CHARACTERIZATION AND DECOMPOSITION OF SELECTED GREEN MANURE PLANTS IN AN ALFISOL

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Affectionately dedicated
to my beloved
PARENTS

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES BANGALORE

CERTIFICATE

This is to certify that the thesis entitled **"CHARACTERIZATION AND DECOMPOSITION OF SELECTED GREEN MANURE PLANTS IN AN ALFISOL"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, Bangalore, is a record of bonafide research work carried out by **M.B. DEVARAJA** during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis of the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore
January, 2004

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INTRODUCTION

I. INTRODUCTION

Indian agriculture is dominated by drylands, which account for nearly 65 per cent of the net cultivated area of about 139 m. ha, contributing nearly 45 per cent of food production. Increase in population demands a continuous increase in agriculture production. Continuous and excessive use of high analysis fertilizers to enhance the productivity has resulted not only in the pollution of ground water and atmosphere but also resulted in deficiency of nutrients especially secondary and micro nutrients.

In view of long term sustainability, integrated use of fertilizers, organic manures and biofertilizers become inevitable. In fact, the availability of traditional organic manures such as FYM and compost being inadequate, there is an urgent need to explore alternate sources of organic manures especially green manure plants as an alternate source of nutrients. They have the capacity to fix atmospheric nitrogen if they are legumes, produce higher biomass, can be easily incorporated and undergo rapid decomposition.

To convert the green revolution into evergreen revolution and for sustainable crop production under rainfed condition, efficient management of the available natural resources are absolutely essential. With the increase in input cost and ecological safety under threat, integrated nutrient management with organic manures, biofertilizers, crop rotation and minimal use of chemical fertilizers is the need of the day. Green manures plants have wide scope for soil fertility maintenance, enhanced crop productivity, reduced environmental hazards, lower input costs and higher farm income. But the choice of green manure plants has to be appropriate, as the dry land farmer cannot be expected to sacrifice an economic crop for green manure plants. The various options available for growing green manure plants should be carefully examined taking into consideration the amount of rainfall, length of growing period, soil type, and management risks before deciding the crop to be raised even in areas of limited rainfall. There is a very good opportunity for growing green manure plants in sustainable rainfed farming.

Research conducted elsewhere have revealed that factors like soil fertility, nutrient uptake and yield are positively correlated with the application of green manures (Varadarajan *et al.,* 1966)

There is always need to study the effect of decomposition of green manures on mineralization of nutrients and biological systems in the soil. The activities of soil enzymes important for releasing simple carbon and nitrogen sources for the growth and multiplication of microorganisms which inturn play an important role in building soil fertility.

It has been observed that the studies relating to the usage of green manures for maintenance of organic matter has been confined much to temperate soils and literature on these aspects in tropical and subtropical soils is quite inadequate. Very little work has been carried out on biochemical and nutrient status of green manures in India

In view of the paucity of information and a need for knowledge on these aspects, a study was conducted using twelve different green manures collected from GKVK campus were characterized and among them only 3 green manure plants were used for decomposition study.

Objectives of investigation

The study was conducted with the following objectives

1. To asses the nutrient status and chemical composition of selected green manures plants.

2. To study the decomposition of selected green manure plants at two moisture levels i.e., at 50% field capacity, and 100% field capacity, and

3. To investigate the microbial biomass at different periods of decomposition.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Green manure plants are incorporated in to soil for improvement of the physicochemical and biological properties. A review of literature regarding the characterization and decomposition of green manure plants in the soil is presented in this chapter under different headings.

2.1 Chemical and biochemical composition of green manure plants

2.2 Nitrogen mineralization and nitrification

2.3 Changes in nutrient status of the soil during and after decomposition of green manure plants

2.4 Evolution of carbon dioxide from soil as a measure of rate of decomposition of green manure plants

2.5 Soil microbial biomass

2.1 Chemical and biochemical composition of green manure plants

2.1.1 Quality of green manure plants

Fresh green manure plants added to soils largely to supply nutrients and enhance the microbial activity. The nutrient composition varies with green manure plants.

Titan *et al.* (1992) reported that of glyricidia leaves contain 11.6 per cent lignin, 19.4 per cent cellulose, 12.20 per cent hemicellulose, 1.62 per cent polyphenols, 47.3 per cent carbon, 3.60 per cent nitrogen, 13:1 C:N ratio, 0.13 per cent phosphorus, 2.74 per cent potassium, 1.63 per cent calcium, 0.45 per cent magnesium and 0.59 per cent SiO_2. The nitrogen content of different cultivated legumes ranged from 2.50 to 3.91 per cent (Yadvinder Singh *et al.,* 1992).

The leaves of dhaincha were analysed for its chemical composition by Dey and Jain (1997) and they reported that the leaves contained 42.10 per cent carbon, 2.03 per cent nitrogen, 0.22 per cent phosphorus, 2.02 per cent potassium, 7.80 per cent cellulose, 17.01 per cent lignin, 1.50 per cent ash and 20.70 C:N ratio.

Dey and Jain (1997) reported that the cowpea leaves contained 44.40 per cent carbon, 1.56 per cent nitrogen, 0.26 per cent cellulose, 17.01 per cent lignin, 1.50 per cent ash and 20.70 C:N ratio.

The chemical composition of pongamia leaves contains 3.79 per cent nitrogen, 0.17 per cent phosphorus, 0.22 per cent magnesium, 0.32 per cent sulphur, 349.20 ppm Iron, 164.20 ppm manganese, 100.40 ppm zinc, 10.62 C:N ratio, 38.28 per cent cellulose and 27.96 per cent lignin (Rajashekar Rao , 2000).

The nitrogen composition of green manure plants like sunhemp, glyricidia dhaincha and pongamia ranged from 2.30 to 3.50 per cent respectively (Bellaki and Badnur, 1998).

2.1.2 Composition of weed species

The leaves of *Lantana camera* contained 17.69 per cent ash, 98.10 per cent carbon, 1.62 per cent total nitrogen, 0.92 per cent phosphorus, 1.21 per cent potassium, 3.66 per cent calcium, 1.04 per cent magnesium, 0.93 per cent sodium, 0.66 per cent sulphur, 26.62 ppm iron, 49.6 ppm Zn, 8.90 ppm, Cu 29.69 C:N ratio and 52.80 C:P ratio (Shukla and Vimal 1969).

The nutrient content (N, P and K) of weeds like eupatorium, parthenium and water hyacinth ranged from 2.86 to 3.15 per cent, 0.50 to 0.98 per cent and 1.56 to 2.13 per cent respectively (Gajanan, *et al.,* 2000).

2.1.3 Composition of tree species

The leaves of *Accacia nilotica* from Rajasthan were analysed for its chemical composition by Ganguli *et al.* (1964) and reported the leaves contain 13.90 per cent crude protein, 7.10 per cent ash, 0.10 per cent phosphorus, 2.60 per cent calcium and 0.40 per cent magnesium on oven dry basis.

Singh *et al.* (1967) reported the chemical composition of the leaves of subabul collected from Haryana had 36.39 per cent dry matter, 25.57 per cent crude protein, 4.25 per cent ash, 2.70 per cent calcium and 0.17 per cent phosphorus.

The leaves collected from *Cassia seratia* analysed for its biochemical composition by Karen *et al.* (1992) revealed that leaves contained 3.92 per cent polyphenols, 2.31 per cent nitrogen and 10.3 per cent lignin.

2.2 Nitrogen mineralization and nitrification

Nitrogen mineralization is a process by which organic forms of nutrients in the organic materials are converted to inorganic forms mediated by heterotrophic microorganisms. Generally these organic materials includes green leaf manure, farmyard manure, compost, oil cakes and other crop residues. Incorporation of organic residues with wide C:N ratio initially immobilizes soil nitrogen and results in what is known as nitrogen sickness, where as in narrow C:N ratio materials the rate of decomposition is fast and the problem of nitrogen sickness is not observed.

Bardin (1967) reported increase in the rate of mineralization when soil was incorporated with ground leaves of *Glyricida maculata* containing 4.5 to 4.7 per cent nitrogen and C:N ratio of 9 over straw and compost.

Floate (1970) did not observe any significant differences in the rate of mineralization of nitrogen of plant materials and sheep feaces in soils incubated at 25, 50 and 100 per cent of their maximum water holding capacity.

Singh and Rai (1975) observed that soils amended with 60 to 75 days old sesbania leaf litter resulted in higher concentration of ammonical nitrogen after 15 and 30 days of incubation.

In an incubation experiment Nagarajan *et al.* (1989) observed that the release of ammonical nitrogen from different green manures increased rapidly upto 4 weeks and there after remained nearly constant for 8 to 12 weeks. The peak ammonia released was observed from 7 to 15 days of incubation and later on decreased quickly due to loss of nitrogen.

Patra *et al.* (1992) studied the effect of incorporation of cowpea and wheat straw on nitrogen mineralization in soil and concluded that the sum of the mineral (Intial) N in soil and that mineralized during incubation of fumigated soil (Flush N) may be suitable index of available N status in a soil. Thus when sugarcane trash and pine apple residue in a finely ground state were mixed with soil at different levels with and without N fertilization and there was no noticeable loss of N from the soil due to denitrification.

Mineralization of nitrogen was highest and rapid in *Sesbania rostrata* followed by rice straw and farmyard manure (Sarmah and Bordloi, 1994).

Brar and Sidhu (1995) reported that the ammonical N accumulation increased significantly with increase in soil water content but release of nitrate nitrogen was reverse. The total mineral N production and rate of mineral-N accumulation also significantly lowered with decrease in soil moisture levels.

In a field study, the rate of nitrogen mineralization in soil amended with dairy pond sludge was rapid and release of nitrate occurred during the first 6 weeks of incubation and the amount of N released at lower rate of sludge was greater than that at higher rate of sludge treatment. The rapid N release and nitrification rates observed were attributed to their C:N ratio (Zaman *et al.,*1998).

In an incubation study the mineralization of N from sesbania under flooded conditions increased significantly with increase in incubation temperature. N mineralization increased upto 40th week and decreased there after (Sihag and Singh, 1999).

Mishra *et al.* (2001) reported that during decomposition of wheat straw, N content increased and C:N ratio decreased with time. There was practically no N mineralization from the rice straw during the first phase but there after N mineralization proceded gradually.

Dinesh and Dubey (1999) noticed that the net-N mineralization was significantly higher in soils amended with organic manures compared to unamended soils. This indicates that soils amended with organic manure are likely to have high N supplying capacities.

Dey and Jain (1997) reported that net ammonification under submerged condition and net nitrification at field capacity soil water regime can be taken as an index of net mineralization. Cummulative nitrogen mineralization was positively correlated with total N and N release from green manure increased by enrichment of urea.

Net N mineralization was negatively correlated with initial soluble polyphenol content in the early phases of decomposition and with initial lignin content in later phases. Neither initial per cent N or lignin to N ratio was strongly correlated with N mineralization (Karen *et al.,* 1992).

2.3 Changes in nutrient status in the soil during and after decomposition of green manure plants

2.3.1 Organic carbon and nitrogen

Organic carbon and nitrogen content in soil changed due to addition of green manure/organic manures.

Kanwar and Prihar (1962) observed that both organic manure and fertilizer application had increased the organic carbon and total nitrogen at higher levels than control.

Gaur *et al.* (1971) recorded 77 and 75 per cent increase in organic carbon with application of farm yard manure and wheat straw respectively over control.

Varadarajan *et al.* (1966) stated that green manure application increased the nitrogen content and minor elements in the soil.

Incorporation of green lupin increased the utilization of soil nitrogen by 10 to 15 per cent and soils treated with dhaincha maintained higher levels of NH_4-N and NO_3-N and also showed as increase in available nitrogen (Zakharchenko and Leonchik, 1971)

Bairthi *et al.* (1974) reported that incorportion of legume residues with fertilizers increased organic carbon and total nitrogen content. The highest organic carbon (0.15%) and total nitrogen (0.03%) was observed with incorporation of guar leaf residues.

Aggarwal and Sharma (1980) reported that soils treated with oak leaves showed much higher increase in nitrate content than control throughout the period of incubation.

Helkiah *et al.* (1981) found that application of compost significantly increased (0.49%) organic carbon over control (0.32%) in black soils. Increased availability of nitrogen was found with the addition of different levels of organic manures.

Verma *et al.* (1983) reported higher organic carbon content in soil with incorporation of sunhemp when compared to application of fertilizers.

In a laboratory experiment incorporation of fresh and dried leaves of *Leucaena leucocephala* leaves increased the nitrogen status and total nitrogen (Read *et al.*, 1985).

Jeyaraman (1988) reported increase in organic carbon content of soil due to addition of green manures and fertilizers.

While experimenting with wheat straw, Cogle *et al.* (1989) reported that the soluble carbon source of wheat straw was quickly exhausted during decomposition but continued straw decomposition was largely dependent on mineralization of the initially insoluble pool of straw carbon.

Application of nitrogenous compounds increased the decomposition of crop residues and decreased carbon content and increased the nitrogen content of humic acids (Singh *et al.*, 1995).

Mishra *et al.* (2001) reported that during decomposition of rice straw carbon content decreased N content increased and C:N ratio decreased with time.

2.3.2 Changes in phosphorus

According to Joseph *et al.* (1952) the organic anions and hydroxy acids liberated during decomposition of organic manure complexes with Fe and aluminium and increased the availability of phosphorus.

Sen and Bains (1955) pointed out that decomposition of FYM had solubilising effect on iron and aluminium and increase the availability of phosphorus content in the soil.

The experiments conducted by Khan *et al.* (1964) revealed that the decomposition of green manures increased P availability by 20 to 25 per cent.

Prabhakar *et al.* (1972) reported that addition of organic manures in the form of compost and *Glyricidia maculata* increased the availability of phosphorus and further increased due to combined effect of organic manures and nitrogen salts.

Ahamad *et al.* (1981) reported that amount of organic phosphorus mineralized usually increased with incubation period.

Das *et al.* (1991) observed an increase in available phosphorus status of Alfisol with the application of organic manures after 12 days of incubation.

Incubation of soil with graded levels of inorganic P without sesbania addition resulted in decreased amount of Olsen P up to 40 days of incubation there after it increased and the release of P from soils amended with green manure was maintained at higher levels (Yasphal *et al.,* 1993).

In a laboratory experiment the availability of P increased in soil with increased soil water content, rate of addition of P and time. Application of P through ammonium phosphate showed higher P availability under different water regimes, levels of P and incubation period (Patel and Trivedi, 1994).

The soil inoculated with glyricidia along with graded levels of P showed higher P concentration throughout the incubation period compared to no green manure incubated soil. The increased may be partly be ascribed to the release of P during mineralization of added green manure Anilkumar and Shivakumar (1984)

In a laboratory investigation higher mineralization of added plant and soil organic P under submerged conditions as compared with field capacity was noticed (Vig Didor Singh, *et al.*, 1997).

2.3.3 Changes in potassium content

Levin and Joffe (1947) observed that organic matter reduces potassium fixation hence the availability of potassium increase with green manure application.

Shukla and Vimal (1969) observed the release of potassium from different weeds is more under submerged conditions compared to well drained condition.

Olsen *et al.* (1970) observed that addition of manures tends to increase the exchangeable potassium content in the soil.

Mishra *et al.* (2001) reported that during decomposition of rice straw K content decreased with time.

2.4 Evolution of carbon dioxide from soil as a measure of rate of decomposition of green manure plants

According to Jenny and Waksman (1930) the decomposition of plant materials under anaerobic condition was slower than under aerobic condition and it was much slower when plant material consisted of resistant materials.

The experiment conducted by Richard *et al.* (1964) regarding the effect of moisture tension on carbon dioxide evolution has revealed that a lag period was present in the production of carbon dioxide in soils at zero tension and peak production was reached after 7th day of incubation. In a laboratory experiment highest evolution of carbon dioxide occurred during the first stages of organic matter decomposition of green manure plants (Hudeova and Aplfuer, 1965).

Makarove (1965) found that plowing increased carbondioxide released from the soil and also observed that incorporation of dung increased the release of carbon dioxide from soil.

Cerny (1966) reported that the catch crop green manuring had increased the number of microorganisms and carbondioxide production notably in the following spring

Research conducted by Debnath and Hajra (1972) revealed that as soon as optimum conditions are reached, the carbon dioxide production shoots up from the soils treated with organic matter. Carbon dioxide production gradually declined and become more (or) less constant for 65 days.

The influence of organic matter in the form of glyricidia leaves and rice straw on the chemical kinetics of the soil was studied by Katyal (1977). The results showed that with addition of organic matter the peaks of carbon dioxide production was significantly higher as compared to control.

Patil *et al.* (1984) reported that the quantity of CO_2 evolved from spent wash amended soil was nearly three times more than that of FYM treatment. There was maximum liberation of CO_2 in the second week both the control treated soils with poultry manure showing greater effect than cow dung (Gupta and Tripati, 1986).

Carbon mineralization from added residues further depends on soil characters, nature of organic materials added and incubation temperature as reported by Tsutsuki and Ponnamperma (1987). Mineralization of carbon as CO_2 from sewage sludge and poultry manure under field capacity and submergence revealed that higher per cent carbon mineralization occurred under field capacity moisture regime than submergence (Yadav *et al.*, 1989) under submergence only 30 to 38 per cent of added carbon was mineralized, where as at field capacity it was 46 to 56 per cent.

The glyricidia treatments during decomposition evolved more carbon dioxide and remained superior to coirpith treatments throughout the period of incubation. Among the coir dust treatment microbe inoculated (*Pluerotus sojorcaju*) treatments were superior to urea and rock phosphate incorporated treatments in Oxisols (Jothimani *et al.*, 1997).

Rao and Trafdar (1998) reported that during the decomposition of crop residues at different soil water levels the release of CO_2 was maximum during first week at 60 per cent field capacity and then started declining.

An experiment on decomposition of broad leafed and coniferous forest litter, the CO_2 evolution was more in soils treated with either than the control. Carbon dioxide evolution was observed from the soil on the treatments after that rate declined in all cases (Dutta *et al.,* 2001).

2.5 Soil microbial biomass

The soil microbial biomass (SMB) which is the total sum of all microorganisms present in soil and acts as an active reservior for plant available nutrients (Jenkinson and Ladd, 1981). The soil microbial biomass itself is a part of the soil organic matter, accounts for about 2 per cent of the total organic carbon. Soil microbial biomass is defined as the living microbial component of the soil which includes bacteria, actinomycetes fungi, algae and micro fauna (Alexander, 1977).

Schmurer *et al.* (1985) reported that in a long term field experiments mostly soils cropped with cereals, the biomass carbon and their activities were determined by chloroform fumigation method. The results indicate that the microbial biomass carbon ranged from 230 to 600 $\mu g\ g^{-1}$ dry wt of soil and the carbon mineralization after fumigation was positively correlated with organic matter.

The microbial biomass changes more rapid due to the change in ecosystem conditions and its measurement is a valuable tool for understanding and predicting the long term effects and changes on soil properties (Powlsen *et al.,* 1987).

Aerobic long term incubation study for 40 weeks indicates that the microbial biomass C showed rapid decrease upto week three (4 to 36 per cent of initial mass) and slower decrease upto week six (9 to 23 per cent of initial mass) and a very slow decline to the final determination at the end of the incubation (2 to 8 per cent of initial mass). The biomass N also followed the similar pattern (Bound *et al.,* 1988).

Srivastava and Singh (1988) measured the microbial biomass C and N for six tropical soils. The data indicates that biomass ranged from 149 to 667 $\mu g\ g^{-1}$ soil and biomass P from 17 to 35 $\mu g\ g^{-1}$ soil and the amount of biomass P was positively related with soil inorganic P.

Analysis of fertilizer and manurial experiments in tropical conditions of India have shown that soil microbial biomass C and N increased with balanced fertilization. Addition of organic amendments increased microbial biomass even when the organic carbon content of the soil did not increase. The increase in microbial biomass was attributed to better plant growth resulting in higher rhizodeposition (Goyal *et al.* 1994).

In the model, the time course of labelled C and N mineralization arose from microbial consumption of the substrate during the earlier part of incubation and from the microbial consumption of the products of microbial interaction on during the later part, reveled that resolution of microbial biomass into labile and resistant components allowed the model to stimulate changes in active VS quiesent biomass fractions (Grant *et al.,* 1993).

The addition of organic materials resulted in the increase of microbial biomass regardless of N in the soil types however the changes in the pattern of microbial biomass N were related to the N mineralization and immobilization process of the each organic material (Aoyama and Nozawa, 1993).

Shanthy *et al.* (1999) reported that the highest microbial biomass C and N contents were observed under integrated usage of organic matter (FYM) + inorganic fertilizers (NPK). The maximum levels of microbial biomas C and N the observed after cowpea crop during summer. The interaction effect was fertilizer more in plots receiving 100 per cent NPK + FYM on influencing the clay content and water holding capacity of soil rather than on silt and sand

In a laboratory incubation studies that addition of compost increased the microbial biomass carbon, soil respiration urease and phophatase activities of the compost. (Bhattachrya *et al.,* 2001).

MATERIAL AND METHODS

III MATERIAL AND METHODS

A laboratory experiment "Characterization and decomposition of selected green manure plants in an Alfisol", was conducted during the year 2002- 2003, in the Department of Soil Science and Agricultural Chemistry, GKVK campus, UAS, Bangalore. The details of treatments, replications, materials used, methodology employed in the study and procedures followed for analysis of plant and soil are presented in this chapter.

3.1 Collection and preparation of green manure plants samples for analysis.

Twelve (12) green manure plant samples were collected from AICRP on Dryland Agriculture. The samples collected were glyricidia, pongamia, lantana, neem, sun hemp, dhaincha, cowpea, horse gram, eupatorium, parthanium, water hyacinth and cassia sp. The samples were washed with distilled water and dried before grinding. The dried plant samples were powdered using German made blender and preserved for analysis.

The green manure plants used in this study were

Common name	**Scientific name**
Glyricidia	*Glyricidia maculata*
Pongamia	*Derris indica*
Lantana	*Lantana camara*
Neem	*Azardiarchta indica*
Sunhemp	*Crotalaria juncea*
Dhaincha	*Sesbania acculeta*

Plate 1 : Glyricidia (*Glyricidia maculata*)

Plate 2 : Dhaincha (*Sesbania acculeta*)

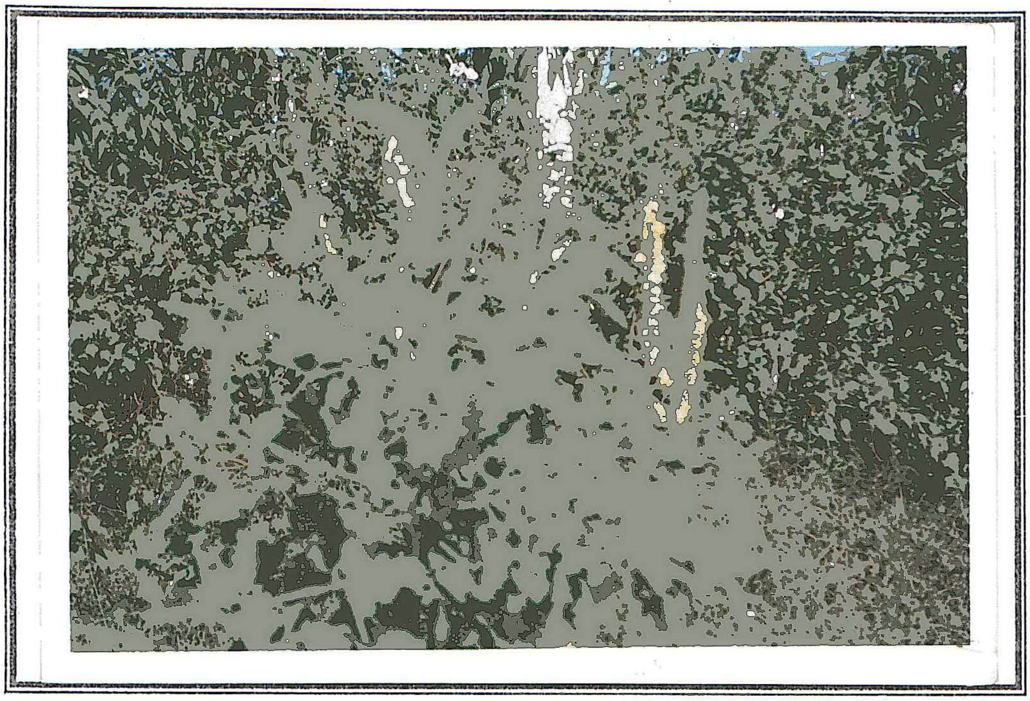

Plate 3 : Cassia sp. (*Cassia uniflora*)

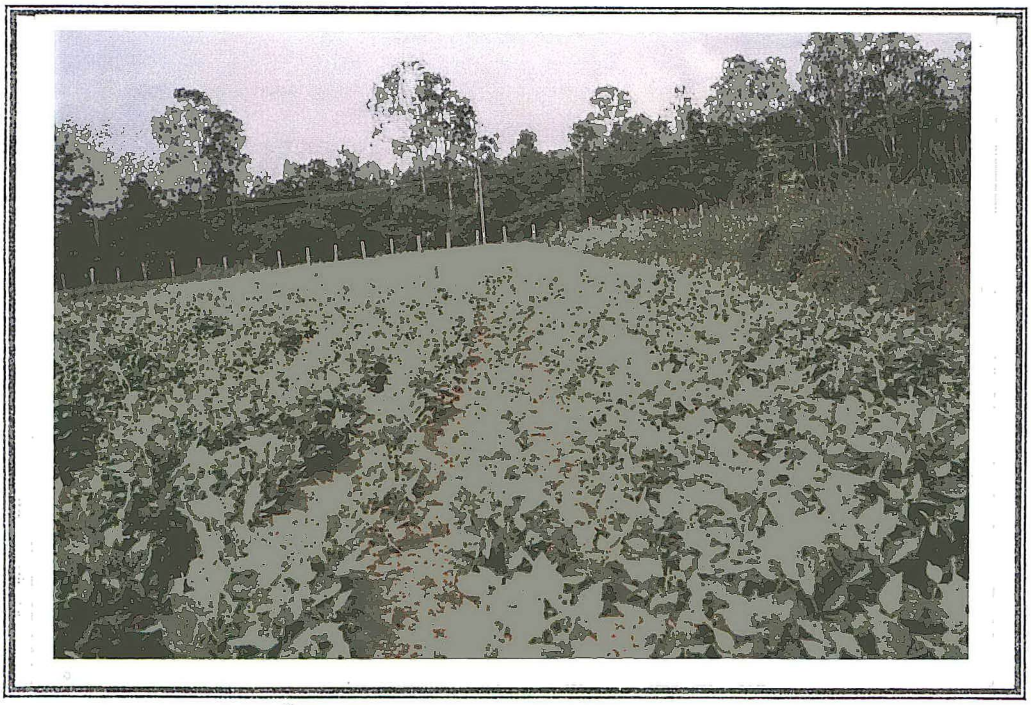

Plate 4 : Horse gram (*Phaseolus bicolar*)

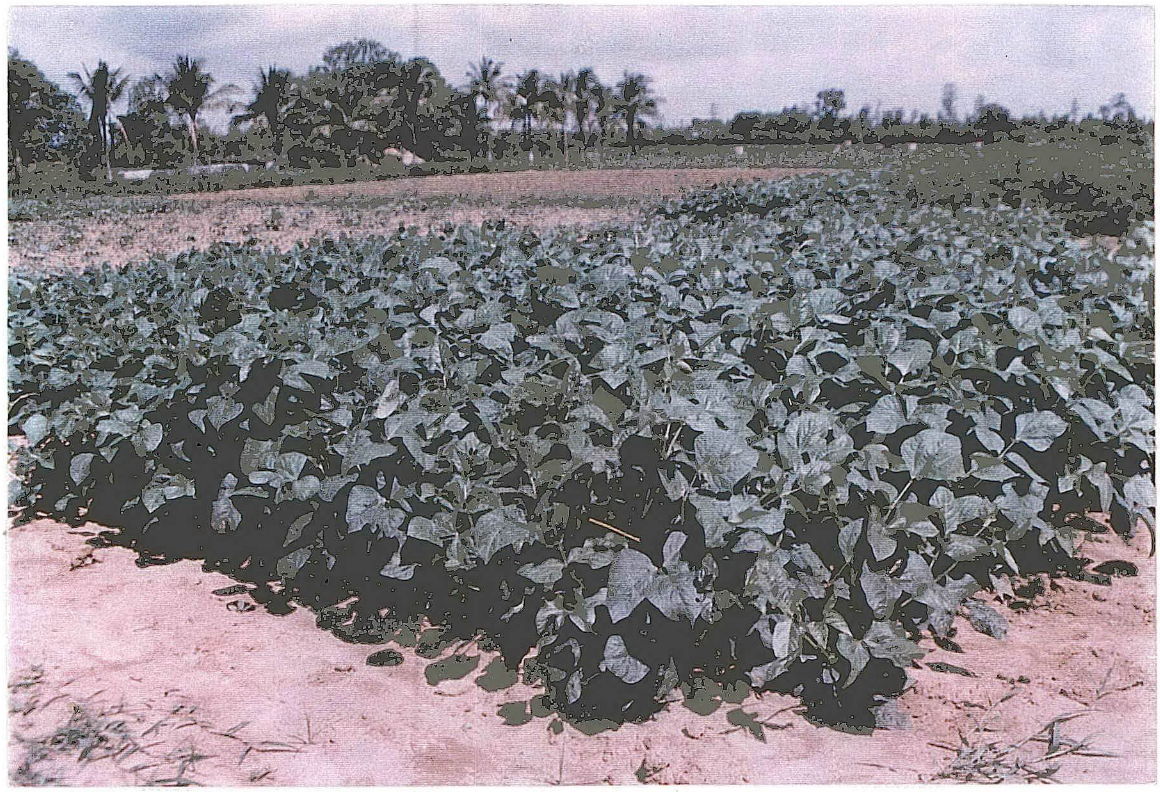

Plate 5: Cowpea (*Vigna unguinculata*)

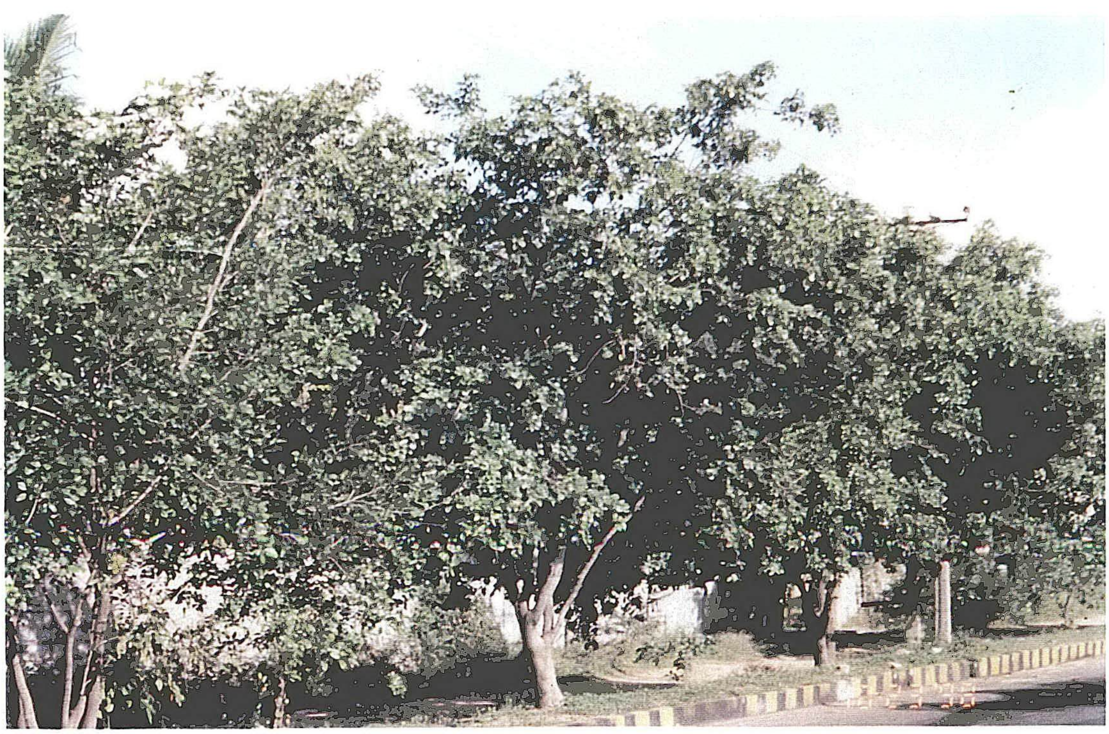

Plate 6 : Pongamia (*Derris indica*)

Plate 7 : Eupatorium (*Chromolaena odorata*)

Plate 8 : Parthenium (*Parthenium hysterophorus*)

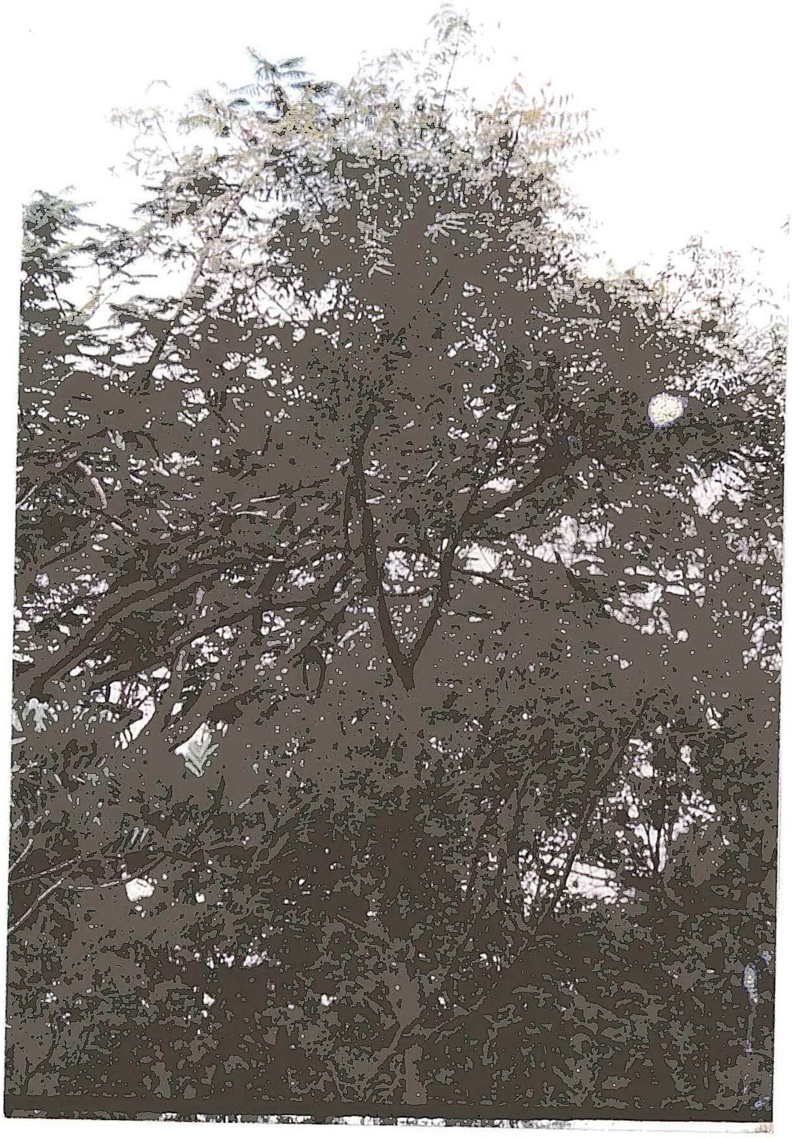

Plate 9 : Neem (*Azardiarchta indica*)

Plate 10 : Water hyacinth (*Eichorinia crassipes*)

Cowpea	*Vigna unguinculata*
Horse gram	*Phaseolus bicolar*
Eupatorium	*Chromolaena odorata*
Parthenium	*Parthenium hysterophorus*
Water hyacinth	*Eichorinia crassipes*
Cassia sp.	*Cassia uniflora*

3.1.1 Determination of nitrogen in plant samples.

The nitrogen content in plant samples was determined by using micro-Kjeldahl method as described by Piper (1950).

3.1.2 Wet digestion of plant material

Wet digestion of plant material was done using diacid mixture (HNO_3: $HClO_4$) and preserved for analysis of phosphorous, potassium, calcium, magnesium, sulphur and other micronutrients (Piper 1950).

3.1.3 Determination of phosphorous content in plant sample

The phosphorus content of the plant samples was determined by yellow colour method as described by Piper (1950). The intensity of yellow colour was read at 420 nm in spectrophotometer.

3.1.4 Determination of potassium content in plant samples

The potassium content in the plant samples was determined by using flame photometer as described by Piper (1950).

3.1.5 Determination of sulphur content in plant samples.

The sulphur content of digested plant material was estimated using spectrophotometer at 420 nm (Jackson 1973).

3.1.6 Determination of calcium and magnesium content in plant samples

Calcium and magnesium were estimated by versonate titration method as described by Jackson (1973).

3.1.7 Determination of micronutrient status in plant samples

The method developed by Lindsay and Norwell (1978) was adopted to estimate micronutrients.

3.2 Biochemical properties Lignin and Total Phenols

Lignin and total phenols in green manure plant samples were estimated by using the procedures outlined by Sadasivan and Manickam (1996).

Acid Detergent Fibre (ADF): one gm of the sample was taken in a 250 ml round bottom flask and to that 100 ml of acid detergent solution (cetyl tri methyl ammonium bromide) was added. The contents were heated to boil for 10 minutes and refluxed for one hour after the onset of boiling. Later the content was cooled and filtered through pre-weighed sintered glass crucible by suction and washed with hot water. Then again washed twice with acetone to breakup the lumps. It was dried to 100°C in a hot air oven for 12 hours and weight was taken after cooling in a desicator.

Acid detergent lignin (ADL): The residue from ADF was transferred into 100 ml beaker containing 50ml of 72% sulphuric acid and allowed to stand for 3 hours and boiled for 4 hours after diluting the contents were cooled and filtered through pre-weighed whatman No.1 filter paper. The residue was washed several times with distilled water to get rid of the acid. Filter paper along with residue was dried at 100°C and weight was recorded after cooling in a desicator. The filter paper was transformed along with residue to pre-weighed silica crucible and the contents were ashed in a muffle furnace kept at 555°C for 3 hours. Weight of the crucible was recorded after cooling in a desicator and the ash content was calculated.

Lignin can be calculated by using formula.

Lignin = residue after extraction with 72% H_2SO_4 – ash.

Total Phenols: Sample (0.25g) was ground with 10ml of 80% Ethanol using Pestle and mortar and centrifuged the homogenate at 10,000 rpm for 20 min. The supernatant was collected. The residue was re-extracted with 5 ml of 80% Ethanol, centrifuged and supernatants were pooled. The supernatant was evaporated to dryness. The residue was dissolved in 20ml of distilled water and 1 ml aliquot was pipetted into test tubes. The volume was made up in each tube to 3 ml with water and 0.5 ml of Foli-ciocalleau reagent was added. After 3 min 2 ml of 20% Na_2CO_3 solution was added to each tube. The absorbance at 650 nm was measured after one hour against a reagent blank. From the standard curve the concentration of Phenols were calculated expressed as mg phenols per 100g materials.

Preparation of standard graph: 1000 ppm stock solution was prepared by dissolving 100 mg Catechol in 100 ml of distilled water. From this 10 ppm working standard solution was prepared. Different aliquots (0.2 to 1.0 ml) were pipetted into test tubes. The value was made upto 3 ml with water. All regents were added as given in the above procedure and absorbance at 650 nm was measured.

3.3 Preparation of Soil sample

The soil used in this experiment represents 0-15 cm depth collected from G.K.V.K Farm Unit, U.A.S, Bangalore. Air dried soil passed through 2 mm sieve was used in the experiment.

3.4 Treatments imposed for decomposition study

Incubation of soil samples with green manures was carried out in a porcelain dish. The details of treatments imposed are given below.

T_1 Control 50% Field Capacity

T_2 Control 100% Field Capacity

T_3 Sun hemp to supply 25kg N/ha at 50% field capacity

T_4 Sunhemp to supply 50kg N/ha at 50% field capacity

T_5 Sunhemp to supply 25kg N/ha at 100% field capacity

T_6 Sunhemp to supply 50kg N/ha at 100% field capacity

T_7 Eupatorium to supply 25kg N/ha at 50% field capacity

T_8 Eupatorium to supply 50kg N/ha at 50% field capacity

T_9 Eupatorium to supply 25kg N/ha at 100% field capacity

T_{10} Eupatorium to supply 50kg N/ha at 100% field capacity

T_{11} Glyricidia to supply 25kg N/ha at 50% field capacity

T_{12} Glyricidia to supply 50kg N/ha at 50% field capacity

T_{13} Glyricidia to supply 25kg N/ha at 100% field capacity

T_{14} Glyricidia to supply 50kg N/ha at 100% field capacity

Incubation of soil samples with 3 species of green manures that is glyricidia, eupatorium and sun hemp was carried out in a Porcelain dish. 450 g of soil was taken in each dish. The green manure samples were added at the rate of 25kg N/ha and 50kg N/ha. On fresh weight basis a control was maintained through out the experimental period. The water level was maintained at 50% and 100% of field capacity through out the period. The treatments were replicated thrice. The soil samples in duplicate were collected at different intervals that are 5, 10, 15, 20, 40, 60, 80, 100 days of incubation for analysis of total nitrogen, ammonical nitrogen, nitrate nitrogen, available phosphorus, available potassium, organic carbon, CO_2 evolution and microbial biomass.

3.5 Studies on nutrient release during incubation

The incubated green manure samples were analysed for the following parameters at periodic intervals.

3.5.1 Total nitrogen

Total nitrogen was estimated by micro-kjeldahl method described by Black (1965).

3.5.2 Determination of NH_4 nitrogen (NH_4-N)

Ammonical nitrogen in soil was extracted with 2 N potassium chloride and estimated colorimetrically by Nessler reagent using spectrophotometer at 420 nm (Jackson1973)

3.5.3 Determination of nitrate nitrogen (NO_3-N)

NO_3-N was determined colorimetrically on suitable aliquots taken from $CuSO_4$ extract of soil by employing phenol disulphonic acid. The intensity of yellow colour was read at 420 nm using spectrophotometer (Black, 1965).

3.5.4 Organic Carbon

Finely ground (0.2mm) sieved soil was used for estimation of organic carbon by wet oxidation using potassium dichromate and sulphuric acid for oxidation of organic matter (Walkley and Black 1934).

3.5.5 Available phosphorous and potassium

Available phosphorous in soil was extracted with Olsen's / Bray's solution and P in the extractant was estimated by chlorostannous reduced molybdo-phosphoric acid blue colour method (Jackson, 1973).

Available potassium in the soil was extracted using neutral normal ammonium acetate solution and potassium in the extract was measured by using Flame Photometry (Jackson, 1973).

3.6 Determination of rate of carbon-dioxide evolution as a measure of rate of decomposition of green manures

450g of soil was taken in wide mouthed glass bottles. The green manure samples were added at the rate of 25Kg N/ha and 50Kg N/ha on fresh weight basis. Control was maintained without any green manure. The treatments were replicated twice after thorough mixing of green manures with soil and they were maintained at 50% and 100% field capacity moisture conditions.

Ten ml of 0.5N NaOH was taken into 50ml test tube and the test tube was suspended inside the bottle with the help of a thread. The mouth of the bottle was closed tightly to make it airtight using rubber cork and wax.

At periodic intervals the CO_2 trapped in the alkali was determined by titrating the excess alkali against 0.5N HCl using 5 ml saturated barium chloride solution to prevent the interference of sodium carbonate. The amount of carbon dioxide produced during decomposition was calculated as outlined by Wilde *et al.* (1972) and results were expressed as mg of CO_2 /100g soil.

3.7 Soil microbial biomass carbon

The soil samples, which were incubated for different intervals, were used for soil microbial biomass carbon.

Microbial biomass was estimated following fumigation extraction method as prepared by Carter (1991). Ninhydrin reactive nitrogen released during the fumigation of soil was determined by using ninhydrin reagent and was used as a measure of microbial biomass.

Each soil sample was divided into two sets and one set of a moist soil sample (10g of soil on oven dry basis) was fumigated with ethanol free chloroform for five days in screw capped bottles. Then the caps were removed and kept in an oven at 400°C for over night to remove all the chloroform and was extracted with 2 N KCl by placing the bottles on a reciprocal shaker for 30 min. The suspension was filtered using whatman No 42 filter paper. In a similar manner unfumigated set of the soil sample was extracted.

To a known aliquot of soil extract, 4 ml of freshly prepared *Ninhydrin* reagent was added and the mixture was boiled in the water bath for 20 min. The contents were allowed to cool and the volume was made up to 10ml using 1:1 mixture of *Methoxy* ethanol and distilled water. The intensity of purple colour was read at 570 nm wave length. A standard cure was developed using 5 different concentration of L -leucine N (3.5 to 16.8 μg N ml^{-1}) dissolved in 2M KCl absorbance values were compared with a standard curve and the microbial biomass C was calculated using the following formulae.

$$\text{Biomass C}(\mu g\ /100g\ \text{of soil}) = \frac{\text{Ninhydrin reactive in fumigated soil} - \text{Ninhydrin reactive in un fumigated soil}}{\text{Weight of the soil sample}}$$

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of different laboratory experiments conducted to know the characterization and decomposition of selected green manure plants in the soil are presented in this chapter.

4.1 Intial Physico-chemical properties of the soil

The surface soil samples (0-15 cm depth) were collected from Agronomy farm unit, UAS, GKVK, Bangalore. The soil belongs to the textural class sandy clay loam (Table 1) having the pH 6.73, EC (dSm^{-1}) 0.38, OC 0.30 per cent, available N (kg ha^{-1}) 166.16, available P_2O_5 (kg ha^{-1}) 26.00, available K_2O (kg ha^{-1}) 144, exchangeable calcium (c mol (P^+) kg^{-1}) 2.50, exchangeable magnesium (c mol (P^+) kg^{-1}) 0.98, available S (ppm) 8.50, DTPA extractable Zn (ppm) 0.90, Cu 1.30 ppm, Fe 8.43 ppm and Mn 8.22 ppm (Table 1)

4.2 Chemical composition of selected green manure plants

Data on chemical composition of green manures used in the experiment are presented in Table 2. Studies on chemical composition indicated that highest nitrogen content was noticed in glyricidia (3.10%) followed by sunhemp (3.00%), dhaincha (2.85%), horsegram (2.80%), neem (2.60%) lantana (2.50%), cow pea (2.45%) cassia sp (2.40%), pongamia (2.33%), parthenium (2.30%), eupatorium (2.25%) and least was noticed in water hyacinth (2.00%). Phosphorus content was higher in dhaincha (0.28%) and lowest was noticed in parthenium (0.13%). Potassium content of green leaf manures, ranged from 1.26 to

Table 1. Initial physicochemical properties of the soil

a. Physical properties of the soil

Sand (%)	61.96
Silt (%)	8.69
Clay (%)	29.35
Textural class	Sandy clay loam
Soil type	Typic kandiustalfs
Moisture at field capacity	12 per cent

b. Chemical properties of the soil

PH	6.73
EC (dSm^{-1})	0.38
Organic carbon (%)	0.30
Available N (kg ha^{-1})	166.16
Available P_2O_5 (kg ha^{-1})	26.00
Available K_2O (kg ha^{-1})	144.00
Available S (ppm)	8.50
Exch. Ca (Cmol (P+) kg^{-1})	2.50
Exch Mg (Coml (P+) kg^{-1})	0.98
DTPA extractable Zn (ppm)	0.90
DTPA extractable Cu (ppm)	1.30
DTPA extractable Fe (ppm)	8.43
DTPA extractable Mn (ppm)	8.22

Table 2. Nutrient composition of different green manure plants (on oven dry basis)

Sl. No.	Green manure crops: Common name	Green manure crops: Scientific name	Total N	Total P	Total K	S	Ca	Mg	Fe	Mn	Zn
			Per cent						ppm		
1	Glyricidia	*Glyricidia maculata*	3.10	0.20	2.05	0.057	1.86	1.00	466	103	21
2	Pongamia	*Derris indica*	2.33	0.24	1.75	0.065	1.42	0.76	491	110	20
3	Lantana	*Lantana camara*	2.50	0.24	2.00	0.038	1.40	0.37	408	70	32
4	Neem	*Azardiarchta indica*	2.60	0.17	1.90	0.036	1.40	0.80	316	210	12
5	Sunhemp	*Crotalaria juncea*	3.00	0.22	1.52	0.080	1.40	0.73	250	256	38
6	Dhaincha	*Sesbania acculeta*	2.85	0.28	1.80	0.074	1.60	0.86	735	146	41
7	Cowpea	*Vigna unguinculata*	2.45	0.17	1.96	0.074	1.56	0.62	550	260	36
8	Horse gram	*Phaseolus bicolar*	2.80	0.25	1.45	0.064	1.76	0.70	304	156	39
9	Eupatorium	*Chromolaena odorata*	2.25	0.15	1.90	0.054	1.50	0.80	290	180	29
10	Parthenium	*Parthenium hysterophorus*	2.30	0.13	1.40	0.073	1.40	0.70	490	173	24
11	Water hyacinth	*Eichorinia crassipes*	2.00	0.20	1.26	0.040	1.25	0.30	425	80	25
12	Cassia sp.	*Cassia uniflora*	2.40	0.21	1.70	0.063	1.31	0.76	316	83	28
	SEm ±		0.66	0.05	0.57	0.007	0.57	0.10	10.82	3.16	3.34
	CD		NS	NS	NS	0.020*	NS	0.29*	31.60*	9.23*	9.77*
	CV (%)		4.58	4.95	4.93	2.04	6.71	4.56	4.46	3.59	4.12

Table 3. Composition of organic constituents in green manure plants (on oven dry basis)

Sl. No.	Green manure crops		Organic carbon (%)	C:N ratio	Crude protein	Lignin	Phenols
	Common name	Scientific name			Per cent		
1	Glyricidia	*Glyricidia maculata*	38.20	12.3	19.49	21.00	1.60
2	Pongamia	*Derris indica*	40.20	17.20	14.65	25.00	1.62
3	Lantana	*Lantana camara*	49.00	19.60	15.72	27.00	2.06
4	Neem	*Azardiarchta indica*	55.52	21.30	16.35	18.60	2.00
5	Sunhemp	*Crotalaria juncea*	43.00	14.30	18.87	22.86	1.78
6	Dhaincha	*Sesbania acculeta*	46.50	16.30	17.92	23.30	1.55
7	Cowpea	*Vigna unguinculata*	33.00	13.40	15.41	23.00	2.20
8	Horse gram	*Phaseolous bicolar*	45.50	16.20	17.61	18.40	1.85
9	Eupatorium	*Chromolaena odorata*	40.20	17.80	14.15	23.00	2.44
10	Parthenium	*Parthenium hysterophorus*	48.50	21.00	14.46	24.00	1.98
11	Water hyacinth	*Eichornia crassipes*	35.00	17.50	12.58	16.00	1.34
12	Cassia sp.	*Cassia uniflora*	50.00	20.80	15.09	20.30	1.28
	SEm ±		2.19	1.37	1.04*	3.35*	0.10
	CD		NS	Ns	3.03*	NS	0.31*
	CV (%)		8.71	3.75	11.24	6.24	10.34

2.05 per cent, lowest was in case of water hyacinth (1.26%) and highest in glyricidia (2.05%).

Maximum sulphur content was noticed in Sunhemp (0.08%) and lowest in *Cassia Uniflora* (0.063%). Substantial quantintes of secondary nutrients (Ca^{2+} and Mg^{2+}) was noticed in glyricidia (1.86 and 1.00 per cent) and lowest in case of water hyacinth (1.25 and 0.30 per cent).

Iron content of the green manures ranged from 250 to 735 ppm. The lowest was in case of sunhemp (250 ppm) and highest was noticed in case of dhiancha (735 ppm). Manganese content ranged from 70 to 260 ppm highest was noticed in case cow pea (260 ppm) and least was noticed in lantana (70 ppm). Zinc content was highest in case of sun hemp (41 ppm) and least was noticed in case neem (12 ppm) wider in neem (21.35) and C: N ratio among the green leaf.

The C:N ratio was narrow in case of glyricidia (12.32) and manure crops studied showed non significant difference (Table 3). Crude protein was highest in case of glyricidia (19.49%) and least was noticed in water hyacinth (12.58%). Lignin content was maximum incase of water hyacinth (24.00%) and least was in case of cassia sp. (16.00%) (Table.3). The phenol content was highest in case of eupatorium (2.44%)and least in case of cassia (1.28%)

4.3 Mineralization studies

4.3.1 Changes in ammonical nitrogen

The changes in ammonical nitrogen during decomposition of green manures are presented in Table 4 and Fig. 1. The results indicates that release of ammonical-N increased upto 15 days and then decreased. After 15 days the release of ammonical N steadily decreased upto 100 days of incubation. Further there was significant variation in the release pattern of ammonia among the treatments and also period of incubation.

The maximum ammonical nitrogen released on the 15th day was highest in T_{14} treatment ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (85.40 ppm) followed by T_6 treatment ie., sun hemp to supply 50 kg N/ha at 100 per cent field capacity (84.50 ppm) and lowest was in T_7 treatment ie., glyricida to supply 25 kg N/ha at 50 per cent field capacity (58.50 ppm). The mean ammonical-N released was highest in T_{14} treatment ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (55.45 ppm) and least was in T_7 treatment ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (37.83 ppm).

In case of time of incubation the highest release of ammonical nitrogen was on 15th day (66.46 ppm) and least was in (24.51 ppm) on 100th day of incubation. In case of different doses of green manure to supply nitrogen application of 50 kg N/ha increased the ammonical nitrogen in all the sources of green manures compare to 25 kgN/ha. The highest ammonical nitrogen was observed at 100 per cent field capacity in all the

Table 4 . Changes in ammonical nitrogen during decomposition of green manures at different soil moisture regimes

Treatments	Ammonical-N (ppm)								
	Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	37.76	35.80	19.50	19.50	12.00	10.50	10.00	10.00	19.38
T_2 Control 100% field capacity	39.20	42.50	45.80	35.60	30.00	25.00	20.00	15.50	31.70
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	37.50	48.50	75.30	43.40	35.50	30.50	20.80	20.00	38.06
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	47.60	50.60	76.00	66.60	43.60	33.30	21.50	20.50	44.81
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	56.40	65.50	83.40	66.60	50.60	35.90	25.30	21.50	51.27
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	60.60	70.77	84.50	70.00	63.50	38.00	28.50	25.00	55.22
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	37.70	47.50	59.06	48.90	36.00	28.50	24.50	20.50	37.83
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	49.65	62.40	68.70	61.50	40.00	35.00	30.50	25.60	46.66
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	43.80	56.10	68.70	58.90	38.40	33.50	31.50	30.10	45.12
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	56.66	66.66	76.50	68.90	36.00	35.80	35.20	31.50	50.90
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	40.36	42.21	58.50	48.60	38.00	35.00	30.80	28.30	40.22
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	40.70	55.20	65.04	55.80	50.56	43.60	36.40	29.50	47.10
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	46.20	54.43	65.04	58.60	45.50	40.60	38.20	30.20	47.34
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	47.40	63.40	85.40	72.00	54.80	45.80	40.00	35.00	55.45
Period effect	45.82	54.04	66.46	55.35	41.03	33.42	25.58	24.51	

Test of significance		
	SEm ±	CD at 5%
Treatments	0.756	2.09*
Days	9.57	1.58*
Days x Treatments	2.13	5.92*
CV (%)	-	8.42

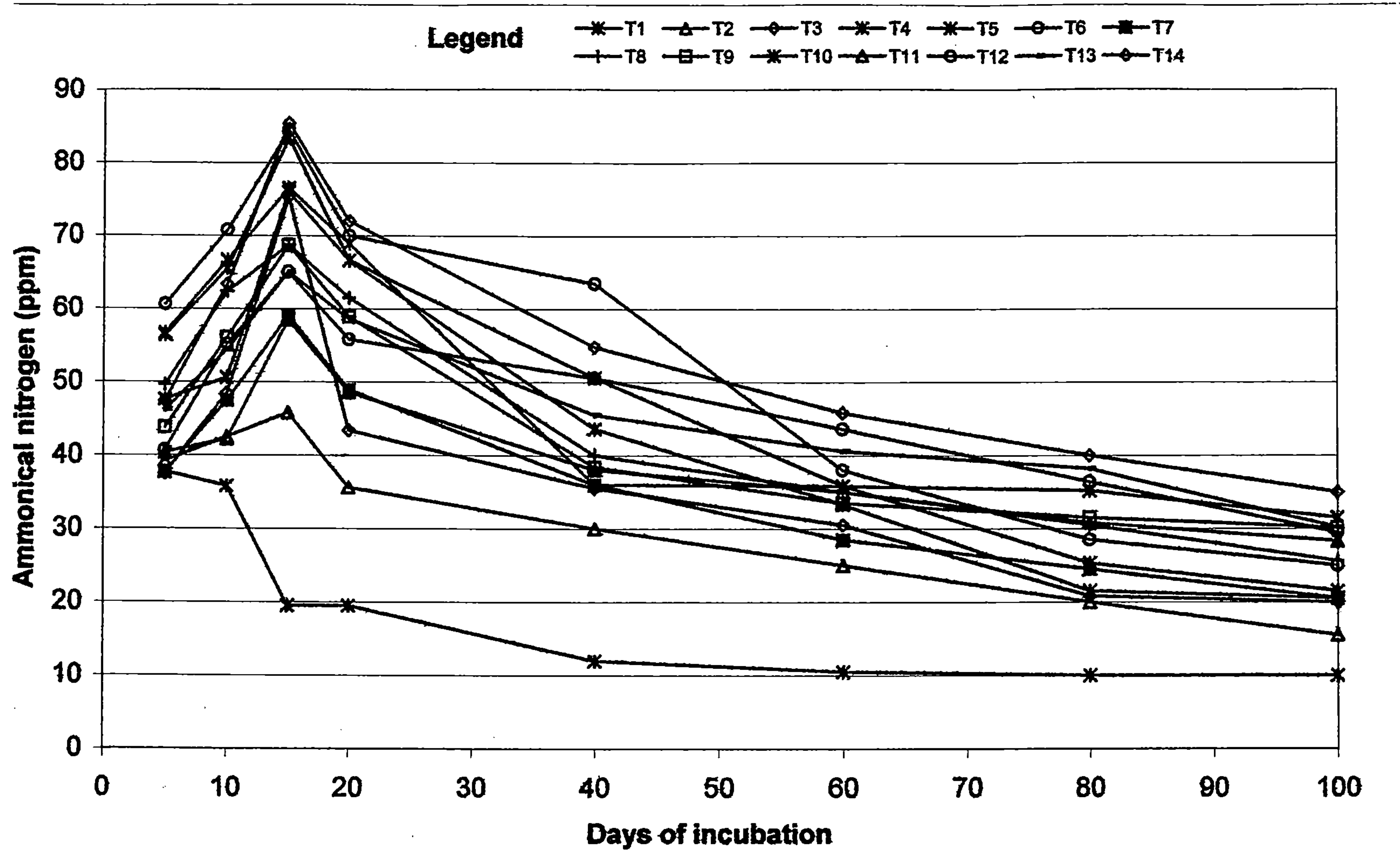

Fig. 1 Changes in ammonical nitrogen during decomposition of green manures at different soil moisture regimes

treatments. Interaction between the treatments and incubation period also showed the significant difference in the release of ammonical nitrogen.

4.4 Nitrate nitrogen

Changes in nitrate nitrogen due to incorporation of different organic amendments are presented in Table 5 and Fig. 2. The results indicated that, in general there was concomitant increase in NO_3-N upto 100 days of incubation.

The maximum nitrate nitrogen was recorded on 100th day of incubation in T_{12} treatment ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (130.00 ppm) followed by T_{14} ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (125.00 ppm) and least was recorded in T_3 treatment ie., sunhemp to supply 25 kg N/ha at 50 per cent field capacity (70.00 ppm). The mean NO_3-N accumulation during the incubation study was highest in T_{12} ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (72.12 ppm) and least was in T_3 ie., sunhemp to supply 25 kg N/ha at 100 per cent field capacity (47.64 ppm). In case of period of incubation highest NO_3-N accumulation was on 100th day (94.50 ppm) and least was (27.80 ppm) on 5th day of incubation.

Among the different sources of green manures glyricidia recorded the maximum NO_3-N accumulation at 50 per cent field capacity. Application of 50 kg N/ha recorded the highest NO_3-N accumulation. The highest NO_3-N accumulation was observed at 50 per cent field capacity in all the treatments when compared to 100 per cent field capacity. Further interaction between the

Table 5 . Changes in nitrate-N during decomposition of green manures at different soil moisture regimes

Treatments	Nitrate-N (ppm) Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	25.60	28.50	35.50	40.50	50.50	55.50	27.00	15.00	34.76
T_2 Control 100% field capacity	20.50	22.00	30.50	20.50	28.50	38.00	40.50	60.00	32.56
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	26.40	30.53	35.40	46.50	50.93	55.60	65.80	70.00	47.64
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	35.40	38.65	40.65	49.50	68.60	82.80	80.83	100.00	62.05
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	20.50	25.50	30.50	38.90	45.90	55.60	70.60	95.60	47.88
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	28.60	30.30	35.50	40.50	50.50	68.13	95.60	120.00	58.64
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	27.70	37.70	45.70	50.60	70.80	75.80	60.80	85.50	56.82
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	23.80	39.65	48.65	55.80	75.80	80.73	78.60	90.50	61.69
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	30.65	25.80	30.80	42.50	45.80	50.80	80.80	100.50	50.95
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	30.60	30.80	35.50	45.50	60.46	65.60	100.20	120.50	61.14
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	28.50	35.00	35.50	48.50	61.50	80.60	80.60	90.50	57.58
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	37.40	41.50	49.50	58.50	78.60	95.60	85.60	130.00	72.12
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	26.26	30.50	40.50	42.50	58.60	70.60	95.60	120.00	60.57
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	27.40	35.50	45.00	55.60	70.50	75.60	120.50	125.00	69.38
Period effect	27.80	30.56	38.51	45.43	57.63	67.92	77.35	94.50	

Test of significance		
	SEm ±	CD at 5%
Treatments	0.8102	2.2453*
Days	0.6124	1.6973*
Days x Treatments	2.2915	6.3507*
CV (%)		7.21

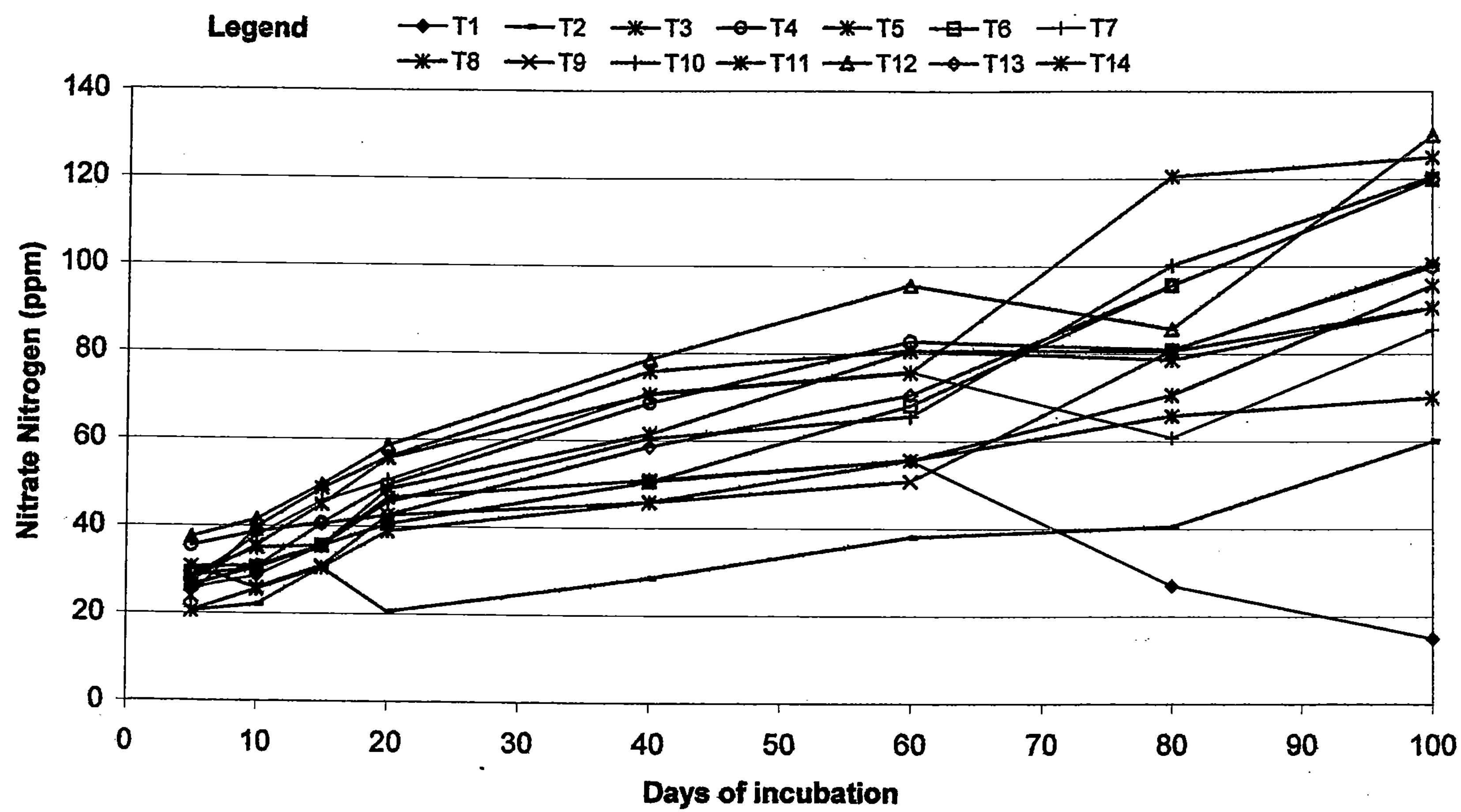

Fig. 2 Changes in nitrate nitrogen during decomposition of green manures at field capacity moisture levels

treatments and incubation period showed significant difference in the accumulation of NO_3-N.

4.5 Changes in total nitrogen

Changes in total nitrogen during decomposition of green manures at different field capacity moisture levels are presented in Table 6 and Fig. 3. In general the total nitrogen content increased as the incubation period increased from 5 to 100 days in all the treatments.

The highest total nitrogen was recorded was on 100th day of incubation in T_{12} treatment i.e., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (0.070 per cent) followed by T_4 treatment ie., sun hemp to supply 50 kg N/ha at 50 per cent field capacity (0.069) and least was in T_9 ie., eupatorium to supply 25 kg N/ha at 100 per cent field capacity (0.055%).

The mean total-N during the incubation was highest in T_{12} ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (0.061%) and least was in T_7 ie., eupatorium to supply 25 kg N/ha at 100 per cent field capacity (0.047%). In case of period of incubation the highest total N was recorded on 100th day (0.060%) and least (0.041%) was on 5th day of incubation.

In case of different rates of green manures application to supply nitrogen at 50 kg N/ha at 50 per cent field capacity recorded the highest total-N accumulation than all the treatments. Interaction between the treatments and incubation period showed non-significance in the total-N content during the decomposition of green manures.

Table 6 . Changes in total nitrogen during decomposition of green manures at different soil moisture regimes

Treatments	Total N (per cent)								
	Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	0.043	0.043	0.044	0.044	0.044	0.044	0.045	0.045	0.044
T_2 Control 100% field capacity	0.035	0.036	0.041	0.041	0.041	0.041	0.042	0.042	0.039
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	0.044	0.049	0.055	0.061	0.062	0.064	0.066	0.067	0.058
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	0.047	0.050	0.061	0.062	0.064	0.065	0.068	0.069	0.060
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	0.039	0.043	0.049	0.055	0.058	0.060	0.061	0.063	0.053
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	0.043	0.050	0.054	0.056	0.060	0.062	0.064	0.066	0.056
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	0.041	0.042	0.047	0.050	0.052	0.055	0.056	0.058	0.050
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	0.047	0.051	0.054	0.056	0.058	0.061	0.062	0.065	0.056
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	0.035	0.041	0.043	0.049	0.051	0.052	0.054	0.055	0.047
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	0.045	0.049	0.053	0.055	0.058	0.060	0.061	0.062	0.055
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	0.043	0.049	0.054	0.060	0.062	0.068	0.065	0.066	0.057
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	0.049	0.051	0.059	0.065	0.066	0.068	0.067	0.070	0.061
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	0.037	0.043	0.050	0.055	0.056	0.064	0.061	0.062	0.053
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	0.042	0.047	0.053	0.056	0.060	0.065	0.065	0.066	0.056
Period effect	0.041	0.046	0.049	0.054	0.056	0.058	0.059	0.060	

Test of significance		
	SEm ±	CD at 5%
Treatments	0.0051	0.0141*
Days	0.0039	0.0107*
Days x Treatments	0.0149	NS
CV (%)	-	10.80

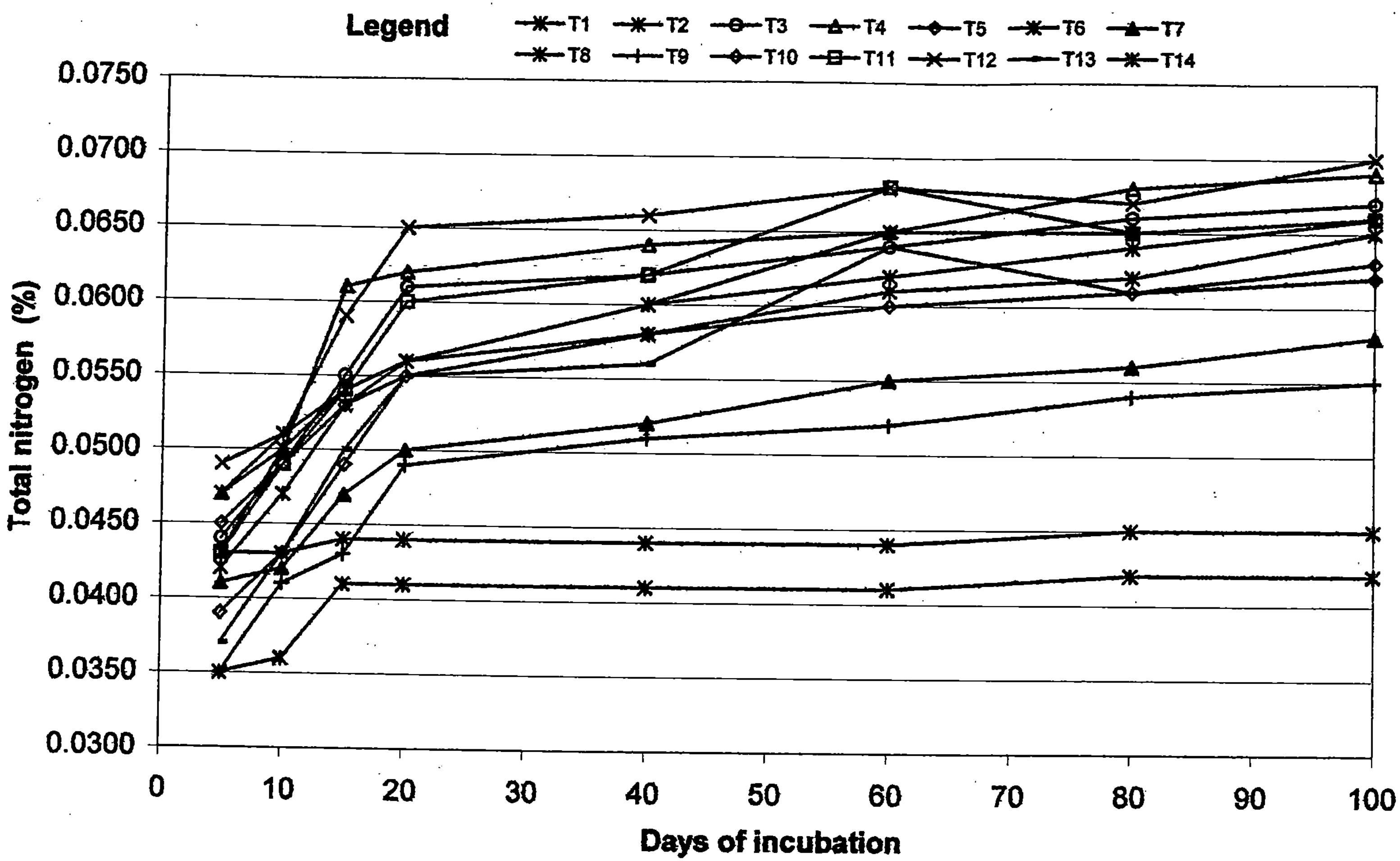

Fig. 3 Changes in total nitrogen during decomposition of green manures at different soil moisture regimes

4.6 Changes in available phosphorus

Changes in available phosphorus during decomposition of green manures at different field capacity moisture are presented in Table 7 and Fig. 4. The results indicated that available P content increased as the period of incubation increased from 0 to 100 days of incubation in all the treatments. Further there was significant variation in the release of available phosphorus among the treatments and also period of incubation.

The maximum available phosphorus was recorded in 100th day of incubation in T_{14} treatment ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (41.80 kg/ha) and followed by T_{13} ie., glyricidia to supply 25 kg N/ha at 100 per cent field capacity (40.20 kg/ha) and least was in T_7 treatment ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (30.50 kg/ha).

The mean available phosphorus content during the incubation study was highest in T_{14} ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (37.84 kg/ha) and least was in T_7 ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (27.44 kg/ha). In case of period of incubation highest available phosphorus was recorded on 100th day (34.43 kg/ha) and least was (25.63 kg/ha) on 0th day of incubation.

Among the different doses of green manures applied to supply nitrogen through glyricidia recorded the highest available P accumulation at 100 per cent field capacity to all treatments. Interaction between the treatments and incubation period showed non-significanct in the release of available phosphorus.

Table 7. Changes in available phosphorus during decomposition of green manures at different soil moisture levels

Treatments	Available phosphorus (kg ha^{-1}) Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	20.20	21.80	25.00	24.50	24.60	23.00	23.00	22.50	23.07
T_2 Control 100% field capacity	21.05	22.00	26.00	26.00	26.50	26.00	26.00	25.00	24.81
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	24.60	25.00	26.50	28.60	32.30	33.00	33.50	33.80	29.66
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	28.00	29.50	32.00	35.00	34.00	34.50	35.00	35.30	32.91
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	25.00	28.60	30.00	35.50	35.00	36.00	36.20	37.00	32.91
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	28.60	30.50	33.00	36.16	36.50	38.50	39.00	39.50	35.22
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	24.61	25.00	25.27	25.81	28.61	29.60	30.13	30.50	27.44
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	25.98	26.60	29.50	31.02	30.86	32.26	33.00	33.20	30.30
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	22.65	24.60	28.81	29.03	30.00	31.03	32.00	32.50	28.82
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	26.20	31.62	33.09	34.72	33.03	34.03	35.00	35.30	32.87
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	26.46	28.60	32.50	35.00	35.50	36.00	36.40	37.00	33.43
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	28.50	30.50	33.00	38.00	36.50	37.50	38.01	38.50	35.06
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	28.80	32.00	35.00	36.40	38.56	39.33	39.50	40.20	36.22
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	28.30	35.00	36.40	38.46	40.40	41.20	41.16	41.80	37.84
Period effect	25.63	27.94	30.43	32.44	33.02	33.70	34.13	34.43	

Test of significance		
	SEm ±	CD at 5%
Treatments	0.75	2.12*
Days	0.57	1.60*
Days x Treatments	2.16	NS
CV (%)		11.9

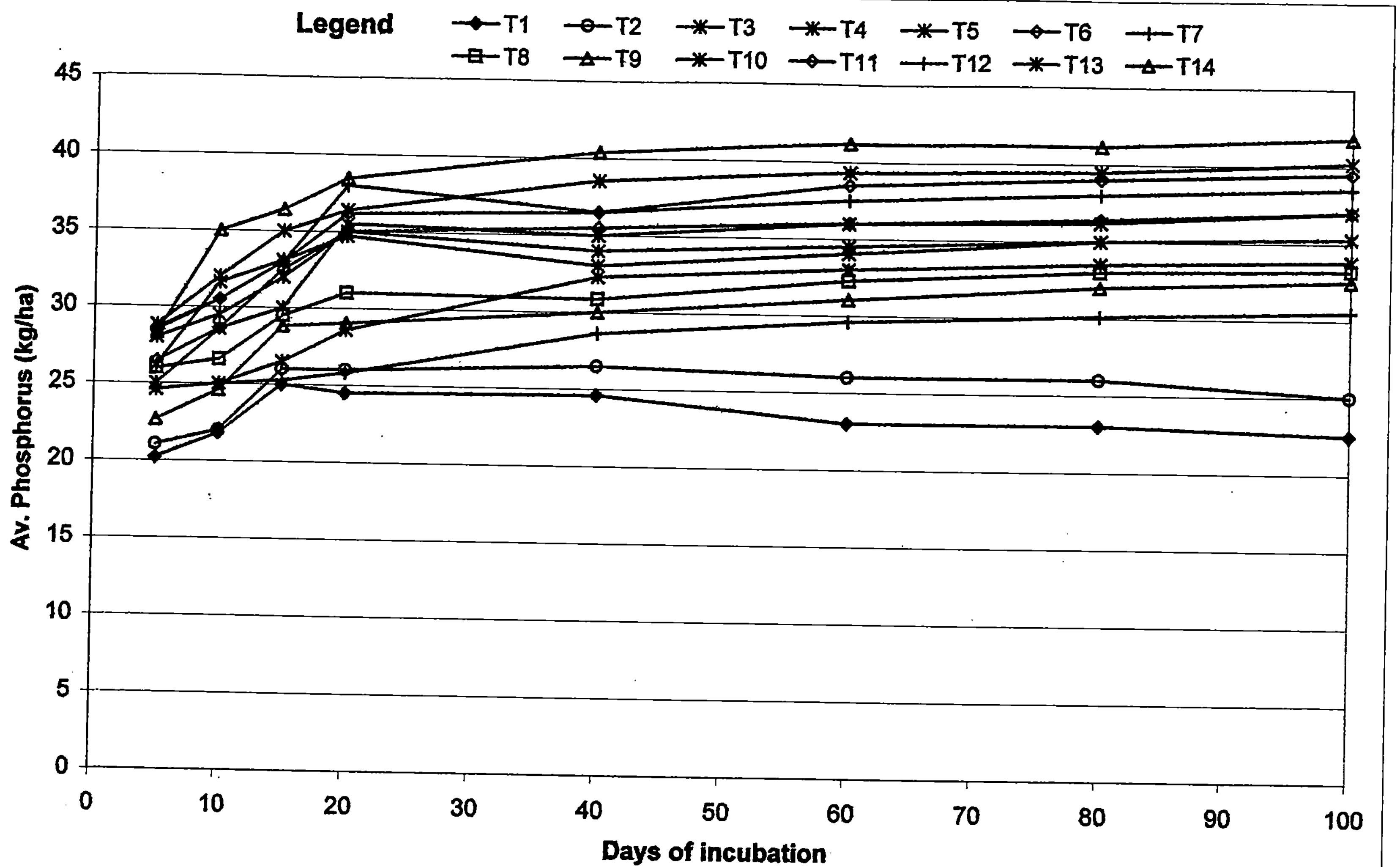

Fig. 4 Changes in available phosphorus during decomposition of green manures at different soil moisture regimes

4.7 Changes in available potassium content

Changes in available potassium during decomposition of green manures at different moisture regimes are presented in Table 8 and Fig 5. In general the available potassium content increased upto 80 days of incubation and further incubation upto 100 days decreased the available potassium content in all the treatments.

The maximum available potassium was recorded on 80th days of incubation in T_{14} treatment ie., glyricidia to supply 50 kg N/ha and 100 per cent field capacity (325.00 kg/ha) followed by T_{12} ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (300 kg/ha) and least was in T_9 ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (220 kg/ha). The mean available potassium content was highest in T_{14} ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (278.25 kg/ha) and least was in T_7 ie., eupatorium to supply 25 kg N/ha and 50% field capacity (203.16 kg/ha) during the incubation study. In case of period of incubation highest available K was recorded on 80th day (264.62 kg/ha) and least was recorded in 0th day (174.20 kg/ha).

Among the different doses of green manure applied to supply nitrogen 50 kg N/ha at 100 per cent field capacity showed the highest potassium release during the decomposition period. Interaction between the treatments and incubation period showed a non-significance difference in the release of available potassium content in the soil.

Table 8 . Release of available potassium during decomposition of green manure at different soil moisture regimes

Treatments	Av. Potassium (kg ha^{-1}) Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	126.70	126.70	128.62	130.00	130.00	130.12	130.00	130.00	129.01
T_2 Control 100% field capacity	134.64	135.60	136.00	139.00	140.00	140.00	140.00	140.00	138.15
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	134.21	130.48	158.40	172.56	192.00	198.33	205.80	202.80	974.32
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	142.50	150.86	168.40	198.56	220.00	230.00	235.50	232.00	197.22
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	141.66	142.50	158.40	198.00	200.00	230.00	240.56	238.40	193.69
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	142.56	150.48	178.00	208.00	227.60	237.00	256.56	242.60	205.35
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	130.00	136.00	140.80	155.00	165.00	185.00	192.00	195.00	162.35
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	134.00	164.00	185.80	190.00	195.00	200.00	210.00	208.00	185.85
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	150.40	174.00	198.00	200.00	217.00	237.00	242.50	242.66	207.61
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	160.40	178.00	204.50	220.00	245.00	250.00	255.00	252.66	220.69
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	173.79	158.00	178.00	205.60	225.44	230.00	238.00	236.00	205.60
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	150.48	178.00	198.00	220.60	252.44	256.34	260.00	258.00	221.74
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	158.40	168.85	178.24	210.00	227.00	240.00	252.20	250.66	210.66
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	160.54	174.09	199.60	237.00	268.60	270.00	273.50	271.33	231.83
Period effect	145.73	154.83	172.06	191.73	207.50	216.69	223.65	221.38	

Test of significance		
	SEm ±	CD at 5%
Treatments	1.44	3.99*
Days	1.09	3.02*
Days x Treatments	4.08	11.30*
CV (%)	-	3.68

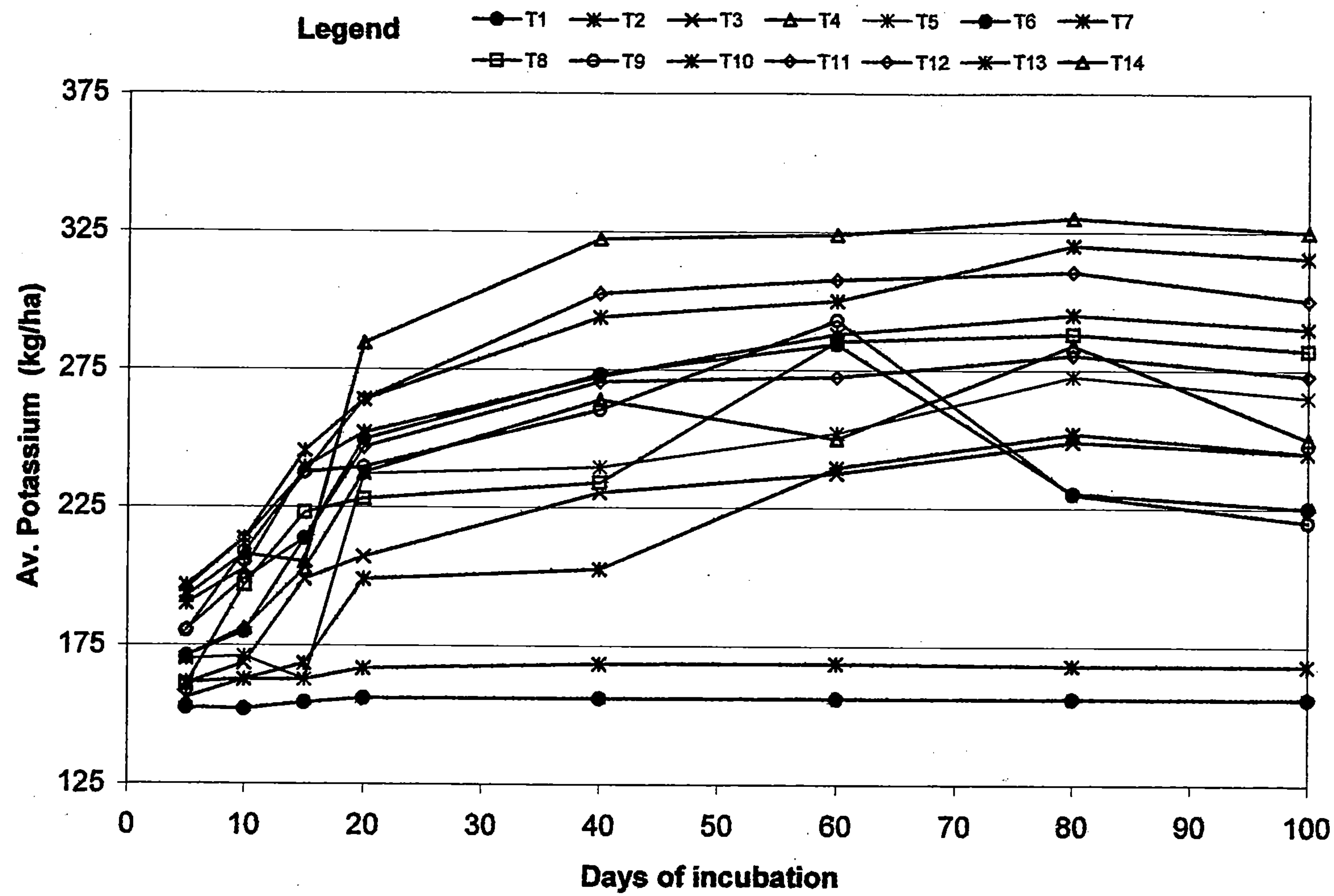

Fig.5 Release of available potassium during decomposition of green manures at different soil moisture regimes

4.8 Changes in organic carbon

Changes in organic carbon content in soil during decomposition of green manures at different moisture regimes are presented in Table 9 and Fig. 6. The results indicated that the organic carbon content decreased as the period of incubation increased from 5 to 100 days. Further there was significant difference in the variation of organic carbon among the treatments and also during the period of incubation.

The highest organic carbon content in the soil was recorded during incubation in T_{10} treatment ie., eupatorium to supply 50 kg N/ha at 100 per cent field capacity (0.56%) followed by T_{14} ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (0.50%) and least was in T_{11} ie., glyricidia to supply 25 kg N/ha at 50 per cent field capacity (0.42%).

The mean organic carbon content was highest in T_{10} treatment ie., eupatorium to supply 50 kg N/ha at 100 per cent field capacity (0.45%) and least was in case T_{11} treatment glyricidia to supply 25 kg N/ha at 50 per cent field capacity (0.34%). In case of period of incubation highest organic carbon was recorded on 5th day (0.44%) and least was (0.30%) on 100th day of incubation.

Among different doses of green manures applied to supply nitrogen 50 kg N/ha at 100 per cent field capacity noticed highest organic carbon compared to all other treatments. Interaction between the days and treatments showed non-significant difference in the release of organic carbon during the incubation study.

Table 9 . Changes in organic carbon status in the soil during decomposition of green manures at different moisture regimes

Treatments	Organic carbon (%)								
	Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	0.25	0.23	0.22	0.22	0.20	0.20	0.20	0.20	0.21
T_2 Control 100% field capacity	0.28	0.26	0.23	0.23	0.22	0.21	0.21	0.21	0.23
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	0.43	0.42	0.40	0.38	0.35	0.33	0.32	0.30	0.36
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	0.49	0.47	0.45	0.43	0.40	0.36	0.34	0.32	0.40
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	0.47	0.45	0.42	0.40	0.38	0.35	0.33	0.32	0.39
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	0.50	0.48	0.46	0.44	0.41	0.38	0.35	0.33	0.42
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	0.45	0.43	0.40	0.37	0.35	0.34	0.32	0.30	0.37
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	0.46	0.44	0.42	0.40	0.37	0.35	0.33	0.32	0.38
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	0.55	0.50	0.48	0.45	0.41	0.39	0.36	0.34	0.43
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	0.56	0.53	0.49	0.48	0.45	0.42	0.40	0.35	0.45
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	0.42	0.40	0.38	0.35	0.33	0.30	0.28	0.27	0.34
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	0.45	0.42	0.40	0.38	0.36	0.34	0.33	0.32	0.37
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	0.45	0.42	0.40	0.38	0.36	0.33	0.32	0.30	0.37
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	0.50	0.48	0.45	0.42	0.41	0.38	0.35	0.33	0.41
Period effect	0.44	0.42	0.40	0.38	0.35	0.33	0.31	0.30	

Test of significance		
	SEm ±	CD at 5%
Treatments	0.0190	0.0527*
Days	0.0144	0.0398*
Days x Treatments	0.0538	NS
CV (%)	-	10.5214

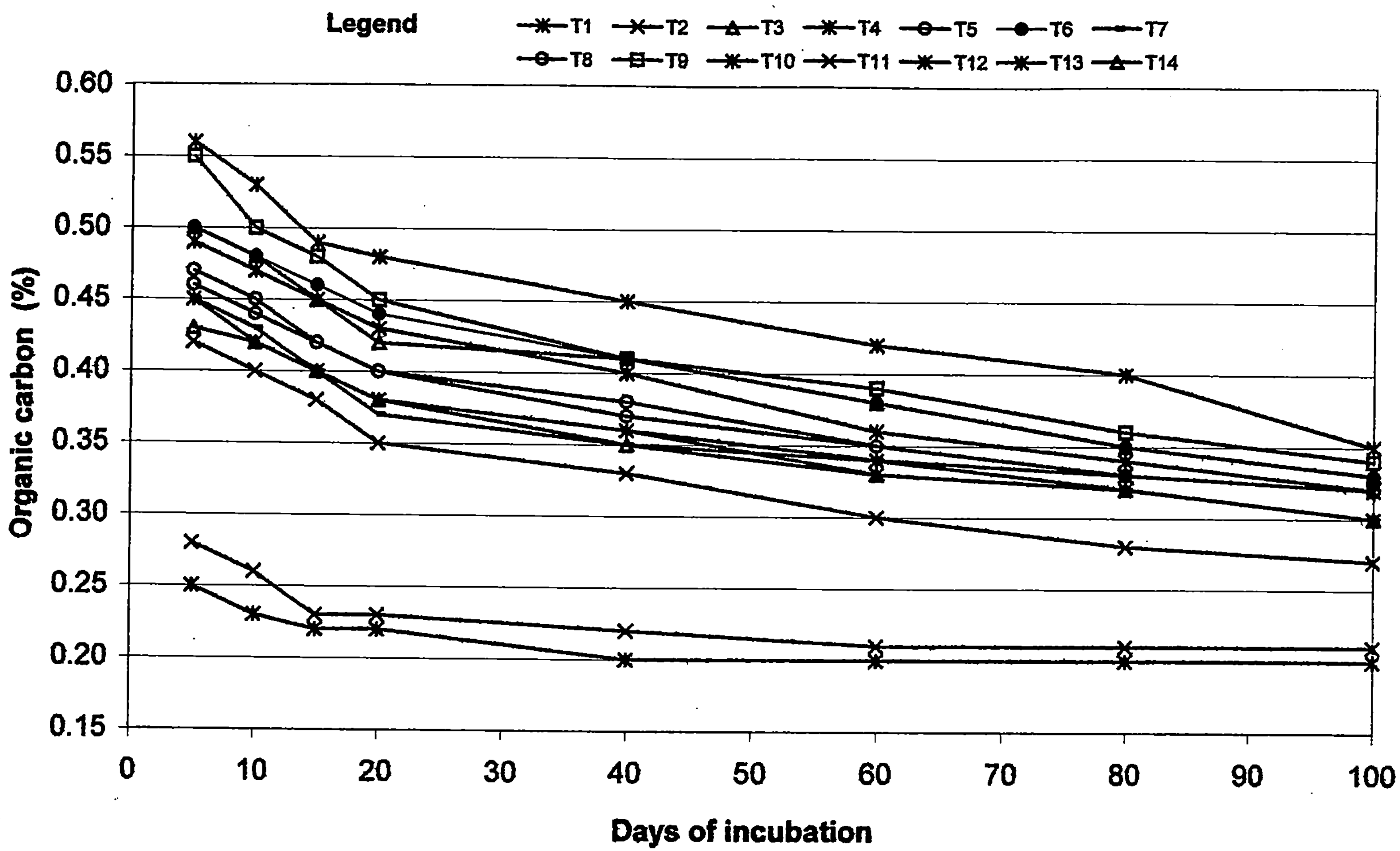

Fig. 6 Changes in organic carbon status in the soil during decomposition of green manures at different moisture regimes

4.9 Evolution of carbon dioxide

Evolution of carbon dioxide during decomposition of green manures are presented in Table 10 and Fig. 7. The results indicated that evolution of carbon dioxide increased up to 40 days of incubation then slowly decreased upto 100 days of incubation. Further there was significant variation in the evolution of carbon dioxide among the treatments and also among period of incubation.

The maximum carbon dioxide evolved on 40th day was in T_{12} treatment ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (24.65 mg 100^{-1}g soil) and followed by T_{14} ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (24.00 mg 100^{-1} g soil) and least was in T_5 ie., sun hemp to supply 25 kg N/ha at 100 per cent field capacity (18.20 mg 100^{-1} g soil). The mean carbon dioxide evolution was highest in T_{12} treatment ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (22.79 mg 100^{-1} g soil) and least was recorded in treatment T_7 ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (17.91 mg 100^{-1} g soil). In case of time of incubation the highest carbon dioxide evolution was on 40th day (20.72 mg 100^{-1}g soil) and least was in 5th day (17.85 mg 100^{-1}g soil).

In case of application of different doses of green manures applied to supply nitrogen 50 kg N/ha at 50 per cent field capacity recorded the highest carbon dioxide evolution in all the treatments. Further interaction between the treatments and period of incubation showed non-significant.

Table 10 . Evolution of carbon dioxide during decomposition of green manures at different soil moisture regimes

Treatments	CO_2 mg/100g of soil Incubation period (days)								
	5	10	15	20	40	60	80	100	Treatment effect
T_1 Control 50% field capacity	9.00	10.44	12.64	14.00	13.64	13.00	12.50	11.50	12.09
T_2 Control 100% field capacity	7.80	8.30	9.24	12.60	10.24	10.12	10.00	9.50	9.72
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	21.64	21.94	22.50	22.94	23.84	23.04	21.20	20.05	22.14
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	22.00	22.64	22.70	23.00	23.85	23.00	21.00	20.33	22.31
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	17.92	18.00	18.50	18.72	20.80	18.00	17.30	17.00	18.28
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	19.00	19.64	20.00	20.22	20.44	20.20	19.50	19.20	19.77
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	16.00	18.64	18.85	22.00	22.72	22.12	22.10	22.00	20.55
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	19.62	20.57	22.00	23.45	22.45	22.04	22.00	21.80	21.74
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	19.65	16.94	17.20	18.64	18.20	18.00	17.50	17.20	17.91
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	18.64	19.85	20.00	21.64	21.50	20.50	20.00	19.50	20.21
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	20.12	21.00	22.00	23.65	23.70	22.50	22.00	21.00	21.87
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	21.00	21.93	22.50	23.65	24.65	24.50	22.14	22.00	22.79
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	18.64	19.00	19.50	21.00	20.18	19.50	19.00	18.50	19.47
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	19.00	19.25	19.64	22.50	24.00	22.50	21.12	20.12	21.01
Period effect	17.85	18.39	19.05	20.50	20.72	19.93	19.07	18.54	

Test of significance		
	SEm ±	CD at 5%
Treatments	0.501	1.38
Days	0.37	1.05
Days x Treatments	1.41	NS
CV (%)	-	12.62

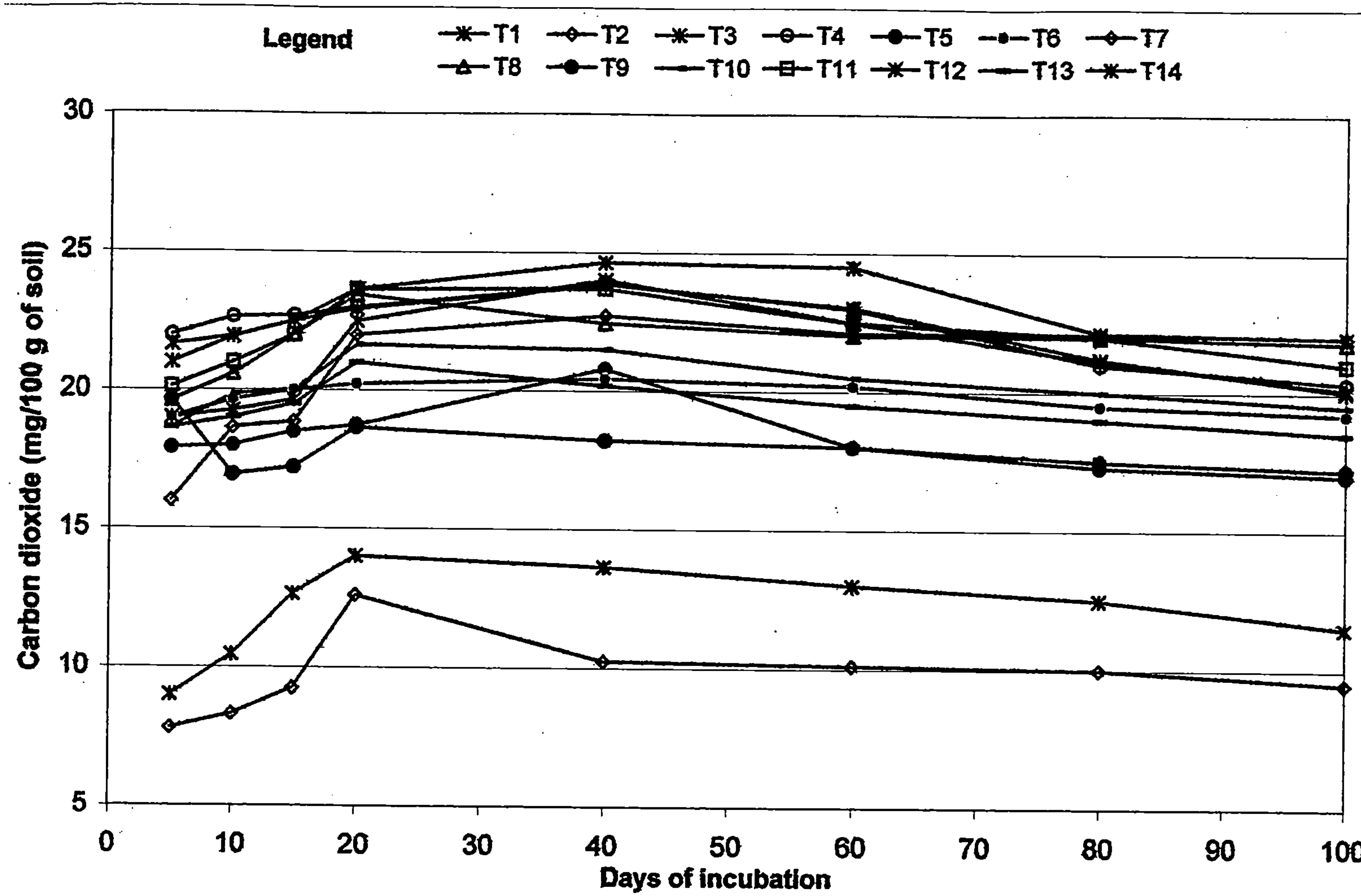

Fig. 7 Evolution of carbon dioxide during decomposition of green manures at different soil moisture regimes

4.10 Microbial biomass carbon

Changes in soil microbial biomass carbon as influenced by different green manures at different periods of incubation was presented in Table 11 and fig 8. The data indicated that the microbial biomass carbon was higher on 30th day in T_{14} treatment ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (675.40 µg g^{-1} soil) followed by T_{13} ie., glyricidia to supply 50 kg N/ha at 50 per cent field capacity (666.41 µg g^{-1} soil) and least was recorded in T_7 treatment ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (321.70 µg g^{-1} soil). Further there was significant difference in the microbial biomass carbon among the treatments and also period of incubation.

The mean microbial biomass carbon released was highest in T_{14} treatment ie., glyricidia to supply 50 kg N/ha at 100 per cent field capacity (515.34 µg g^{-1} soil) and least was in T_7 ie., eupatorium to supply 25 kg N/ha at 50 per cent field capacity (218.88 µg g^{-1} of soil).

In case of period of incubation the highest microbial biomass carbon was recorded on 30th day (416.66 µg g^{-1} soil) and least was in 10th day (254.91 µg g^{-1} soil).

In case of different sources doses to supply nitrogen 50 kg N/ha at 100 per cent field capacity recorded the highest microbial biomass carbon in all the sources. Further interaction between the days and treatments differed significantly.

Table 11 . Microbial biomass carbon (μg/g) in soil amended with green manures at different moisture regimes

Treatments	Biomass carbon (μg/g of soil)			
	10	30	50	Treatment effect
T_1 Control 50% field capacity	156.74	140.5	130.20	140.48
T_2 Control 100% field capacity	332.47	307.11	288.21	309.26
T_3 Sunhemp to supply 25kg N ha^{-1} at 50% field capacity	126.91	451.36	225.25	268.00
T_4 Sunhemp to supply 50kg N ha^{-1} at 50% field capacity	127.79	457.86	250.50	278.71
T_5 Sunhemp to supply 25kg N ha^{-1} at 100% field capacity	443.77	551.86	246.40	414.01
T_6 Sunhemp to supply 50kg N ha^{-1} at 100% field capacity	497.30	557.86	265.50	440.22
T_7 Eupatorium to supply 25kg N ha^{-1} at 50% field capacity	126.80	321.70	208.14	218.88
T_8 Eupatorium to supply 50kg N ha^{-1} at 50% field capacity	176.97	324.02	215.14	238.71
T_9 Eupatorium to supply 25kg N ha^{-1} at 100% field capacity	164.80	328.52	205.18	232.83
T_{10} Eupatorium to supply 50kg N ha^{-1} at 100% field capacity	224.27	340.50	225.25	263.34
T_{11} Glyricidia to supply 25kg N ha^{-1} at 50% field capacity	184.00	349.30	310.56	281.28
T_{12} Glyricidia to supply 50kg N ha^{-1} at 50% field capacity	184.62	360.45	335.29	293.45
T_{13} Glyricidia to supply 25 kg N ha^{-1} at 100% field capacity	328.25	666.41	356.24	450.30
T_{14} Glyricidia to supply 50kg N ha^{-1} at 100% field capacity	500.12	675.40	370.56	515.34
Period effect	254.91	416.66	259.47	

Test of significance		
	SEm ±	CD at 5%
Treatments	8.79	24.73*
Days	4.07	11.45*
Days x Treatments	15.23	42.84*
CV (%)	-	8.4156

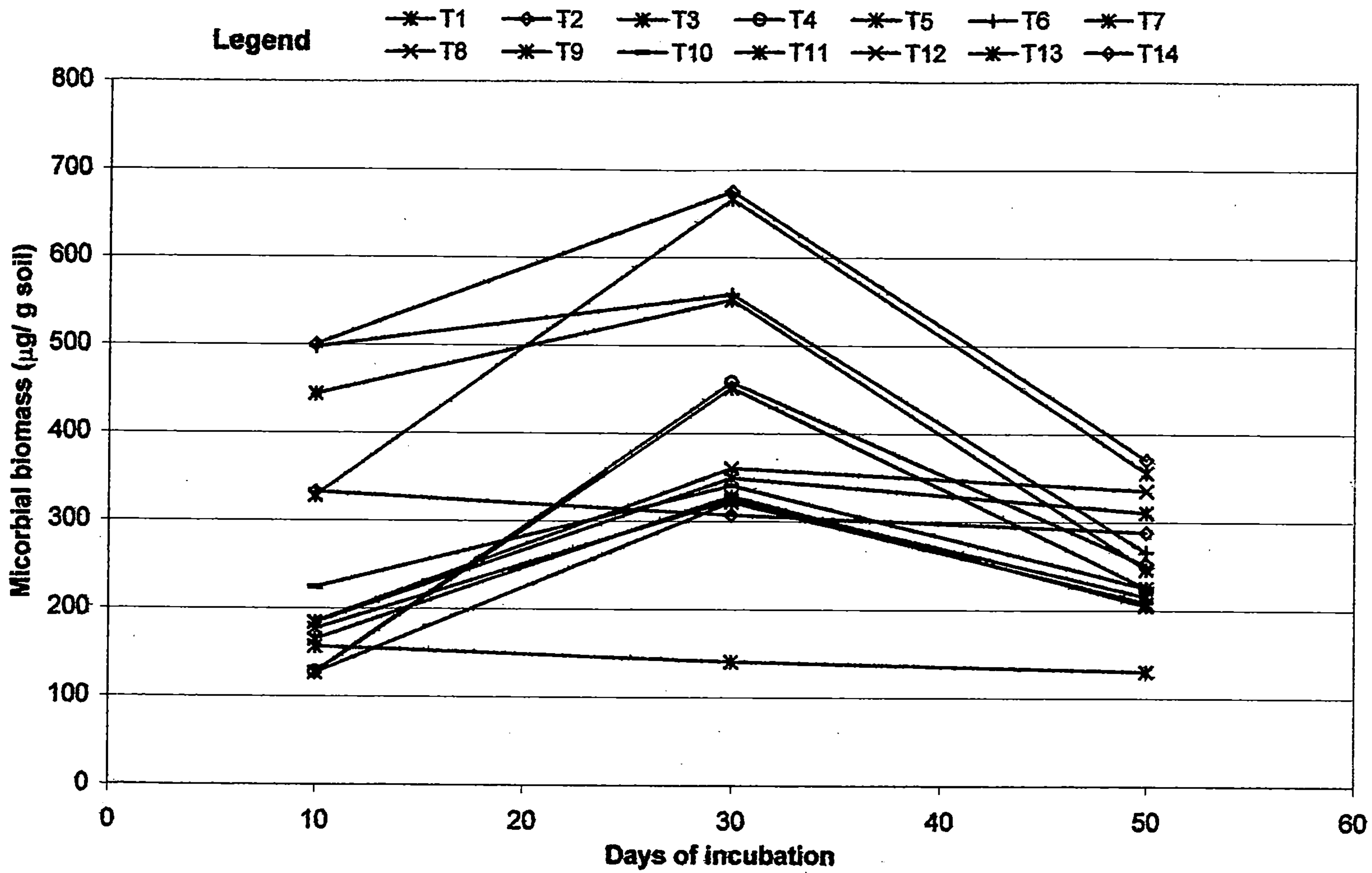

Fig . 8 Microbial biomass carbon (µg/g) in soil amended with green manures at different moisture regimes

DISCUSSION

V. DISCUSSION

5.1 Characterization of green leaf manure plants

Green manures are fresh materials which are added to soil largely for supplying nutrients contained in biomass and its favourable effect on soil properties. Such biomass can be grown *in situ* or brought from outside (ex situ) and incorporated.

In the present study, it was observed that the green leaf manure plants contains appreciable amount of nitrogen. The maximum was in glyricidia and minimum was in water hyacinth. Even though nitrogen content ranged from 2.00 to 3.10 per cent, significant differences were not observed among the green leaf manure plants studied. The range of nitrogen values was almost similar to that of the reports of Bellaki and Badnur (1998) and Palaniappan (1997). Appriciable amount of nitrogen in green leaf manure plants may be due to its tenderness and leguminous in origin (Gajanan, 2000). The variation in phosphorus content was also non-significant (0.13 to 0.24 per cent). Similar values of phosphorus content was also reported by Dey and Jain (1997). The variation in potassium content was also non-significant. Potassium content ranged from 1.26 to 2.05 per cent. Similar values of potassium was also reported by Dey and Jain, (1997). The sulphur content was highest in sun hemp (0.08 per cent) and least in case of neem (0.036 per cent). Further there was significant difference in the sulphur content among the crops studied.

The calcium and magnesium content was also in appreciable quantity, however the variation was not significant in calcium among the green leaf manure plants studied and significant difference was observed in magnesium among the crops studied. The calcium content was highest in glyricidia and lowest in water hyacinth and magnesium was highest in dhiancha and lowest in water hyacinth. The reports are in accordance with the findings of Shukla and Vimal (1969).

Iron content among the green leaf manure plants was highest in dhaincha and lowest in case of eupatorium. Significant variation in iron content was observed among green leaf manure plants studied the manganese content highest in cowpea and minimum in lantana.

The zinc content was highest in dhaincha and lowest in neem. The variation in zinc content among the green leaf manure plants was significant as reported by Shukla and Vimal (1969).

5.2 Mineralization of green leaf manure plants
Ammonification

In the present study significant variation in the release of NH_4-N among the green leaf manure plants was observed. The release was maximum on 15th day in most of the treatments and then decreased. The release of ammonia was maximum in glyricidia applied at the rate of 50 kg N/ha and maintained at field capacity level (85.50 ppm) (Table 4)

The lowest ammonical N was recorded on 100th day of incubation. Bardin (1967) reported that when ground leaves of

Glyricidia maculata containing 4.5 to 4.7 per cent N and C:N ratio of 9 was incorporated and incubated in soil, higher rate of mineralization was observed over straw and compost manures. In most of the laboratory (or) green house studies it is evident that the N release increases rapidly and reaches a plateau and then declines (Nagarajan *et al.,* 1998). Release pattern of C and N indicated that green manure underwent a rapid decomposition and mineralization. About 80 per cent of nitrogen and 40 per cent of carbon in sesbania was released in about 10 days. Further several workers have also reported that when fresh residues containing high N, initially liberated substantial quantity of N in available form, followed by decreasingly lower rates of mineralization with the progress of decomposition (Naik and Ballal 1968).

Among the green leaf manure plants studied glyricidia at the rate of 50 kg N/ha at 100 per cent field capacity released maximum amount of ammonical nitrogen compared to all other crops except sun hemp at 50 kg N/ha at 100 per cent field capacity. This may be due to higher nitrogen and narrow C:N ratio which facilitated quick release of ammonical nitrogen.

5.3 Nitrification

The nitrification process increased significantly upto 100 days of incubation. Even though the increase in NO_3-N first 10 days was marginal with the increase in time the rate of NO_3-N release was higher. The lower release of NO_3-N during the first 15 days was may be due to the release of ammonical N in the first 15 days. The decrease in ammonical N after 15 days confirms the release of NO_3-N. The release of NO_3-N was maximum in T_{12} i.e. glyricidia to supply 50kg N ha^{-1} at 50% field capacity and was least in T_7 i.e. eupatorium to supply 25kg N ha^{-1} at 50% field capacity (Table 5 and Fig 2). Highest release of nitrogen in glyricidia can be attributed to N concentration and C:N ratio. Frankenberger and Abdlmagid (1985) studied the mineralization of four legumes and observed that N concentration and C:N ratio were good predictors of mineralization. Similar results were observed in the study in which glyricidia contain higher concentration of N and narrow C:N ratio.

The release of nitrate-nitrogen was higher at higher level of nitrogen i.e. at 50 kg N/ha when compare to 25 kg N/ha. The release of NO_3-N was higher at 50 per cent field capacity compare to 100 per cent field capacity may be due the type of soil was highly porous or coarse.

5.4 Total nitrogen

Total nitrogen in general increased significantly up to 100 days of incubation. The maximum amount of total nitrogen content was noticed on 100^{th} day of incubation and least was in case of 5^{th} day of incubation (Table 6 and Fig 3). The increase in total nitrogen up to 100 days may be due to reduction in volume of organic sources (Katyal, 1977).

The release of total N was maximum in T_{12} treatment i.e. glyricidia to supply 50kg N ha^{-1} at 50% field capacity treatment and least in T_5 i.e. T_5 treatment Sunhemp to supply 25kg N ha^{-1}

at 100% field capacity. Highest release of total-nitrogen was in glyricidia may be attributed to the higher nitrogen content and narrow C:N ratio. Similar results were observed in a glyricidia contains higher nitrogen and narrow C:N ratio (Rao and Tarafdar 1998).

The release of total nitrogen was highest at higher level of nitrogen i.e. 50 kg N/ha than 25 kg N/ha. The release of total-nitrogen was highest at 50 per cent field capacity compare to 100 per cent field capacity. Katyal (1977) reported that under higher moisture condition microbial activity and decomposition was adversely effected due to lack of aeration. Yadvinder Singh *et al.* (1984) also observed higher amount of nitrogen at field capacity (or) near field capacity compared to higher moisture level

5.5 Phosphorus mineralization

In the present study significant variation in the release of available phosphorus from green leaf manure plants was observed. The release was maximum on 100th day of incubation in most of the treatments and was least on 5th day of incubation (Table 7 and Fig 4). The increased availability of phosphorus observed in this experiment was possibly due to production of carbon dioxide as a result of mineralization of organic matter (Shukla and Vimal 1969). According to Khan and Gupta (1964) application of green leaf manure increased the phosphorus availability by 20 to 25 per cent.

Joseph *et al.* (1952) reported that organic anions and hydroxy acids such as tartaric, citric, malanic, and malic acids liberated during the decomposition of green manures may complex (or) chelate iron, aluminium, magnesium and calcium prevent them reaching with phosphate ions to form soluble phosphates. Further organic acids being dominant in anionic character may compete with phosphate ions for adsorbing sites and there by increased the phosphorus content in soil solution.

The highest release of available phosphorus in T_{14} treatment i.e. application of glyricidia 50 kg N/ha at 100 per cent field capacity. This differential behaviour of green leaf manure in the release of phosphorus was possible because of their varying C:P ratio. Organic materials with narrow C:P ratio are likely to increase available phosphorus as compared to those with wider C:P ratio (Shukla and Vimal 1969). The increase in phosphorus availability at higher moisture level can be attributed to the formation of stable complexes of organic acids produced with Fe and Al during decomposition and reduction process resulting in less readsorption of mineralized P (Rajagopal and Idani, 1963).

5.6 Available potassium

The release of available potassium into soil pool showed significant variation with the period of incubation. The rate of release of available potassium was fast in all the treatments up to 80^{th} day of incubation after 80^{th} day available potassium content gradually declined in all the treatments. Available potassium content of soil increased gradually but the major amount of release occurred with in 80 days of incubation (Table 8 and Fig 5). It may be due to the potassium ion unlike that of nitrogen and sulphur is not strongly bound in organic combinations so microbial action is not a critical input for the release of potassium for mineralization of organic bound elements. Moreover potassium exists only in monovalent state in biological system hence the oxidation reduction reaction which effect the transformation of nitrogen and sulphur do not effect its availability. Thus, the higher availability of potassium in the initial stages appears to be due to the liberation of potassium contained in the organic materials. Chemindae (1955) stated that two third of potassium in plants was not strongly bound and immediately soluble in water. Debnath and Hajra (1972) attributed quick release of potassium from green manures due to the presence of potassium in plants in inorganic form. Inorganic acids and organic acids formed during decomposition of organic matter helped in the release of mineral bound insoluble potassium. After an initial increase and subsequent decrease in potassium content was attributed due to biological immobilization and soil K fixation (Levin and Joffe 1947).

The release of available potassium was highest in case of T_{14} treatment i.e. glyricidia 50 kgN/ha at 100% field capacity. This may be due higher K content in glyricida compared to sun hemp and eupatorium.

5.7 Organic carbon

In the present study significant variation in the release of organic carbon with different period of incubation was noticed.

The results indicated that organic carbon content in the soil decreased with time and it was maximum on 5th day of incubation and least was observed on 100th day of incubation (Table 9 and Fig 6). Mishra *et al.* (2001) reported that the carbon content in the soil during decomposition of rice straw decreased with time. This rapid decomposition may be due to easily decomposable carbohydrates, proteins, and other substance (Christen, 1985).

The maximum organic carbon content in the soil was observed in T_{10} treatment i.e application of eupatorium 50kg N/ha at 100 per cent field capacity. This may be due to the low N content and wider C:N ratio. Due to the wider C:N ratio carbon mineralization was slow and carbon dioxide evaluation was also decreased (Prasad and Sinha, 1996).

The highest organic carbon at 100 per cent field capacity was due to lower activity of dehydrogenase enzyme and the activity was highest during first week of incubation and subsequently started declining (Rao and Trafdar 1998). In the present study higher organic carbon content at 100 per cent field capacity compared to 50% field capacity this may be due to lower aeration at 100 % field capacity compare to 50 % field capacity.

5.8 Carbon dioxide evolution

The rate of decomposition of green manure plants was measured indirectly as the rate of carbon dioxide evolved during decomposition in the soils. In the present study significant variation in the evolution of carbon dioxide from green leaf manure was observed. The evolution was maximum upto 40th day of incubation in all the treatments and then decreased upto 100th day of incubation (Table 10 and Fig 7). This may be due to the fact thus water soluble substances of provide readily available source of energy for the growth and activity of microorganisms during early stages of decomposition they are metabolized in aerobic system (Christen 1985, Singh, 1991). The decline in CO_2 production after 40th days of incubation is due to the presence of lesser amount of resistant constituents like lignins and phenols responsible for slower decomposition

Among the green manure plants studied glyricida at the rate of 50 kg N/ha at 50 per cent field capacity release maximum amount of CO_2 compared to all other treatments. This may be due to the higher nitrogen and narrow C:N ratio (Jothimani *et al.*, 1997) and also maximum activity of dehydrogenase during first week of incubation at 60 per cent field capacity (Rao and Tarafdar, 1998).

5.9 Microbial biomass carbon

Soil microbial biomass is a labile fraction of soil organic matter and it acts as a source and sink for many plant nutrients.

A significant increase in microbial biomass was recorded upto 30th days of incubation and then decreased. The trend of variation in microbial biomass carbon in the control soil showed that the values declined with time of incubation. Maximum microbial biomass was recorded on 30th days of incubation and lowest at 50th day of incubation (Table 11 and Fig 8). The increase in microbial biomass upto 30th day of incubation suggest that upon addition of organic matter into the soil microbial biomass increased due to high microbial activity. Such an increase in microbial biomass in soils was also been reported by many workers (Powlsen *et al.*, 1987, Goyal *et al.*, 1994, Patra *et al.*, 1992).

The decreasing trend of microbial biomass carbon in control soil during the entire period of incubation seemed to be related to the depletion of nutrients at the disposal of biomass. In contrast the gradual increase in green leaf manured soils upto 30 days of incubation can be attributed to the easily available and biodegradable organic matter in green manure which stimulated the biomass carbon (Jenkinsen, 1988).

The maximum microbial biomass was recorded in T_{14} i.e. application of glyricidia at 50 kg N/ha at 100 per cent field capacity. This may be due to the high nitrogen, narrow C:N ratio and higher microbial activity.

SUMMARY

VI. SUMMARY

An investigation was carried out to study the characterization and decomposition of green manures in an Alfisol. It was found that glyricidia contains highest content of nitrogen and lowest was in case of water hyacinth. The phosphorus content was maximum in case of dhaincha and minium in case of parthenium. The potassium content was highest in case of glyricidia and was lowest noticed in case of water hyacinth. The sulphur content was noticed maximum in case of sun hemp and minimum was noticed in case of water hyacinth. The calcium and magnesium content was maximum in case of glyricidia and minimum was noticed in case of water hyacinth. Iron content was maximum in case of dhaincha and lowest was in case of sun hemp. The highest manganese content was in case of cowpea and least was noticed in case of lantana. The zinc content was highest in case of dhaincha and was lowest in case of neem. The C:N ratio was narrow in case of glyricidia and wider in case of neem. The highest crude protein content was noticed in case of glyricidia and was least in case of water hyacinth. The maximum lignin content was noticed in eupatorium and was least in case of neem. The highest phenol content was noticed in case of eupatorium and least was noticed in case of dhaincha.

Maximum ammonification was recorded up to 15th day of incubation. Maximum nitrification was recorded upto 100th day of incubation in all the treatments. Glyricidia recorded higher ammonification at 100 per cent field capacity and nitrification at

50 per cent field capacity followed by sun hemp and least was noticed in eupatorium. Application of higher dose (50 kg N/ha) of nitrogen recorded higher ammonification and nitrification.

The total nitrogen content increased up to 100 days of incubation in glyricidia treatment followed by sunhemp and least was noticed in eupatorium at 50 per cent field capacity.

Mineralization of phosphorus was maximum at 100th day of incubation and least was noticed on 5th day of incubation. The maximum phosphorus mineralization was observed in glyricidia followed by sun hemp and least in case of eupatorium. The mineralization of phosphorus was highest at 100 per cent field capacity compare to 50 per cent field capacity.

The release of available potassium was maximum on 80th days of incubation and least was noticed on 5th day of incubation. Maximum release of potassium was recorded in glyricidia followed by sun hemp and minium was recorded in eupatorium. The release of potassium was highest at 100 per cent field capacity.

Maximum organic carbon content observed on 5th day of incubation and least was noticed on 100th day of incubation. Among the treatments eupatorium recorded highest organic carbon content in the soil followed by sun hemp and least was noticed in case of glyricidia. The organic carbon content in the soil was highest at 100 per cent field capacity compared to 50 per cent field capacity.

The evolution of carbon dioxide was highest on 40th day and least was noticed on 5th day of incubation. Among the treatments the carbon dioxide evolution was highest in glyricidia followed by sun hemp and least was noticed in case of eupatorium. The maximum carbon dioxide evolution was noticed 50 per cent field capacity at 50 kg N/ha compared to 100 per cent field capacity at 25 g N/ha.

The green manures significantly influenced the microbial biomass carbon maximum microbial biomass carbon was recorded on 30th day of incubation and there was sudden decrease on 50th day of incubation. Maximum microbial biomass carbon was noticed in glyricidia followed by sun hemp was least in case of eupatorium. The microbial biomass was highest at 50 per cent field capacity compare to 100 per cent field capacity.

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