contact with the soil, especially after the first three weeks, and thus these materials decomposed faster. It is also probable that if the postulated toxicity factor (section 4.1.1) exists, then it was more severe at the higher manure application rate, thereby reducing the rate of manure decomposition.

4.1.3 Residual total nitrogen

The general pattern of N release was similar to that of mass loss and carbon release (Figure 4.6 and 4.7). Residual total N decreased rapidly, to about 50% (on average) of the initial amount added to soil, during the initial first stage of decomposition. There was a reduced release rate between the 3rd and the 9th week of incubation followed by a comparatively faster rate in the last three weeks. On average the total amount of N released during the entire incubation period was about 80% of the amount initially added to the soil.

Soil type did not affect the rate of N release from the manure at the low application rate, but the N release was faster in soil 1 compared to soil 2 in the higher manure rate (Figure 4.6; Tables 4.5 and 4.6). The N release rate was influenced by the manure application rate. The smaller quantity of manure decomposed significantly ($p=0.05$) faster than the larger quantity as reflected by the lower residual N values (Table 4.5) and further by the higher N loss constants (Table 4.6). This effect was more pronounced in soil 2 than in soil 1 (Figure 4.7). The C:N ratio of the manure generally increased over the incubation period (Figure 4.8).

Similar trends in N release from leguminous plant residues have been observed by Handayanto *et al.* (1994) and Frankzluebbers *et al.* (1994). Lehmann *et al.* (1995) found that the pattern of N release from *Senna siamea* twigs and leaves was similar to that of carbon loss and that most of these were released during the first 20 days of residue placement in the field. This agrees well with results of the present studies.

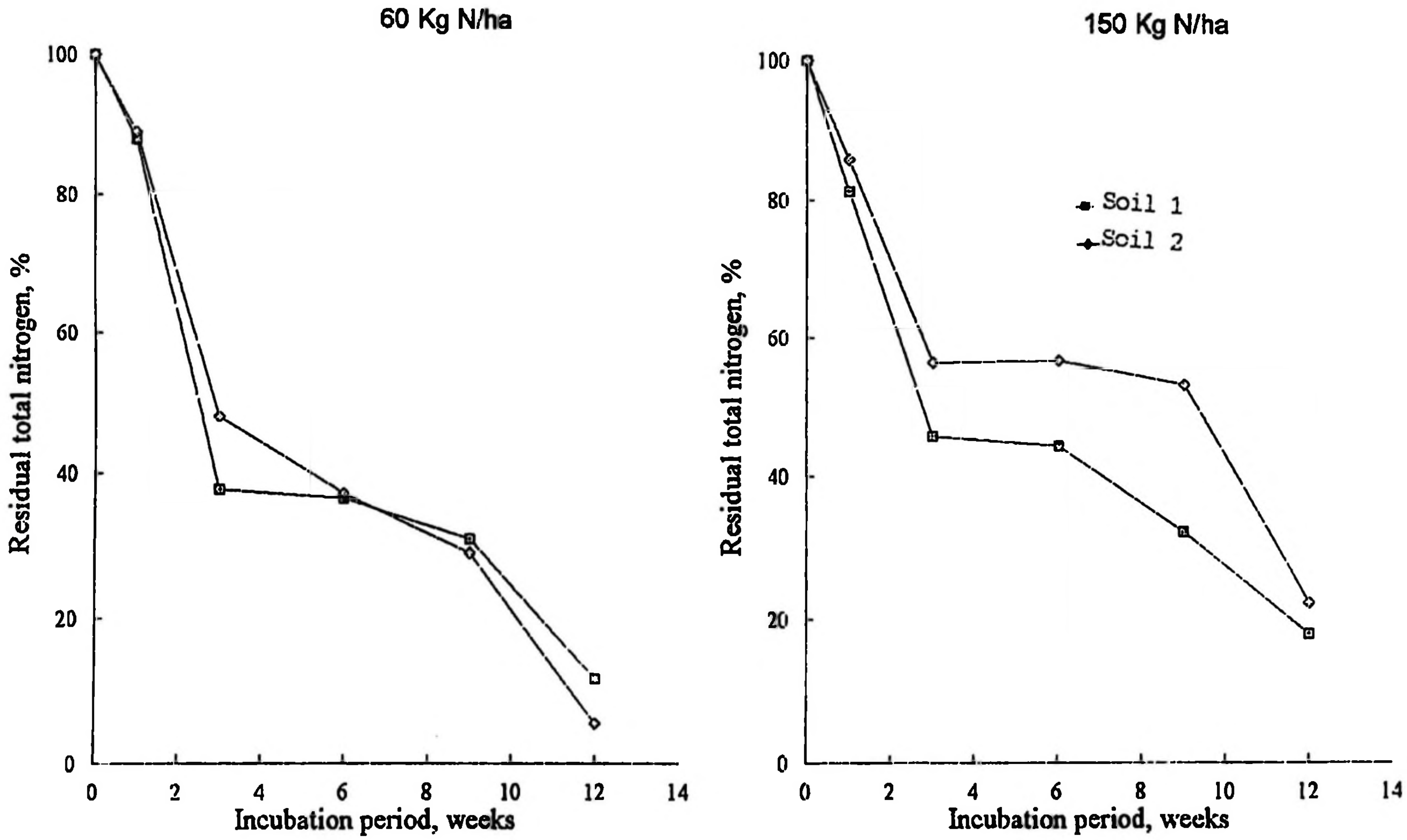

Figure 4.6. Effect of soil type on the decomposition of *Senna siamea* green manure under glasshouse conditions, as indicated by residual total nitrogen.

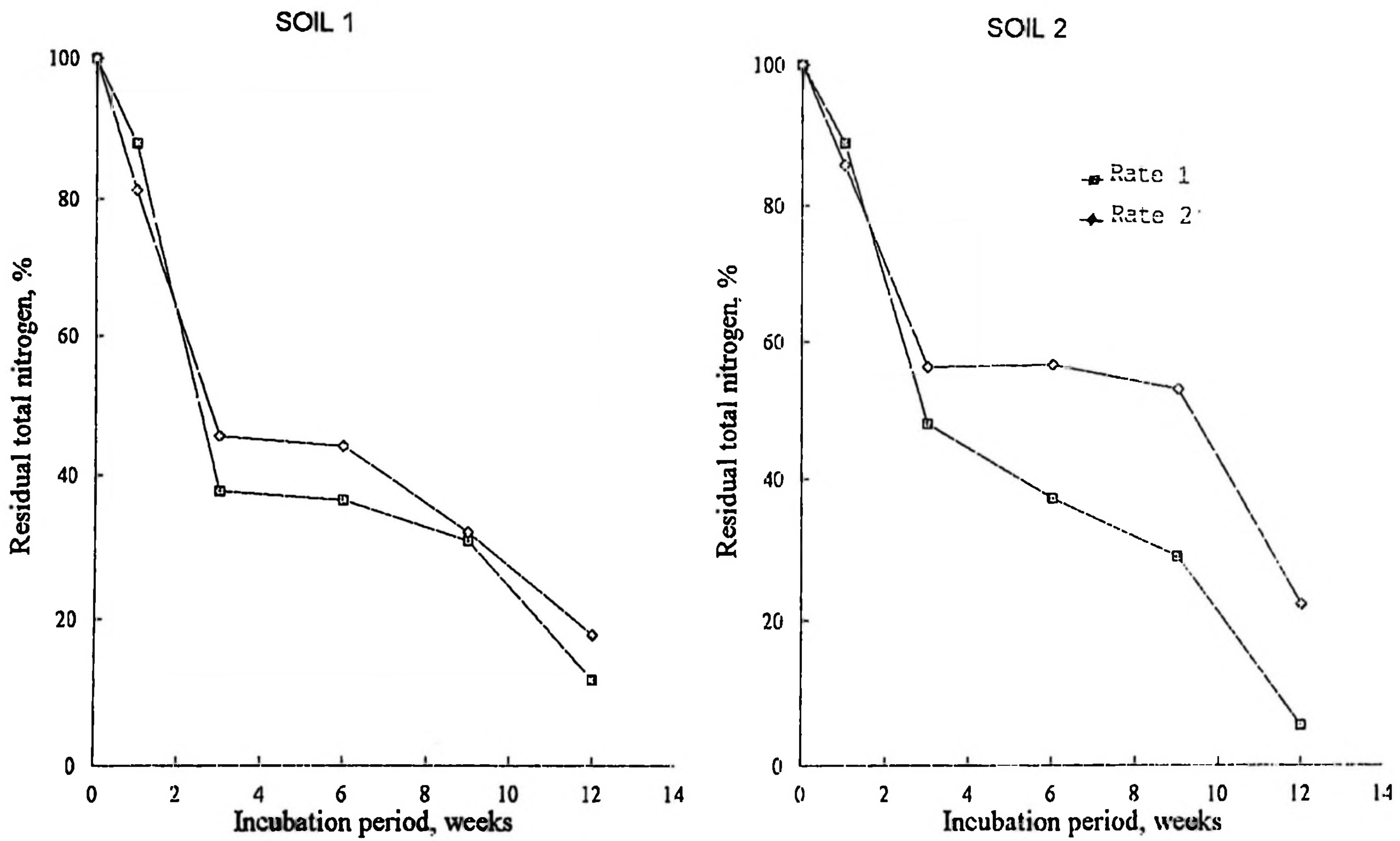

Figure 4.7. Effect of application rate on decomposition of *Senna siamea* green manure, as indicated by residual total nitrogen.

Table 4.5 **Overall effect of soil type and manure application rate on the decomposition of *Senna siamea* green manure as indicated by residual total nitrogen averaged over the sampling periods.**

Soil type	Rate of manure-N application (Kg manure-N/ha) 60	150	Soil type means	LSD (p=0.05) for soil type means
	----% residual total N---			
1	41.15	44.40	42.77	± 4.44
2	41.85	55.02	48.44	
Rate of application means	41.50	49.71		
LSD (p=0.05) for rate of application means	± 4.44			

Table 4.6 **Total N loss rate constants at the two rates of manure-N application**

Treatment	Total N loss rate constant (week^{-})
Soil 1 + 60 Kg N/ha	0.177
Soil 1 + 150 Kg N/ha	0.142
Soil 2 + 60 Kg N/ha	0.241
Soil 2 + 150 Kg N/ha	0.124

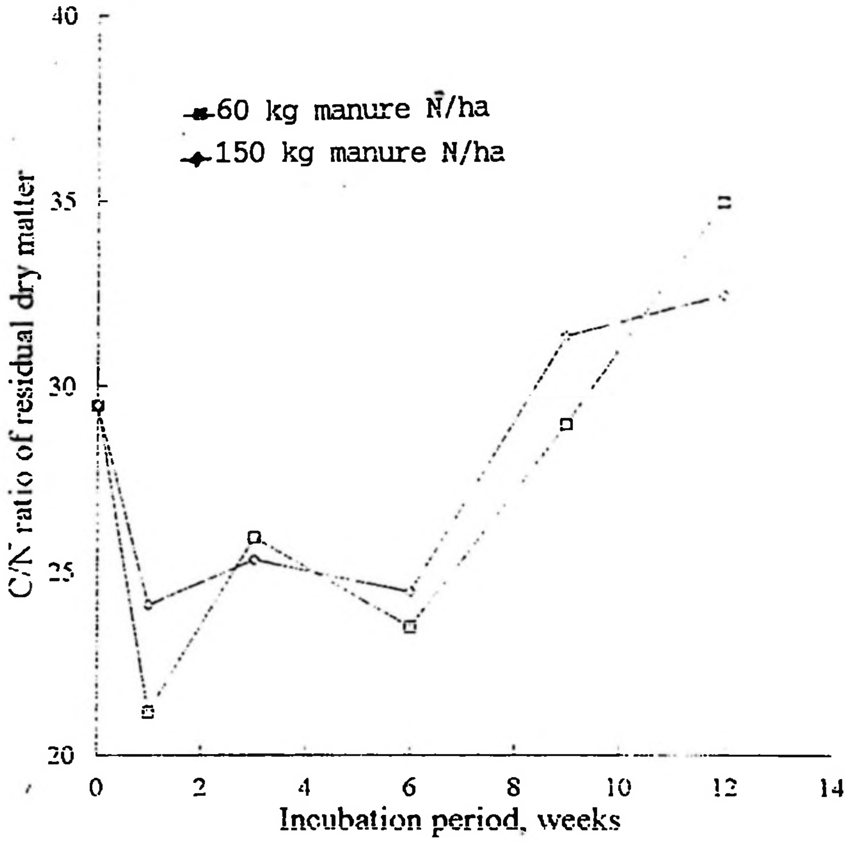

Figure 4.8 Changes in the C/N ratio of *Senna siamea* green manure, with period of incubation.

In an earlier study Sandhu *et al.* (1990) reported that N release patterns from roots of *Leuceana leucocephala* followed the same pattern as their mass loss. As indicated in sections 4.1.1 and 4.1.2 for residual dry matter and organic carbon, the trend for residual total N could be explained in terms of the presence of easily decomposable N compounds during the first weeks of incubation with more resistant substrates remaining subsequent to the initial decomposition. It is probable that the increased loss of N during the last three weeks was due to fragmentation losses during watering and also during the cleaning stage, since by this time the decomposing material had become very fragile. These trends may also be explained from the view point of microbial biomass. The first three weeks may have been associated with a larger biomass as a result of first assimilation and growth. The microbial biomass remained constant between the third and eighth week. Thereafter followed the autolysis of a proportion of the initial population, releasing easily decomposable carbon sources. These sources may have contributed to the subsequent faster rate of N release.

The reduction in the rate of N release during the incubation period may be due to the increased C:N ratio in the present studies as was also shown by Frankenberger and Abdulmagid (1985) and Tian *et al.* (1992). The latter workers observed negative correlation between decomposition rate constants and the C:N ratios. The initial decrease of this ratio during the initial stages of decomposition could be attributed to N immobilization by the twigs in the decomposing twig-leaf mixture (Constantinides and Fownes, 1993).

The means of residual total N averaged over the manure application rate and incubation periods (Table 4.5) indicated that soil type significantly (p=0.05) influenced the N release rate. However, the means at individual sampling times revealed that this effect was statistically significant (p=0.05) at the higher rate of manure application and only at week nine. These results, therefore, suggest that there was a soil type x manure application rate interaction effect on N release. This was confirmed in the ANOVA.

Since the effect of manure application rate on residual N was similar to that on residual dry matter, it is inferred that N release was faster with the lower rate of manure application due to increased contact between manure and soil/soil microorganisms (Section 4.1.1) at the lower rate of manure application. The observations above suggest that the timing of manure application for maximum N utilization by crops will depend on soil type and manure application rate.

4.2 Decomposition of *Senna siamea* under field conditions

The effect of method of plant residue placement and soil type on the decomposition of *Senna siamea* was studied under field conditions. The same parameters (i.e. residual dry matter, residual organic carbon and residual total N) as used in the glasshouse experiment to determine the decomposition rate were also employed in the field.

4.2.1 Residual dry matter

The pattern of residual dry matter decrease was similar to that observed under glasshouse conditions. In general, about 65% or more of the manure added to the soil was lost during the first three weeks of manure placement in the field (Figures 4.9 and 4.10).

The overall decrease in residual dry matter was significantly ($p=0.01$) affected by both the soil type and mode of manure placement (Table 4.7). This is also indicated by the decomposition rate constants shown in Table 4.8.

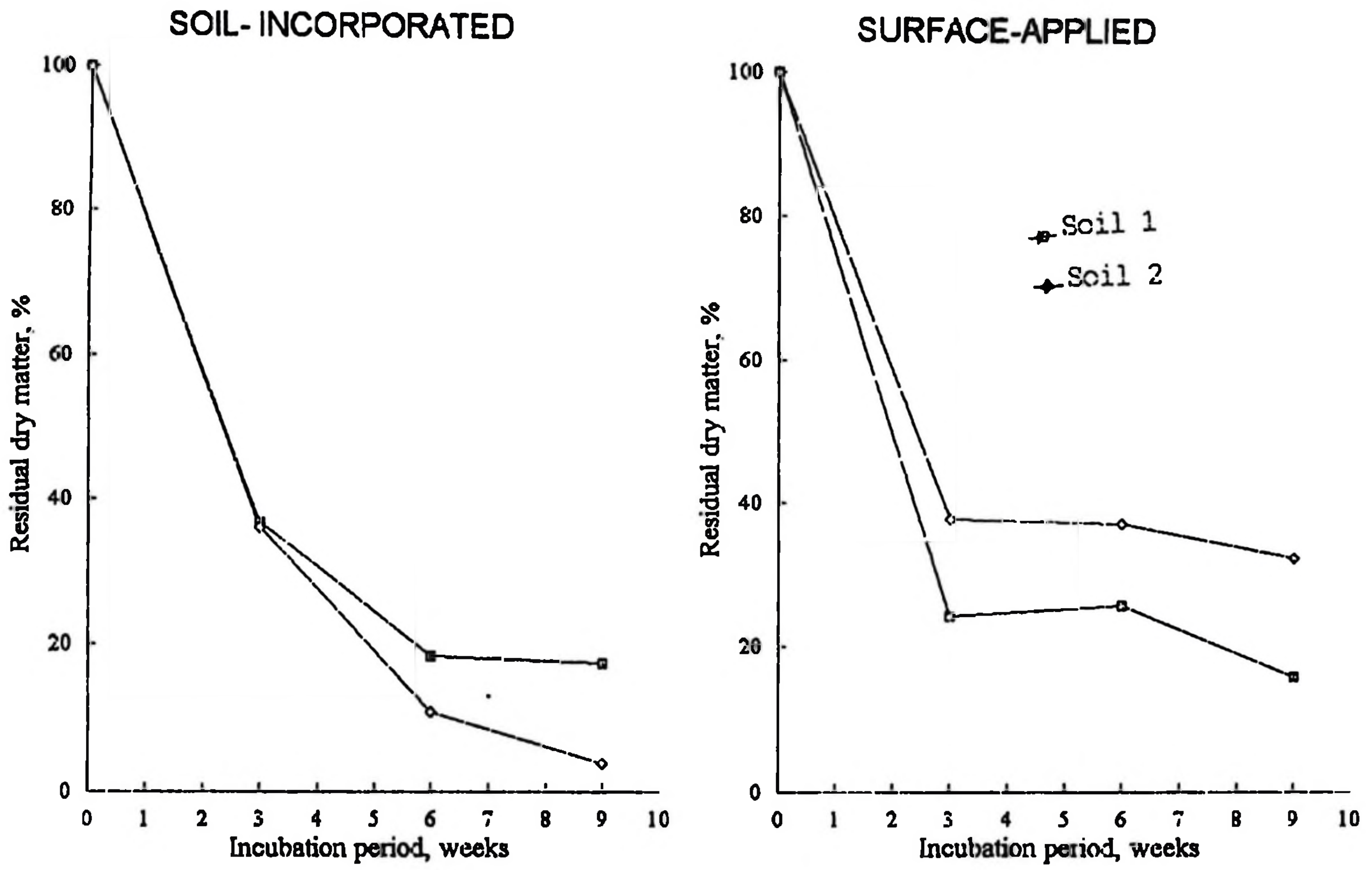

Figure 4.9. Effect of soil type on the decomposition of *Senna siamea* green manure, in the field, as indicated by residual dry matter.

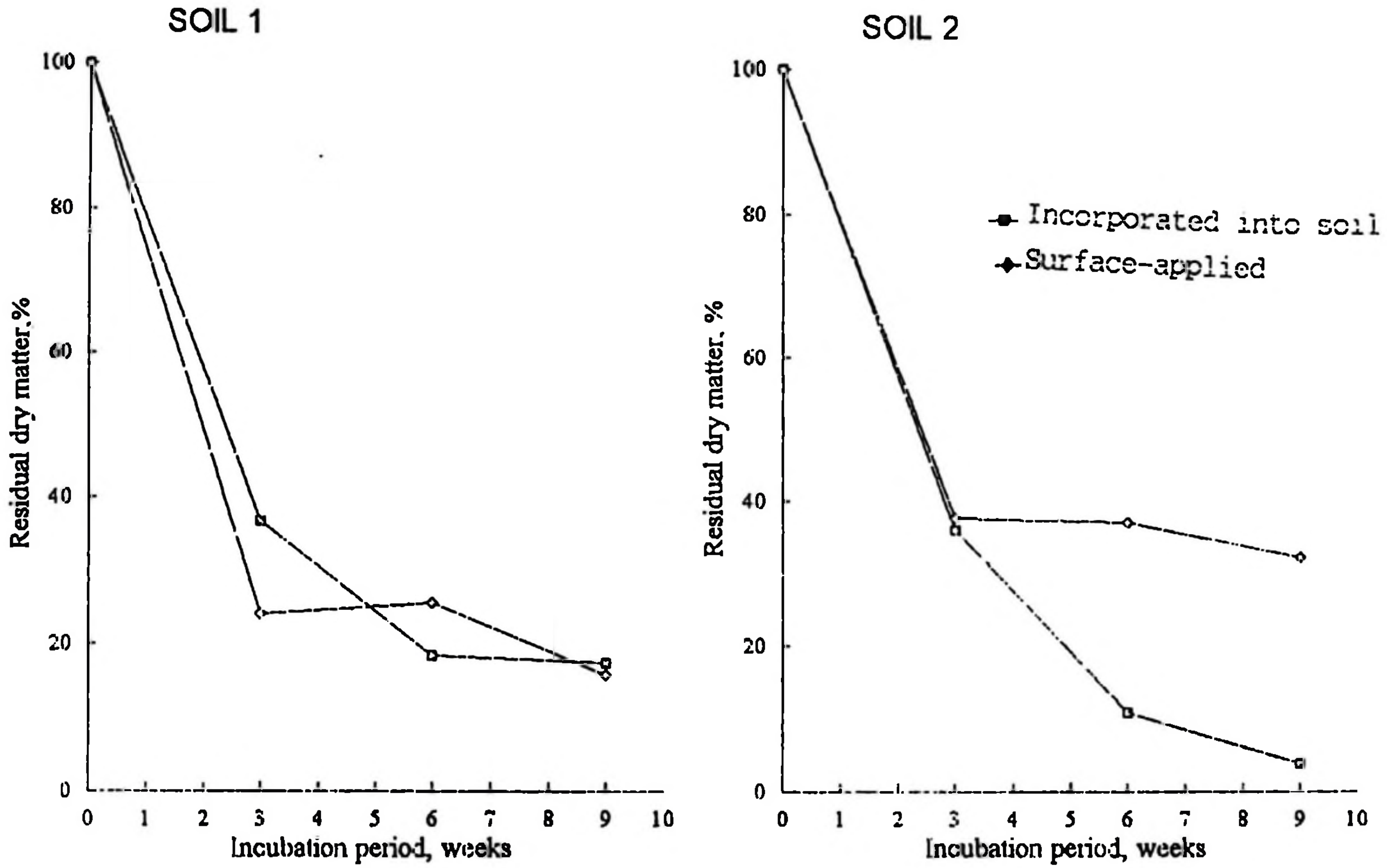

Figure 4.10. Effect of method of green manure placement on the decomposition of *Senna siamea* green manure, as indicated by residual dry matter.

Table 4.7 Overall effect of soil type and method of manure placement on the decomposition of *Senna siamea* green manure, as indicated by residual dry matter averaged over the sampling periods.

Soil type	Method of placement		Soil-type means	LSD(=0.01) for soil type means
	surface-applied	soil-incorporated		
	-----% residual dry matter------			
1	21.95	24.36	23.15	± 1.20
2	35.79	16.97	26.38	
Method of placement means	28.87	20.66		
LSD(p=0.01) for method of placement means	±1.20			

Table 4.8 Decomposition rate constants under the two methods of manure placement

Treatment	Decomposition rate constant (week^{-1})
Soil 1 + surface-applied	0.203
Soil 1 + soil incorporated	0.191
Soil 2 + surface-applied	0.125
Soil 2 + soil incorporated	0.360

During the first three weeks, the residual dry matter decreased fast, at approximately the same rate in the two soils and for the two placement methods. Thereafter the rate of decrease depended on the soil type and manure placement method (Figures 4.9 and 4.10).

Beyond the first three weeks, soil-incorporated manure decomposed faster in soil 2 than in soil 1 while the surface-placed material decomposed faster in soil 1 than in soil 2 (Figure 4.9). The ANOVA indicated a soil type x method of placement effect. In soil 1 the effect of manure placement method was not clear-cut but in soil 2 the buried manure decomposed significantly ($p=0.05$) faster than that applied on the soil surface (Figure 4.10).

The initial rapid decrease in residual dry matter could be attributed to the faster decomposition rate of the water soluble substrates which are used by the soil microorganisms as discussed in section 4.1.1. The slower decomposition rate in the last six weeks was a function of the increased resistance of the remaining plant residue to microbial attack, as well as soil and climatic factors, as indicated in the following explanation. At the 10 cm depth, soil 2 was seen to be moist while soil 1 was almost dry, especially at the sixth and the ninth week, implying that the little rain water received during that period

(Figure 4.11) had drained deeper in the light-textured soil 2 than in the heavier-textured soil 1. Consequently, microbial activity in the buried manure was faster in the former than in the latter soil. It was also observed that earthworms, which also contribute to the decomposition process, were more abundant (though not counted) in soil 2 than in soil 1. Tian *et al.* (1995) reported that these soil fauna accounted for 10.40% of the breakdown of plant residues added to soil.

The higher decomposition rate of the surface-placed material in soil 1 compared to that in soil 2 was also a result of the infestation of soil 1 by termites. Most of the material on soil 1 was consumed by termites while in soil 2 the loss was mostly due to microbial decomposition.

Initially the surface-applied and the soil-incorporated materials decomposed at almost equal rates in both soils (Figure 4.10). This was probably due to the fact that the contact between soil (hence soil microorganisms) and the surface-applied manure was increased as soil was splashed onto the manure by rain. It was further observed, however, that the decomposition process in soil 1 was influenced greatly by termite activity because this soil was infested with termites.

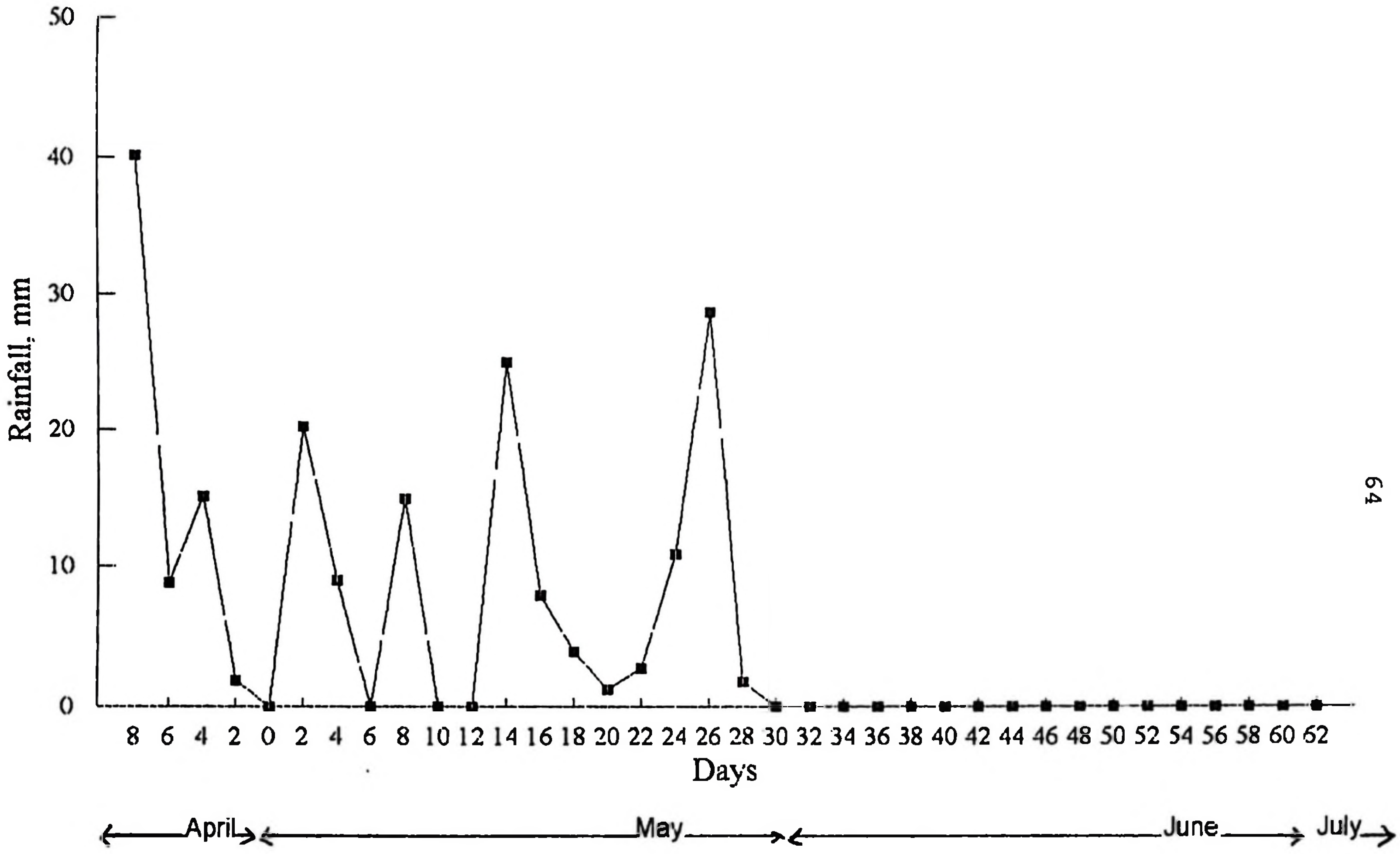

Figure 4.11. Daily rainfall during the period covering the experimental incubation phase. (Morogoro, 1995)
(Zero time=first day of manure incubation)

Therefore, the effect of the mode of application throughout the period of the experimentation was not clear-cut. This observation agrees with that of Lehmann *et al*. (1995) who found that termites increased the mass loss of *Calliandra calothyrsus*, *Gliricidia sepium* and *Senna siamea* decomposing under field conditions. Nandwa *et al*. (1993) reported that termite activity was one of the reasons which accounted for different decomposition rates during the decomposition of maize stover at two different sites in Kenya.

The higher decomposition rate in soil 2 in the case of the buried than in the surface-applied material was probably due to the positional availability of the residue to soil microorganisms in the incorporated material (Nikokwe, 1993). More of the incorporated material was in contact with soil microorganisms than in the case of the manure placed on the surface, hence the increased decomposition rate. Additionally, the surface-applied manure as well as the soil surface were exposed to intermittent dry conditions, a factor which did not affect the deeper soil levels. This might have greatly slowed down the microbial decomposition of the material since availability of moisture in the substrate is a prerequisite for increased microbial activity (Alexander, 1977).

4.2.2 Residual organic carbon

Residual organic carbon followed similar patterns of decrease as observed for residual dry matter (Figures 4.12 and 4.13). Generally the organic carbon release rate was significantly ($p=0.05$) influenced by the soil type. Decomposition was faster in soil 1 than in soil 2 for the surface-applied manure, but the opposite was true in the case of the soil-incorporated manure (Figure 4.12; Table 4.9). This was supported by carbon release rate constants as shown in Table 4.10. There was no clear-cut difference in organic carbon lost by soil 1 in relation to the method of manure placement, but the soil-incorporated manure lost more carbon relative to the surface-applied one in soil 2 (Figure 4.13).

Similar explanations as given for residual dry matter patterns in section 4.2.1 could be used in this case to explain the similar trend observed for the residual organic carbon. Carbon release was initially fast as the microorganisms decomposed the easily degradable components of the manure. The rate of release was lower in the later stages as the material became more resistant to microbial attack. It is worth noting that the soil fauna effect, specifically the termite activity, was the main determinant of the differences due to soil type as observed for the surface-applied manure, as well as of the

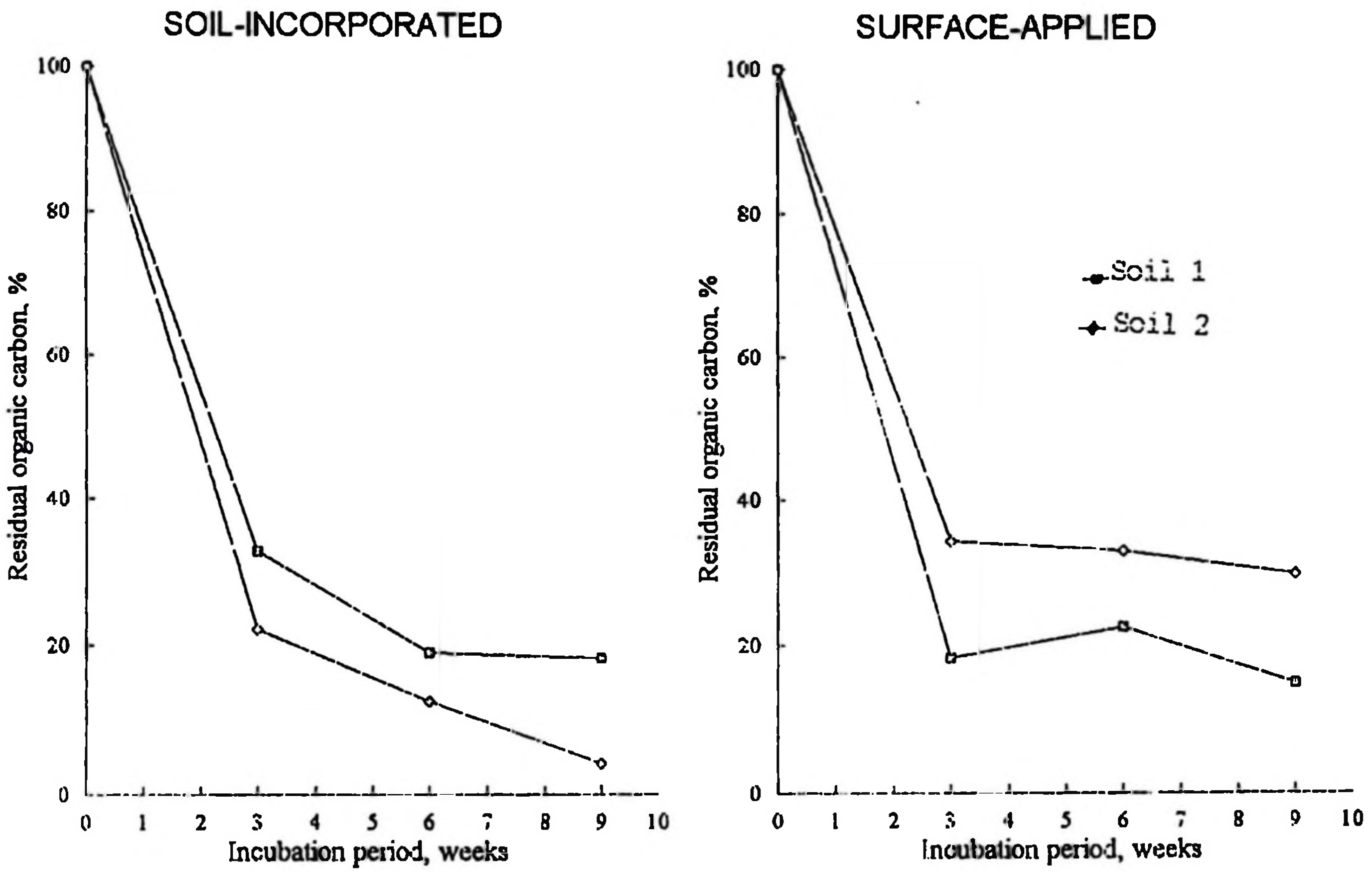

Figure 4.12. Effect of soil type on the decomposition of *Senna siamea* green manure, in the field, as indicated by residual organic carbon.

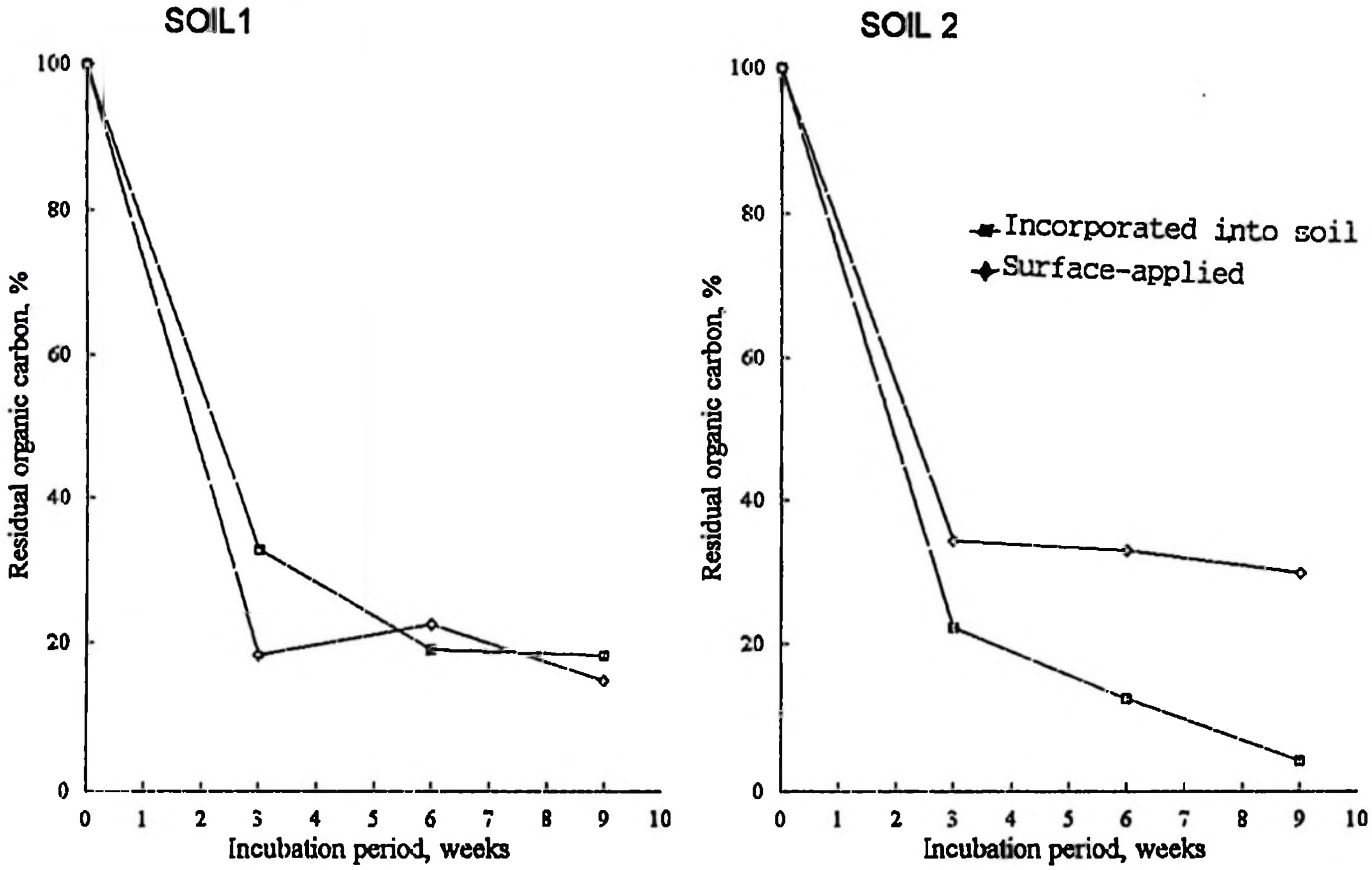

Figure 4.13. Effect of method of placement on the decomposition of *Senna siamea* green manure, as indicated by residual organic carbon.

Table 4.9 Overall effect of soil type and method of manure placement on the decomposition of *Senna siamea* green manure, as indicated by residual organic carbon averaged over the sampling periods.

Soil type	Method of placement surface-applied	 soil-incorporated	Soil-type means	LSD(p=0.01) for soil type means
	---% residual organic carbon--			
1	18.60	23.43	21.02	± 1.60
2	32.43	13.02	22.72	
Method of placement means	25.51	18.22		
LSD (p=0.01) for method of placement means	± 1.60			

Table 4.10 Organic carbon loss rate constants under the two methods of manure placement.

Treatment	Organic carbon release rate constant ($week^{-1}$)
Soil 1 + surface-applied	0.210
Soil 1 + soil incorporated	0.188
Soil 2 + surface-applied	0.134
Soil 2 + soil incorporated	0.353

differences between the modes of manure application in soil 1. Termites were abundantly observed (though not counted) in soil 1 in the field, while there were no termites in soil 2.

In soil 2 the observed differences in carbon mineralization, for the methods of application, was basically due to the differential availability of the manure to microorganisms. A greater proportion of the soil-incorporated manure was exposed to the microorganisms more than in the case of than the surface-applied material. Moreover, the surface-applied material lost moisture with time, and by the fifth week it was almost dry. This may have reduced the decomposition rate of the surface-applied manure relative to that of the buried material. Brown and Dicky (1970) reported that plant residues which were placed 12 cm deep in the soil lost 93% of their weight while those on the soil surface lost only 31%. Bartholomew and Norman (1946) observed slowed decomposition of straw whose moisture content was below 60%, and the process ceased completely at 16%.

4.2.3 Residual total nitrogen

The percentage of residual total N decreased sharply during the first three weeks by the end of which 80 and 70% of the amounts added to soil 1 and soil 2, respectively, had been released (Figure 4.14). Between the sixth and the ninth week the decrease was relatively slow. These trends were similar to those of residual dry matter and organic carbon (sections 4.2.1 and 4.2.2). Soil-incorporated manure had a significantly ($p=0.05$) higher rate of N release (Figure 4.15; Tables 4.11 and 4.12) in soil 2 but not in soil 1. The initial fast rate of decomposition has been explained in terms of the availability of easily degradable substrate (section 4.2.1 and 4.2.2). The N release rate decreased thereafter as the easily degradable components became depleted. Such trends of N release have also been reported by other workers (Weeraratna, 1979; Smith and Peckenpaugh, 1986). Amato *et al.* (1994) found an initial fast release rate of ^{15}N in *Medicago* spp, but decomposition was retarded thereafter. According to Paul and Clark (1989) amino acid N decomposed faster, followed by that of amino sugars.

As reported for residual dry matter and organic carbon, the disappearance of residual N from the surface applied manure, was greatly enhanced by termite activity in soil 1 hence the method of manure placement effect was confounded in this soil. In soil 2 the rapid release of N from the incorporated material compared to the mulch was due to the greater contact between the soil microorganisms and the incorporated material and also due to the

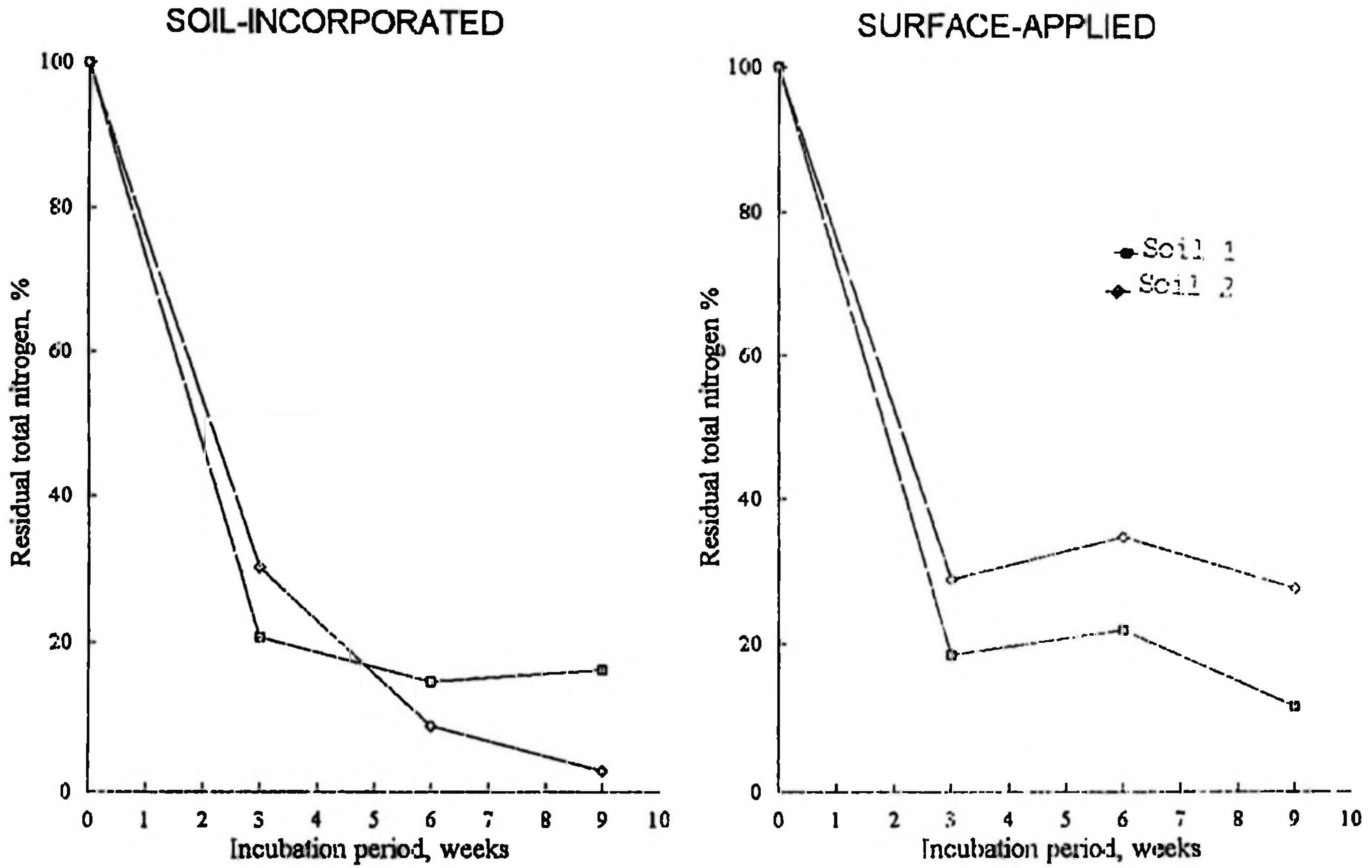

Figure 4.14 Effect of soil type on the decomposition of *Senna siamea* green manure in the field as indicated by residual total nitrogen.

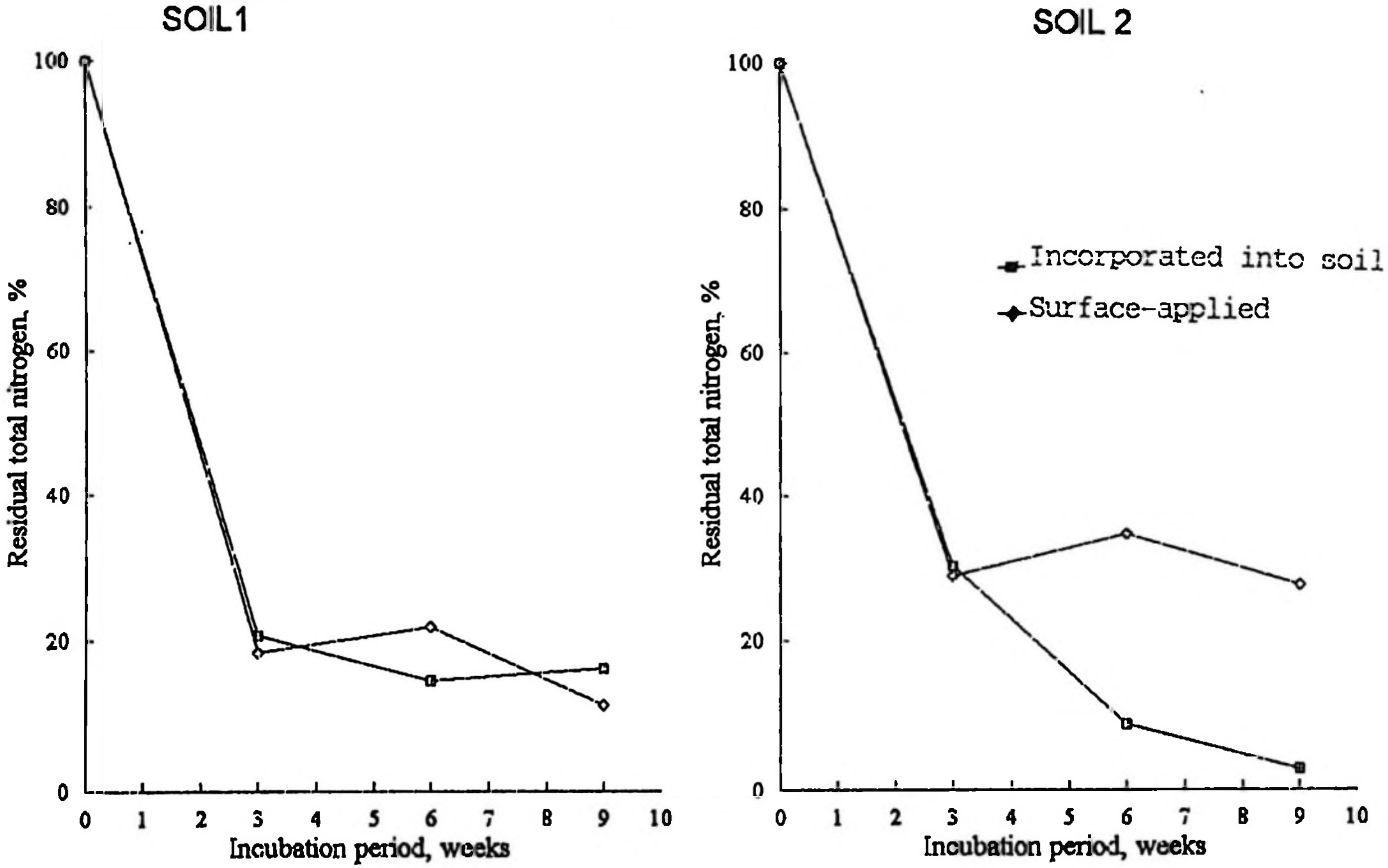

Figure 4.15. Effect of method of placement on the decomposition of *Senna siamea* green manure, as indicated by residual total nitrogen.

Table 4.11 Overall effect of soil type and method of manure placement on the decomposition of *Senna siamea* green manure as indicated by residual total nitrogen averaged over the sampling periods.

Soil type	Method of placement surface-applied	 soil-incorporated	Soil-type means	LSD(p=0.01) for soil type means
	------% residual total N-------			
1	17.29	17.33	17.31	± 2.26
2	30.38	13.97	22.17	
Method of placement means	23.84	15.65		
LSD (p=0.01) for method of placement means	± 2.26			

Table 4.12 Total N loss rate constants under the two methods of manure placement.

Treatment	Total N release rate constant (week^{-1})
Soil 1 + surface-applied	0.240
Soil 1 + soil incorporated	0.200
Soil 2 + surface-applied	0.142
Soil 2 + soil incorporated	0.398

relatively wetter conditions at the 10 cm depth compared to the soil surface. The release of N in the incorporated material in soil 1 compared to soil 2 was retarded by the relatively drier conditions of soil 1 at the 10 cm depth due to reasons given in section 4.2.1. Moreover it is probable that there was increased clay protection and adsorption of the organic N compounds in soil 1, thus reducing their availability to the microbes (Bondietti *et al.*, 1971; Zunizo *et al.*, 1982).

4.3 Comparison between the glasshouse and field conditions results

The trends of *Senna siamea* decomposition under glasshouse conditions compare well with those observed in the field (Figures 4.16, 4.17 and 4.18). The residual dry matter, organic carbon and the total N decreased rapidly during the first three weeks of incubation under both conditions. Overall, the rates of decomposition were significantly ($p=0.05$) faster under field than under glasshouse conditions (Table 4.13).

Decomposition in the field occurred under alternating dry and wet conditions (Figure 4.8) while that in the glasshouse was under uninterrupted moist conditions. These differences in soil moisture regimes in the glasshouse and in the field might have caused the differences in the decomposition rates observed. The remoistening of soils following the dry spell in the field might have activated the newly developing microbial population, enhancing subsequent mineralisation on moistening (Birch, 1964; Griffiths and Birch, 1961). It is also probable that the soils under field conditions were more aerobic than those under glasshouse conditions since the latter were maintained moist throughout the study. Hence the microbial activity was greater in the field than in the glasshouse.

Temperature differences may affect decomposition rates under field and glasshouse conditions. The present glasshouse and field studies were undertaken largely within the same rainy season and the ensuing cool season. Differences in temperature between the glasshouse and the field were minimal.

It is inferred here that, generally, the results of the glasshouse study may be used to give a general trend of the decomposition of *Senna siamea* under field conditions. However, the rate of decomposition of this manure under field conditions may be different from the rate under glasshouse conditions.

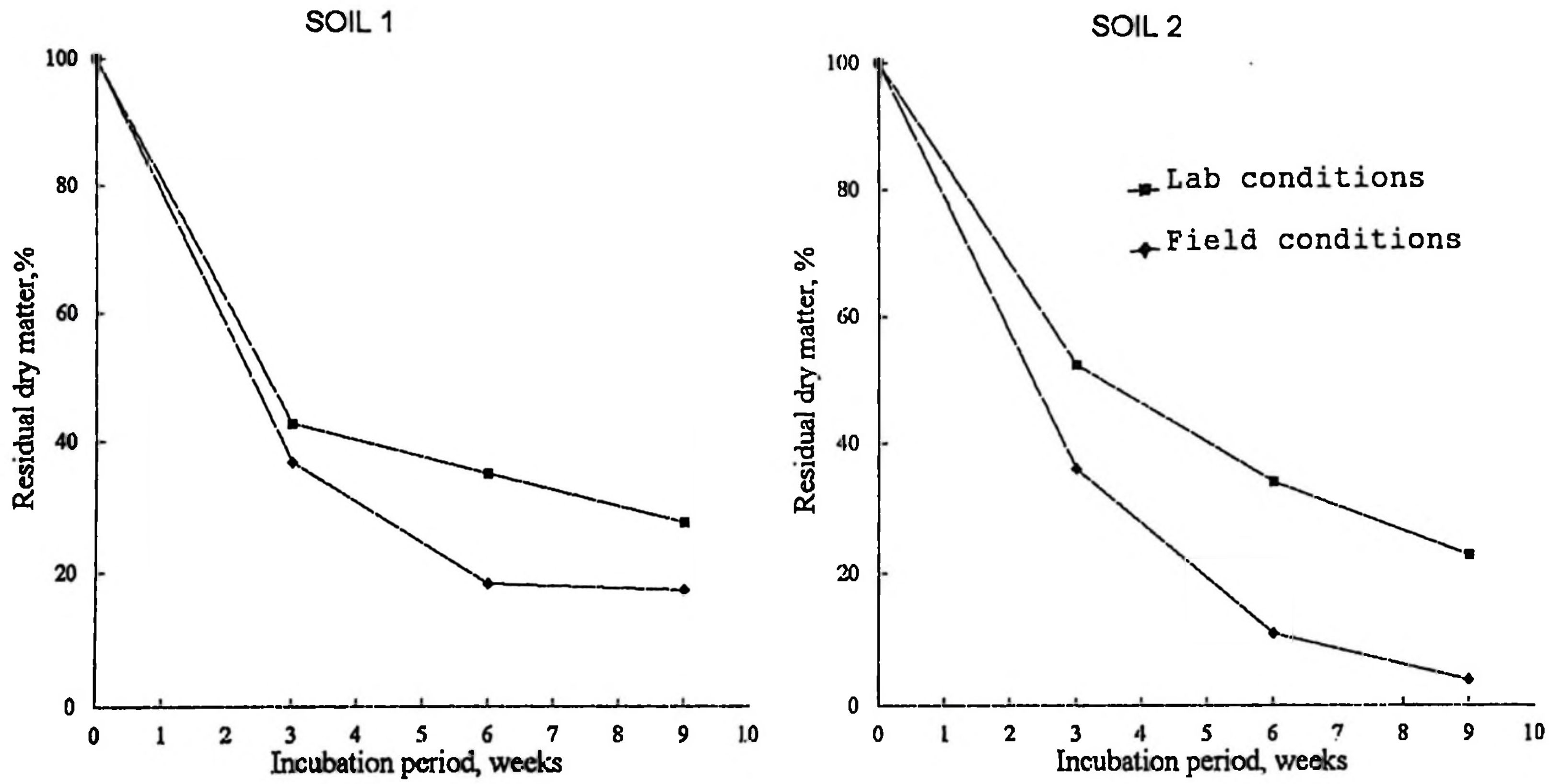

Figure 4.16. Changes in residual dry matter with incubation time under laboratory and under field conditions.

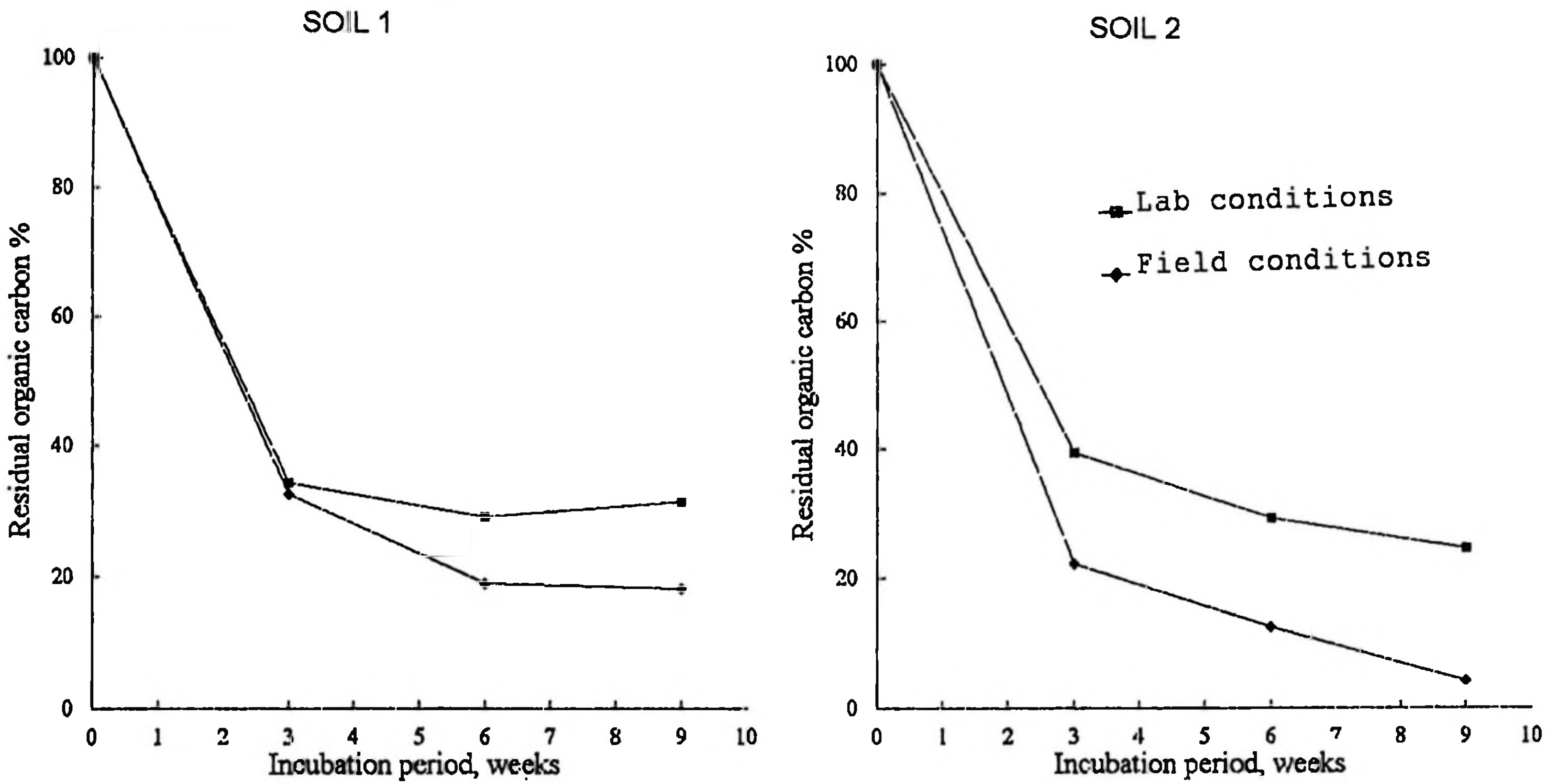

Figure 4.17. Changes in residual organic carbon with incubation time under laboratory and under field conditions.

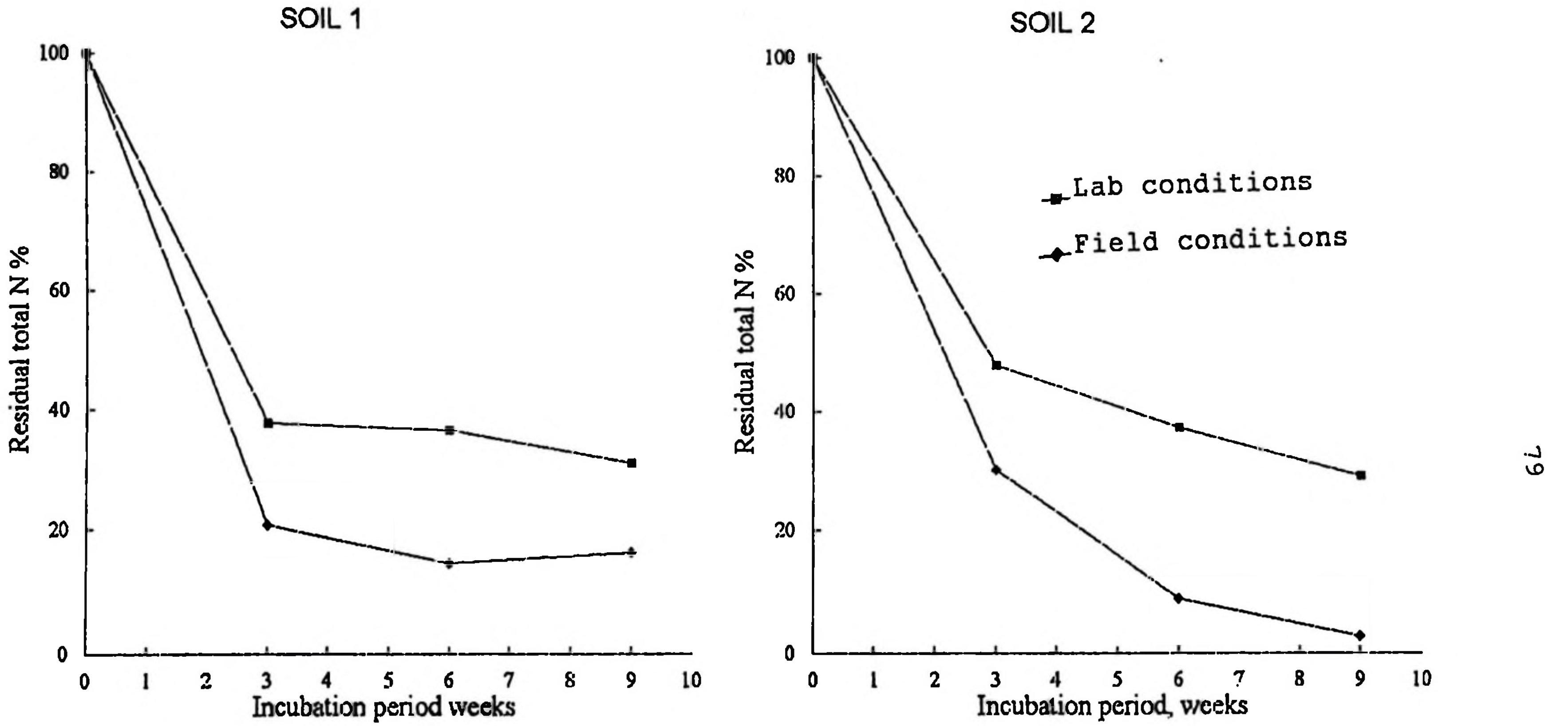

Figure 4.18.Changes in residual total N with incubation time under laboratory and under field conditions.

Table 4.13 Residual dry matter, organic carbon and total N means averaged over the incubation periods under glasshouse and field conditions.

	Dry matter		Organic carbon		Total Nitrogen	
	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
Glasshouse conditions	35.40	36.59	31.85	31.16	33.79	38.23
Field conditions	24.35	16.97	23.43	13.01	17.33	13.93
LSD (p=0.05)	5.38	5.38	4.74	4.74	4.88	4.88

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSIONS

A glasshouse and a field experiment were set up to determine the effect of soil type, manure application rate and placement method on the decomposition rate and extent of nitrogen release of *Senna siamea* green manure. In the glasshouse, the amounts of dry matter , organic carbon and total nitrogen, expressed as a percentage of the original amounts added, were determined at the first, third, sixth, ninth and the twelfth week of manure incubation in two soil types. In the field the determinations were made at the third, sixth and the ninth week.

The results of the glasshouse experiment indicated that the decomposition rate and the nitrogen release was not significantly affected by soil type. However, a manure application rate of 60 kg N/ha resulted in a significantly ($p=0.05$) faster decomposition than an application rate of 150 kg N/ha. Under field conditions, the results revealed an interaction between soil type and method of manure placement on the decomposition rate. In soil 1 the effect of method of manure placement was not defined. This was due to the infestation of this soil by termites which enhanced the decomposition of the surface-applied manure. In soil 2, the soil-incorporated manure decomposed significantly (p=0.05) faster than the surface-applied due to the greater contact between the soil, and hence soil microorganisms, and the incorporated manure. Also there was favourable moisture conditions at the depth of incubation (10 cm) than at the soil surface where moisture loss due to evaporation was greater, making the surface soil drier.

The decomposition under field conditions was significantly faster than in the glasshouse. However, the patterns of N release under both conditions were similar. The manure lost about 50% or more of the total N during the first three weeks of incubation while, the N release rate was slower subsequently.

The results of these experiments led to the following conclusions and suggestion:

1. The rate of *Senna siamea* green manure decomposition in the field will depend on the soil type, the method of placement as well as the rate of application.

2. The effect of these factors depend on the climatic conditions (exemplified by moisture regimes in the glasshouse versus in the field) as well as the faunal activity.

3. Although the efficiency of decomposition (e.g. N release) was greater when the manure was buried in soil 2, incorporation of manure would be more laborious than applying it on the soil surface. This would have practical implications as far as smallscale farmers, relying on hand labour, are concerned.

4. In order to achieve synchrony between the nitrogen release from this manure and the demand of the targeted crop, the factors mentioned in 1 above should be considered in determining the time of applying manure in the field. This needs further studies.

5. It is suggested that the determination of the actual gains of green manure N in the soil and its availability may give more refined data with regard to the potential of this manure in supplying N and other nutrients to crops.

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