BIOMASS PRODUCTION OF GREEN MANURE CROPS AND MINERALIZATION OF ORGANIC NITROGEN IN COCONUT BASINS

By

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THESIS

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requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled " **Biomass Production of Green manure Crops and Mineralization of organic nitrogen in Coconut Basins"** is a bonafide record of research work done independently by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or Society.

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CERTIFICATE

Certified that this thesis "**Biomass Production of Green Manure Crops and Mineralization of organic nitrogen in Coconut basins**" is a record of research work done independently by Ms. Tanie thomas under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of Ms. Tanie Thomas, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled **"Biomass Production of Green Manure Crops and Mineralization of organic nitrogen in Coconut basins"** may be submitted by Ms. Tanie Thomas, in partial fulfilment of the requirement, for the degree.

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Dedicated to
My Appachen & Ammachi

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Introduction

INTRODUCTION

The adoption of modern agricultural technologies has revolutionized agricultural production bringing it upto levels to feed the quickly growing population of the world. The application of plant nutrients to different crops has contributed substantially towards this spectacular increase. In the past three decades, fertilizers have been the most commonly used sources for supplying nutrients to crop plants. In developing countries like India, fertilizer prices have been subsidized, thereby encouraging farmers to apply fertilizers in production maximizing doses. The low cost and readily available chemical fertilizers have pushed the use of organic manures including green manures the traditionally important sources of nutrients, into a decline the world over. But with frequent increases in the price of fertilizers and the growing concern that supplies of natural gas and petroleum will become scarce it is increasingly important to pay more attention to the use of organic sources of plant nutrients. In this context, green manuring assumes significance because of their prominent effect on the maintenance of soil productivity especially in areas of intensive cropping.

The addition of organic matter in the form of green manures greatly influences the transformation and availability of nitrogen and several other essential plant nutrients through its impact on the chemical and biological properties of soils. Research in India, China and elsewhere has shown that some green manures fix atmospheric nitrogen, mobilize plant nutrients, improve soil structure, decrease leaching losses of nutrients and increase the adsorptive capacity of soil (Beri and Meelu, 1979, Bhardwaj and Dev, 1985).

Coconut (*Cocos nucifera*) a crop with a recorded history of 3000 years, is referred to as 'Kalpavriksha', in view of its versatile uses and affinity to Indian culture. With an area of about 1.5 million hectares where 9283 million nuts are produced annually, India is the third largest coconut producing country. More than 90 per cent of the production in the country is from small and marginal holdings. The crop sustains 10 million small farmers and landless labourers and plays a great role in poverty alleviation and employment generation in the rural area. The importance of the commodity as a food article could be gauged from the fact that 60 per cent of the produce is consumed as raw nuts. It also plays a prominent role in the edible oil economy.

The cultivation of coconut palm in Kerala started since the early post-vedic period. The continuous cultivation for long without adequate agronomic care has caused the exhaustion of soil resulting in low productivity. In Kerala, the coconut palms do not receive adequate fertilization and hardly five per cent of the coconut growers adopt balanced manuring. This situation can be retrieved only through the adoption of better management practices.

Organic manures are important in sustaining soil fertility and productivity especially with a perennial crop like coconut. The only remedy to meet the requirements of organic matter and inorganic nutrients of the coconut gardens is to evolve a pattern of manurial schedule woven round a system of green manuring combined with suitable quantities of mineral fertilizers applied suitably. However in intercropped coconut garden practices of growing green manures in the interspaces cannot be followed in any chance. Hence the possibility of growing green manures or cover crops in the available space of the coconut basin is to be tested.

Little information is available on biomass production, Nitrogen accumulation and mineralization of nitrogen from different green manures, which are very important to select a green manure for deriving maximum benefit. A more comprehensive understanding of nitrogen transformation processes and the factors that govern them is essential for synchronizing the release of green manure nitrogen with uptake of nitrogen by the crop. Since the different crops may respond differently to the shade condition and nutrient release upon soil incorporation, a detailed study is envisaged with the following objectives.

- To test the suitability of popular and neglected green manures and cover crops to be grown in coconut basins in terms of growth and biomass accumulation
- To estimate the quantity of major nutrients added by the green manures and cover crops when incorporated in soil
- To study the mineralization pattern of the incorporated green manures
- To study the pattern of mineralization of the green manure ^{15}N in laterite and red soils.

Review of Literature

REVIEW OF LITERATURE

In recent years due to continuing energy crisis, increasing fertilizer prices etc. there is a tremendous renewal of interest in the age old practice of green manuring. An issue of great concern associated with this practice is the sustainability of soil productivity. Also, green manuring is being seriously examined in the countries where chemical fertilizers are not likely to be available in sufficient quantities in the forseeable future and where fertilizer crop price ratios are relatively high. The benefits credited to green manures include increase in organic matter content and available plant nutrients, and improvement in the microbiological and physical properties of the soil. Of these, the role of green manures in supplying plant nutrients, particularly nitrogen, is the most important. The nitrogen fertilizer equivalence, an index used to compare green manure efficiency with chemical fertilizer, has been found to range from 40 to 200 kg N ha^{-1} in different crops but more typically is between 75 and 100 kg N ha^{-1} (Smith *et al.*, 1987).

2.1 Scope of green manuring in coconut based cropping system

Coconut is normally planted at a spacing of 7.5 m x 7.5 m. An individual palm occupies an area of 56.25 m^2 but the area of active root zone is only 12.57 m^2. This works out to a coverage of 22.24 per cent of the land (Kushwah *et al.*, 1972). So over 75 per cent of the area is not effectively utilised by coconut and could be fully exploited by intercropping (Palaniappan, 1988).

Coconut is ideally grown under tropical climatic conditions, where the degradation and loss of organic matter from soil is high due to optimal temperature, porous light textured soil type and high precipitation. Application of organic matter like coconut pith, forest leaves and cattle manure, enormously improved the growth of coconut. In most coconut growing areas, the interspaces between palms are cultivated with tuber crops, cocoa, pepper and banana. So due to the nonavailability of land for cultivating green manures and also the limited supply of cowdung for use as manure, organic manuring is seldom practised in coconut cultivation (Thomas and Shantaram, 1984).

The recommended radius for opening the basins in coconut cultivation is 1.8 m^2 and only this space could be utilised without competing for the inter space which are utilised for raising other crops (Thomas and Shantaram, 1984). Green manure crops like cowpea, sesbania, daincha, kolenji, sunnhemp etc. can be sown in April-May and July-August in a circular band of 1.5 m width at a distance of 1.5 m from the base of the palm (Anon., 1985). Philip (1989) raised the possibility of growing green manures in coconut basins for *in situ* green manuring. Thomas and Mathew (1990) and Thomas *et al.* (1991) examined the possibility of growing certain green manures in coconut basin for *in situ* incorporation, and reported that 150-200 g N per basin can be added by the green manures.

2.2 Green manure crops for *in situ* incorporation

Sesbania sp. and *Crotolaria* sp. are the most widely grown green manures in India. *Sesbania speciosa* can grow as a perennial plant and is more drought tolerant than *Sesbania aculeata* (Patnaik *et al.*., 1957). Vachani and Murty

(1964) and Panse *et al.* (1965) reported that *Crotolaria juncea* (Sunnhemp) is less tolerant to salinity, acidity and excess water conditions than *Sesbania aculeata* (daincha) but it performs better in low rainfall and limited soil moisture areas. Of the cultivated annual legumes, *Crotolaria* sp. and *Sesbania* sp. have been used most widely for rice; but clusterbean, a fairly drought tolerant legume and cowpea which is valued both as a food crop and a green manure crop, are also being grown (Singh *et al.*, 1981). According to Abrol and Palaniappan (1988) *Crotolaria juncea* and *Sesbania aculeata* are the most widely grown green manure crops in India.

Among the stem nodulating legumes, *S. rostrata* and *Aeschynomene afraspera* have received particular attention. These are characterised by profuse stem nodulation, fast growth and more active nitrogen fixation than most root nodulating legumes (Rinaudo *et al.*, 1988).

Samad and Sahadevan (1952) and Raju (1952) have listed a number of tree species and other plants which are used extensively for green leaf manure in the southern Indian States. Some of the important ones are *Cassia auriculata, Melia azadirachta, Calotropis gigantia, Tephrosia purpurea, Glyricidia maculata* and *Cassia tora.*

Pueraria has been recognised as ideal legume to be grown as a cover crop under coconut in the interspaces (Leather, 1972). Magot and Cadigal (1976) while testing six different cover crops under coconut found *Pueraria phaseoloides* to yield the highest drymatter of 20.53 t ha^{-1}. Thomas and Shantaram (1984) reported that *Pueraria phaseoloides, Mimosa invisa* and *Calapagonium mucanoides* established well under coconut in the basins.

Philip (1989) raised the possibility of growing green manure crops like *Crotolaria juncea, Crotolaria striata, Sesbania aculeata, Sesbania speciosa* and *Sesbania rostrata* in coconut basins.

2.3 Biomass accumulation

The benefits accruing from green manures are directly related to the amount of biomass added to the soil. Biomass production of green manure crops varies according to the species of the legume, environmental conditions, soil fertility, crop management practices etc. (Singh *et al.*, 1992).

Sesbania speciosa planted during the month of August on the boundaries of a hectare field produced within four months, an average of about 42 t ha^{-1} of green matter for incorporation in the rice crop transplanted in January (Vachani and Murty, 1964). Brewbaker (1987) reported that among the legume trees *Leucaena leucocephala* yielded more biomass than other shrubby tropical legumes. Chen (1983) observed that milk vetch production averaged to about 30 to 45 t ha^{-1} fresh matter (3.0 to 4.5 t ha^{-1} dry matter) at the full bloom stage, in China and that Sesbania's yield was similar to milk vetch. Singh *et al.* (1991) reported that age is a key factor controlling biomass accumulation in tropical legumes. Forty to forty nine days old tropical legumes produce about 1.3 to 4.9 tonnes of dry matter ha^{-1}, whereas 50 to 60 days old ones produced about 2.9 to 8.9 t ha^{-1}. Food legumes of 80 to 120 days produced 4.0 to 24.0 t ha^{-1} of dry matter. Stem nodulating legumes possessed large potential for biomass production in short periods i.e., within 45 to 60 days they produced about 16 to 19 tonnes of dry matter ha^{-1}.

Magot and Cadigal (1976) reported a drymatter accumulation of 20.53 t ha^{-1} from *Pueraria phaseoloides* under coconut. Thomas and Shantaram (1984) in an attempt to select efficient green manure crops observed that *Pueraria phaseoloides, Mimosa invisa* and *Calapagonium mucanoides* established well under coconuts in the basins, the mean yields obtained were 19.43, 17.00 and 14.71 kg per basin, respectively. They also reported that *Macrotyloma axillaire* produced only 0.95 kg of fresh matter per basin. The fresh matter yield of *Leucaena leucocephala, Sesbania aegiptica, Macroptilium atropurpureum, Glycine wightii* and *Stylosanthes guianensis* when grown under coconut were 2.95, 1.30, 9.10, 2.35 and 3.5 kg per basin, respectively. Philip (1989) found that *Crotolaria juncea* when sown in coconut basins, produced about 10 tonnes of green matter ha^{-1} within two to two and a half months. *Crotolaria striata* produced about 13 tonnes within 4 to 5 months. *Sesbania aculeata* gave 13 to 17 tonnes in 4 months. *Sesbania speciosa* produced two to five tonnes of green manure ha^{-1} within two to three months. *Sesbania rostrata* produced 15 tonnes in three months whereas sunnhemp produced 15 to 20 tonnes in about two months. Pueraria gave 24 tonnes of green matter ha^{-1}.

2.4 Nitrogen accretion from green manures

Hernandez *et al.* (1957) found that N yield of 45 day old green manures ranged from 56 to 226 kg N ha^{-1}. In United States, hairy vetch, crimson clover, subterranean clover and common vetch accumulated 56 to 209 kg N ha^{-1}, but in most cases, it was between 100 to 150 kg N ha^{-1} (Smith *et al.*., 1987).

Ladha *et al.*. (1989) estimated that 44 day old sesbania fixed as much as

303 kg N ha^{-1}. Forty five days old *Sesbania aculeata* and *Sesbania rostrata* accumulated 185 and 219 kg N ha^{-1} in South India (Palaniappen *et al.*, 1990). According to Singh *et al.* (1991), the contribution of N from leguminous green manure crops is their most commonly observed benefit and almost certainly their primary advantage. Nitrogen accumulation ranged from 25 to 199 kg ha^{-1} for tropical legumes, 50 to 338 kg ha^{-1} for winter legumes, 134 to 295 kg ha^{-1} for legume trees, 40 to 240 kg ha^{-1} for grain legumes and 98 to 532 kg ha^{-1} for stem nodulating legumes. They also estimated N accumulation of 80 to 116 kg ha^{-1} in daincha, 68 to 99 kg ha^{-1} in sunnhemp, 49 to 113 kg ha^{-1} in cowpea and 53 to 913 kg ha^{-1} in azolla.

According to Thomas and Shantharam (1984), the nitrogen addition to soil due to green matter application obtained with *Mimosa invisa, Pueraria phaseoloides* and *Calapagonium mucanoides* were 153.19 g, 121.29 g and 102.61 g per basin, respectively. *Macrotyloma axillaire, Leucaena leucocephala, Sesbania aegiptica, Macroptilium atropurpureum, Glycine wightii* and *Stylosanthes guianensis* added about 6.67, 16.55, 6.98, 66.64, 19.20, 12.70 g N per basin, respectively.

2.5 N fixation by green manures

Using ^{15}N isotope dilution technique, Chapman and Myers (1987) estimated that 60 to 72 per cent of total plant nitrogen was from biological nitrogen fixation in legumes. Smith *et al.* (1987) concluded that N fixation values for legume cover crops ranged from 67 to 84 per cent. Pareek (1989) and Meelu *et al.* (1990) observed that 80 per cent of the total N in the tops of 52 day old *Sesbania aculeata* was from biological nitrogen fixation and similar estimates of N fixation have been made for *Sesbania rostrata* and *Sesbania cannabina*.

In a study by Seneviratne *et al.* (1992) the percentage of N derived from the atmosphere by *Sesbania rostrata* is consistent with the results reported by Rinaudo *et al.* (1988) and Ndoye and Dreyfus (1988), who found a 50 to 70 per cent contribution from biological N fixation, using the ^{15}N-dilution technique.

2.6 Nutrient composition of green manures

Mukherjee and Agarwal (1950) and Ghai *et al.* (1985) reported that N content of different green manures ranged from 1.5 to 4.85 per cent. According to Roger and Watanabe (1986), N content in legumes varies from 0.2 to 0.6 per cent on fresh weight basis. Philip (1989) reported the N contents in *Crotolaria juncea, Crotolaria striata, Sesbania aculeata, Sesbania speciosa, Glyricidia maculata* and *Sesbania rostrata* as 2.6, 2.1, 3.3, 2.7, 2.9 and 5.2 per cent by dry weight respectively. Nitrogen concentration in different cultivated annual legumes ranged from 2.5 to 3.91 per cent (Singh *et al.*, 1992). Singh *et al.* (1992) estimated the N contents of *Sesbania aculeata, Crotolaria juncea, Vigna unguiculata*, cluster bean, milk vetch and *Calopogonium mucanoides* as 2.62, 2.86, 2.69, 2.80, 3.20 and 4.20 per cent, respectively.

C:N ratios vary widely among the legume species. Beri *et al.* (1979) estimated the C:N ratio of various green manures such as cowpea, sunnhemp, sesbania, cluster bean etc. and they were found to be about 32, 24, 22 and 22, respectively. Sharma and Mittra (1988) reported the C:N ratio of *Sesbania aculeata* and *Crotolaria juncea* as 16 and 17. Hairy vetch has been observbed to have a narrow C:N ratio ranged from 8.6 to 28.8. The food legume residues have generally high C:N ratios. John (1987) reported that the C:N ratios were 15:1 and 28:1 for green manure and residue, respectively. Legume trees and azolla, however, possess narrow C:N ratios, ranging from 8.0 in centrosema to 12.7 in Leucaena (Singh *et al.*, 1992).

Philip (1989) reported P contents of 0.6, 0.6, 0.7, 0.7, 0.5 and 0.8 per cent in *Crotolaria juncea, Crotolaria striata, Sesbania aculeata, Sesbania speciosa, Glyricidia* and *Sesbania rostrata*, respectively. The phosphorous content of green manure crops ranged from 0.20 to 0.34 per cent. The P content in *Sesbania aculeata* varied from 0.25 to 0.40 per cent while sunnhemp has a P content of 0.18 to 0.40 per cent. Cowpea has a P content ranging from 0.22 to 0.43 per cent. Green leaf manures have lower P content (0.20 to 0.24 per cent) than leguminous green manures and azolla in which P content ranges from 0.28 to 0.38 per cent (Singh *et al.*, 1992).

The concentration of K, S, Ca and Mg vary considerably depending upon the legume species. Philip (1989) reported K contents of 2.0, 2.6, 3.6, 2.2, 2.8 and 3.3 per cent from *Crotolaria juncea, Crotolaria striata, Sesbania speciosa, Glyricidia maculata* and *Sesbania rostrata*. Singh *et al.* (1992) observed the K contents of 1.48, 2.26, 1.73, 2.44, 1.98 and 1.65 per cent from Sesbania, cowpea, Leucaena, Glyricidia, *Sesbania sesban* and Azolla, and sulphur content of 0.3 per cent in Sesbania, 0.28 per cent in cowpea and 0.5 per cent in *Sesbania sesban*. He also reported calcium contents of 1.40, 1.50, 1.88, 1.89 and 1.04 in Sesbania, Cowpea, Leucaena, Glyricidia and Azolla and magnesium contents of 1.62, 1.73, 0.41, 0.43, 0.27 and 1.24 per cent respectively for Sesbania, Cowpea, Leucaena, Glyricidia, *Sesbania sesban* and Azolla. The concentration of micronutrients in leguminous green manaures is expected to be similar to those of non-leguminous crop plants.

2.7 Nitrogen mineralization from green manures

The variation in the mineral nitrogen content (NH_4^+ and NO_3^-) in the soil after addition of green manures will affect the mineralization pattern of green manures (John, 1987). The decomposition and release of nitrogen from green manures generally proceed very rapidly during the first few weeks followed by much slower phases thereafter under aerobic conditions (Wilson and Hargove, 1986; Singh *et al.*, 1988; Jansen, 1989 and Wagger, 1989).

Nair and Ghosh (1984) reported that a minimum of 30 to 45 days of mineralization would be needed before the residues release the plant utilizable nitrate - nitrogen in sufficient quantities. Wilson and Hargove (1986) observed an exponential N mineralization pattern of legume residues under field conditions. N disappearance was very rapid during the first four weeks after placement, and decreased with time reaching a very slow rate by 16th week. The net N release 14 and 112 days after incorporation was 52 and 69 per cent, respectively. Singh *et al.* (1988) observed that N was released rapidly from *Sesbania aculeata* and the amount released two and four weeks after incubation was 59 and 74 per cent, respectively. Gale and Gilmour (1988) observed relatively slow rates of N mineralization from alfalfa residue and apparent net N release was only 12 and 28 per cent in 14 and 30 days after incubation, respectively.

Joachim and Kandiah (1929) monitored the NH_4^+ levels of paddy soil after incorporating with sunnhemp and dhaincha in the laboratory and field. In the incubation study, the NH_4^+ -N reached a peak of 100 ppm during the fourth week of incorporation and maintained the level upto 16 weeks and then declined. Khind *et al.* (1985) reported a peak NH_4^+ -N release at two to four weeks after incorporation and then declining.

The release pattern of NH_4^+ -N from the green manures showed that the green manure N was rapidly mineralized and the peak mineralization was during 7 to 15 days after addition of green manures in soil. Sesbania amended soil released maximum NH_4^+ -N followed by sunnhemp, cowpea, cluster bean and unamended soil (Beri *et al.*, 1989).

Release of N derived from different ^{15}N labelled plant materials decomposing in soil was investigated by Muller and Sundman (1988). They reported that most of the released N was retained in the soil at 0-25 cm, and the soil at 25-35 cm contained only 0.6-1 per cent of plant derived nitrogen. A 12 week green house experiment was conducted to determine the N mineralization rate of legume residues in soil by the difference and ^{15}N recovery methods. Net N mineralization after 12 weeks ranged from 11 per cent of added N with *Cassia rotundifolia* to 47 per cent of added N for alfalfa. Fox *et al.* (1990) estimated the portion of legume N mineralized by ^{15}N recovery methods, from two ^{15}N labelled legumes Medic and Vigna. In Medic the net N mineralized at 2, 6, 9 and 12 weeks were estimated as 14.6, 22, 27.6 and 30.2 per cent, respectively. In Vigna the corresponding values were 17.2, 22.7. 29.5 and 35.5, respectively.

2.8 Factors affecting N mineralization

The decomposition and release of mineral N from green manure are affected by several factors. These include green manaure characteristics (substrate quality), environmental factors, soil characteristics and management factors (Singh *et al.*, 1992).

2.8.1 Nitrogen content

The nitrogen content of plant material is an important factor controlling the rate of decomposition and ensuring that N mineralization exceeds immobilization by a considerable extent.

Ito and Watanabe (1985) noted that the rates of N release from three species of fresh azolla were related to their N content. *Azolla pinnata* with a high N content of 4.88 per cent, released more NH_4^+ -N and at a faster rate than *Azolla mexicana*, which had a lower N content of 3.46 per cent. Frankenberger and Abdelmagid (1985) found a highly significant positive correlation between total N content in legume residues and the cumulative amount of N mineralized in soil. Nagarajah (1988) reported that several leguminous green manures with most similar N content and C:N ratio released nearly similar amounts of NH_4^+ -N under water logged conditions. The initial rate of N release was, however, faster in Sesbania (2.72 per cent N) than sunnhemp (1.68 per cent N), Cowpea (2.43 per cent N), Mung bean (2.42 per cent N) and Pigeonpea (2.6 per cent N). Soybean which had the lowest N content of 1.10 per cent released the lowest amount of N. Jensen (1989) observed a net mineralization of N after 50 days of incubation of pea residues containing 2.35 per cent N, but no net mineralization of N occurred even after 220 days of incubation with pea straw containing 1 per cent N.

In a laboratory incubation study under flooded conditions, Beri *et al.* (1989) observed no significant difference in the amount of NH_4^+ released from 60-day-old Sunnhemp (2 per cent N), Sesbania (2.2 per cent N), Cowpea (1.6 per cent N), and Cluster bean (2.3 per cent N).

However, De Haan (1977) found no correlation between percentage N of the added plant tissue and the rate of decomposition.

2.8.2 C:N ratio

The organic residues with wide C:N ratios often have a slow rate of decomposition (Singh *et al.*, 1992).

Black (1968) reported that in many cases, the critical C:N ratio for N mineralization falls between 15 and 33. Frankenberger and Abdelmagid (1985) reported the critical C:N ratio for N mineralization as 19.

Weeraratna (1979) found that *Centrosema pubescens* leaves with high N content and low C:N ratio released the maximum amount of mineral N under anaerobic conditions compared to other four green leaf manures with low N content. Sunflower leaves which contained the lowest N and the highest C:N ratio released the lowest amount of N. Wagger (1989) observed that under field conditions the rate of N release was greater for hairy vetch with a C:N ratio of 8 to 12, than for crimson clover with a C:N ratio 13 to 16.

The mineralization of N from green manures vary with the hardiness and C:N ratio. The N mineralization is fast for green manures with C:N ratio of 15:1 while it is slow and steady with legume crop residues with C:N ratio 28:1 (John *et al.*, 1989).

2.8.3 Effect of soil properties

The decomposition and release of N from organic materials is subject to the influence of various soil properties. Decomposition typically proceeds more readily in neutral soils.

Bajpai *et al.* (1980) found that N mineralization from sesbania green manure was faster in normal soil (pH 7.2) than in a saline-sodic (pH 9.9) soil. Lin and Wen (1990) suggested the decomposition of green manures slow in soils with low pH values.

Many investigators have observed that organic residues decompose more slowly in soils with higher clay contents, especially with clays having higher ex change capacities (Allison, 1973., Sorensen, 1975). Zhu *et al.* (1984) found that N release from vetch green manure plus rice straw after 32 days of flooding was 15.6 and 26.2 per cent in heavy clayey and clay loam soil, respectively.

Nagarajah *et al.* (1989) studied N mineralization from green manures in four flooded Philippines rice soils. After 83 days of flooding, the apparent net N release from Sesbania and Azolla green manure ranged from 44 to 81 per cent and 27 to 52 per cent, respectively. There seemed to be no single factor controlling the rate of N release from green manure in different soils. From the results of 12 field experiments in a semiarid climate in Australia, Amato *et al.* (1987) found tnat the influence of soil physical and chemical properties on the amount of ^{15}N released from legume residues was small.

2.9 Effect of green manuring on availability of plant nutrients other than nitrogen

P mineralization is closely related to the analogous transformation of N (Thompson *et al.*, 1954). Rao *et al.* (1961) and Subhiah and Mannikar (1964) have shown that green manure taps sub soil P and makes it available to the shallow rooted crops. Upon decomposition of green manure, organically bound P is mineralized and becomes available to crops. Phosphorus content of the added organic matter is perhaps the most important factor in regulating the release of P (Singh and Jones, 1976). Legume plants have the ability to utilize insoluble phosphates through well developed root system, and when used as green manures, upon mineralization release P in the available forms (Gu and Wen, 1981., Singh, 1984).

Prabhakar *et al.* (1972) observed that the addition of *Glyricidia maculata* green manure increaseťd the availability of soil P by 26 to 37 per cent.

The leguminous green manure plants have a strong ability to absorb the rather inaccessible K in the soil (Gu and Wen, 1981). Many workers have reported increased availability of K in soils due to green manuring (Kute and Mann, 1969; Debnath and Hajra, 1972; Katyal, 1977; Tiwari *et al.*, 1980; Swarup, 1987 and Nagarajah *et al.*, 1989).

Materials and Methods

MATERIALS AND METHODS

Experiments were conducted under field and laboratory conditions at the College of Horticulture, Vellanikkara to study the performance of various green manure crops grown in coconut basins and the mineralization of green manure nitrogen, during 1993 and 1994. The details of the materials used and methods followed are presented.

3.1 Experiment 1 - Evaluation of different green manures and cover crops

3.1.1 Location

The experiment was laid out in the coconut farm coming under the Plantation Crops and Spices Farm Unit III (KADP) of the college of Horticulture, Vellanikkara.

The site is located at 10° 31'N latitude and 76° 13' E longitude at an altitude of 22.25 m from MSL.

3.1.2 Climate

The area enjoys tropical humid climate. The data on rainfall, maximum and minimum temperature for 1993-94 are given in Fig.1.

3.1.3 Soil

The soil of the experimental site belongs to the laterite group. The textural class of the soil is sandy clay loam. The physico-chemical properties of the soil are given in Table 1.

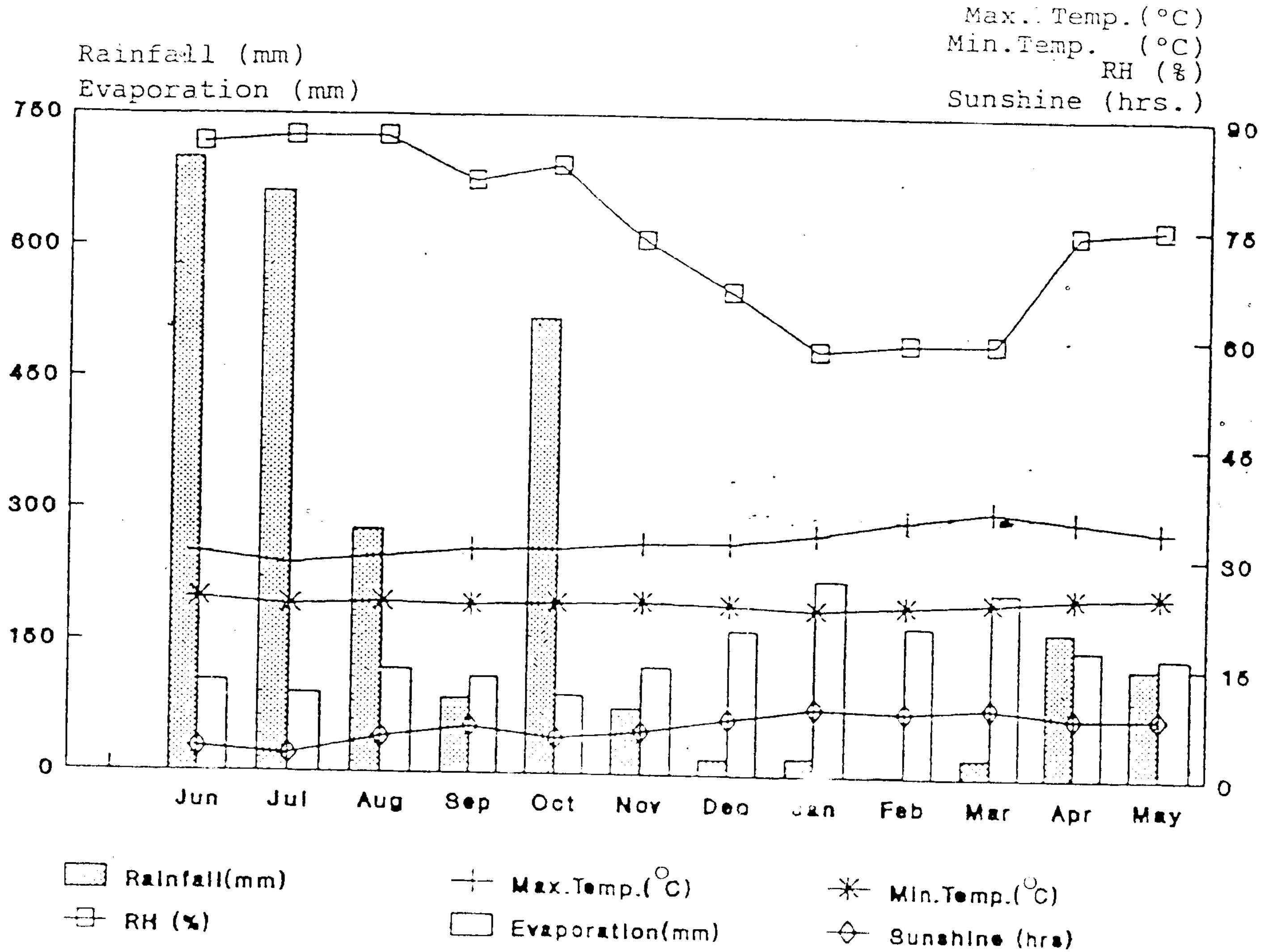

Fig.1. Mean weather parameters during the crop period

Table 1. The physical and chemical properties of soil in the experimental field

Sand	-	17.5 per cent	(Piper, 1942)
Silt	-	5 per cent	
Clay	-	17.5 per cent	
pH	-	4.8 ~~per cent~~	
Total nitrogen	-	0.179 per cent	(Sankaran, 1966)
Available phosphorus	-	17.8 ppm	(Jackson, 1958)
Available potassium	-	150 ppm	(Jackson, 1958)

3.1.4 Design and treatments

The experiment was laid out in a Randomised Block Design with three replications. Each plot comprised of one coconut basin having an area of 12.56 m^2. There were nine treatments comprising of eight green manure crops grown in the coconut basins and one control. The treatments are listed below.

1. *Sesbania aculeata*
2. *Sesbania speciosa*
3. *Crotolaria juncea*
4. *Crotolaria striata*
5. *Cassia tora*
6. *Pueraria phaseoloides*
7. *Calapagonium mucanoides*
8. *Mimosa invisa*
9. No green manure crop

Treatments 1, 2 and 3 represented the popular green manure crops, 4 and 5 represented the neglected green manure crops and 6, 7 and 8 represented the popular cover crops.

3.1.5 Pre-treatment of green manure seeds

Since the seeds of cover crops had very hard seed coat, they were subjected to hot water treatment to obtain a high percentage of germination.

The seeds of all crops were innoculated with Rhizobium culture obtained from Tamil Nadu Agricultural University. The rhizombium culture was made into a slurry in rice gruel and the seeds were uniformly mixed on the previous day and dried under shade.

3.1.6 Establishment of the treatments

The basins of the coconut palms to a radius of about 2 m were opened in April along with the summer showers. The green manure seeds were sown during the 1st week of July, 1993. The seeds were dibbled at a seed to seed distance of 10 cm. The seeds of cover crops were sown in concentric circles around the palm at a distance of 30 cm and at a seed to seed distance of 10 cm. Gap filling was undertaken at 10 days after sowing. Weeding of the basins was done at 20 days and 40 days after sowing.

3.1.7 Incorporation of green manure

At the peak flowering stage of various green manure crops, the plants were harvested, the green matter obtained was cut into small pieces and then incorporated in the respective basins along with shallow tilling of the soil. Treatments 1 and 3 were incorporated at 60 days, treatment 4 at 70 days, treatments 6, 7 and 8 at 95 days, treatments 2 and 4 at 105 days, after sowing.

3.1.8 Initial soil sampling

Soil samples were taken from each replication using an auger to a depth of 0 to 15 and 15 to 30 cm, one day before starting the experiment. Soils from all replications were pooled to make one composite sample for each layer. Results of the physical and chemical analysis are given in Table 1.

3.1.9 Collection of data

3.1.9.1 Biomass accumulation of different crops

The plants were harvested at the peak flowering stage, cut into small pieces, and the fresh weight of the green matter from each plot was recorded. The green matter obtained was returned for incorporation in the respective basins. One kg sample of green matter from each plot was drawn for determination of moisture and nutrient content.

3.1.9.2 N, P and K content of green manures and cover crops

A composite sample of each green manure was analysed for total nitrogen, phosphorus and potassium contents. The total dry matter (kg per basin) was multiplied with the corresponding nutrient content to get nutrient accretion, expressed as g per basin.

3.1.9.3 Nutrient composition of green manures

Kjeldahl digestion and distillation method (Jackson, 1958) was used to find out the total N content in plant samples. For the determination of P and K, a known weight of the sample was digested in a mixture of nitric acid, perchloric acid and sulphuric acid at 10:4:1 proportion, respectively. The P content was determined colorimetrically by vanadomolybdophosphoric yellow colour method in nitric acid medium and K was determined using a flame photometer (Jackson, 1958). Ca, Mg, Fe, Zn and Mn contents were determined by using Atomic Absorption Spectrophotometer. For S determination, diacid digest was made use of and then S content was estimated turbidimetrically (Jackson, 1958). Total carbon content of the plants was determined by ignition at 55°C for 6 hours (Gaur, 1975) for the determination of C:N ratio.

For bulk density determination, the core sampler was pushed to a 30 cm depth of soil. Soil was removed from the sampler and weighed. Bulk density was calculated and these samples were kept for moisture determination.

For ammonium-N and nitrate-N determination samples were collected using a core sampler. Soil cores were drawn from 0 to 15 and 15 to 30 cm depths. One composite sample was drawn from the soil of each depth drawn at five locations in the basin. The samples were collected in separate labelled polythene bags and transferred to a refrigerator. Samplings were done 6 times, each at an interval of 20 days, totally to a period of 120 days after incorporation.

3.1.9.4 Soil chemical analysis

The soil samples were mixed thoroughly and subsampled. Forty grammes of soil were weighed into a 250 ml conical flask, extracted for one hour using 2M KCl solution and filtered through Whatman no. 42 filter paper. The extract was analysed for ammonium-N and nitrate-N by steam distillation method (Bremner, 1965). The values were expressed in g per basin using the following formulae:

$$\mu g\ g^{-1} = \frac{\text{ppm in extract x volume of extract (ml)}}{\text{Soil dry weight (g)}}$$

$$kg\ ha^{-1} = \frac{\mu g\ N\ g^{-1} \text{ x bulk density x depth of soil in cm}}{10}$$

$$\text{g per basin} = \frac{kg\ N\ ha^{-1} \text{ x } 12.56}{10,000}$$

Available P content of soil was determined colorimetrically using ascorbic acid reductant method. The available K was extracted with 1N neutral ammonium acetate and the potassium content was determined flame photometrically (Jackson, 1958).

3.2 Experiment 2 - Mineralization of green manure ^{15}N

Nitrogen mineralization from different green manures was studied in two different soil types using ^{15}N labelled materials in a laboratory incubation study. For this *Sesbania aculeata* - a popular succulent green manure, *Crotolaria striata* - a neglected hardy green manure and *Pueraria phaseoloides* - a common cover crop were selected.

3.2.1 Production of ^{15}N labelled plant materials

Plants were grown in sand culture. Plastic buckets of 5 kg capacity were used for raising green manure crops. The buckets were thoroughly cleaned by water. A small drainage hole was provided at the bottom of the bucket which was covered by a thin pad of cloth from inside. A plastic tube of about 1 m length and 10 cm diameter was pushed into the hole and tightly sealed. These buckets were placed in an area receiving sufficient sunlight. The free end of the tube was inserted into a bottle which was kept at a lower level than the buckets, for the collection of leachate and recirculation of the same.

Fine river sand was thoroughly washed in tap water and drenched with 0.05 per cent emisan for 24 h. The buckets were then filled with four kg of the prepared sand. The seeds were dibbled at a spacing of about 5 cm between seeds. Using a rose can the pots were watered immediately after sowing. The seeds were germinated within three days. Regular watering was undertaken and the sand was never allowed to dry up. Hewitt's nutrient solution with minor modifications as suggested by De Waard (1969) was used to give nutrients to the plants.

Analytically pure chemicals were used for the preparation of the solution. About 300 ml of complete nutrient solution was applied in each pot for the first 15 days. Nitrogen was withdrawn from the nutrient solution for the next two days and added again as 20 per cent atom excess of ^{15}N labelled $(NH_4)_2$ SO_4 obtained from Rashtriya Chemicals and Fertilizers Ltd., Bombay.

The composition of complete nutrient solution is given in Table 2.

Table 2. Composition of complete nutrient solution

Elements	meq l^{-1}	mg pure element l^{-1}
N	12	168.00
P	3	31.00
S	6	96.00
Ca	8	160.00
Mg	3.5	42.60
K	2.0	78.00
Fe (trivalent)	1.3	24.21
Mn (bivalent)	0.02	0.55
Cu	0.002	0.06
Zn	0.003	0.10
B	2 ppm	2.00
Mo	0.03 ppm	0.03

Fresh nutrient solution was prepared by diluting aliquots of appropriate stock solutions to the desired concentrations. Iron was added separately to the pots as it caused precipitation when mixed with solution containing other nutrient elements. Stock solution of iron was prepared by dissolving the required quantity of $FeSO_4$ $7H_2O$ in distilled water and acidifying it with H_2SO_4 (0.5 ml l^{-1}) to avoid precipitation.

3.2.2 Harvesting of the crop

When the green manure crops attained sufficient vegetative growth, the plants were pulled out. *Sesbania aculeata* was harvested at 60 days after sowing and *Pueraria phaseoloides* and *Cotolaria striata* were harvested at 90 days after sowing. The plants were washed thoroughly with water, cut into small pieces and dried well. When the drying was over, they were ground well and kept for further studies.

3.2.3 Laboratory incubation experiment

The study was conducted for a period of 60 days starting from 28th March, 1994. Two soils such as red loam and laterite were used for the study. The laterite soil was collected from the crop museum of College of Horticulture, Vellanikkara and the red soil was collected from the crop museum of College of Agriculture, Vellayani.

The physico-chemical characteristics of the soils are given in Table 3.

Treatments

1. Soil alone
2. ^{15}N labelled *Sesbania aculeata* and soil
3. ^{15}N labelled *Crotolaria striata* and soil
4. ^{15}N labelled *Pueraria phaseoloides* and soil

3.2.4 Preparation of the soil

The soils were collected from 0 to 15 cm depth and dried in shade for 15 days. The soil was ground and sieved through 2 mm sieve, mixed thoroughly and again dried in shade.

Table 3. The physico-chemical characteristics of the soils used for incubation study

Soil type		
Laterite:		
Sand	- 77.5 per cent	Piper, 1942
Silt	- 5 per cent	Piper, 1942
Clay	- 17.5 per cent	Piper, 1942
pH	- 5.4	Piper, 1942
Total N	- 0.153 per cent	(Sankaran, 1966)
Available P	- 12.80 ppm	(Jackson, 1958)
Available K	- 120 ppm	(Jackson, 1958)
Red Soil		
Sand	- 67.32 per cent	Piper, 1942
Silt	- 19.07 per cent	Piper, 1942
Clay	- 10.08 per cent	Piper, 1942
pH	- 5.85	Piper, 1942
Total N	- 0.102 per cent	(Sankaran, 1966)
Available P	- 58.04 ppm	(Jackson, 1958)
Available K	- 24.22 ppm	(Jackson, 1958)

Hundred grams of soil was mixed thoroughly with the respective green manure added at two per cent by weight of soil and put in 250 ml conical flasks. Sufficient water was added to bring the moisture content to field capacity. The mouths of the flasks were plugged with cotton. Field capacity was maintained throughout the period of incubation by frequent replenishment of water lost. Twelve replicates were kept for each treatment of each soil type. Two samples were drawn for each treatment at 0, 5, 10, 15, 30 and 60 days of incubation and analysed for extractable ammonium-nitrogen, nitrate-nitrogen and for ^{15}N.

Soil samples drawn were immediately extracted for one hour with 2M neutral KCl solution and filtered through Whatman No.42 filter paper. The extract was used for analysis. Ammoniacal and nitrate nitrogen contents were determined by steam distillation method (Bremner, 1965).

The distillate was evaporated to dryness by keeping it in a hot air oven. The residue was dissolved in 2-3 ml distilled water and transferred with two washings of 1.0 ml distilled water to a glass vial, stoppered and labelled. It was again evaporated to dryness. These samples were read for ^{15}N atom excess.

^{15}N analysis was done using the Emission Spectrometer available at National Facility for Blue Green Algae, IARI, New Delhi.

^{15}N recovery was calculated according to the following formula

$$^{15}N \text{ recovery} = \frac{V \times A \times R \times (N_S - N_C) \times W_{TD} \times 100}{W_{SD} \times N_F \times W_F \times F_A}$$

where V = sample titration volume (ml)

A = acid normality

R = ratio of total digested volume to volume of sample analysed

W_{SD} = weight of sample analysed

W_{TD} = total dry weight of the sample

N_S = atom per cent excess ^{15}N in sample

N_C = atom per cent excess ^{15}N in control soil

N_F = atom per cent excess ^{15}N in green manure

W_F = weight of green manure applied (g)

F_A = green manure nitrogen analysis (meq N/g)

Per cent nitrogen derived from green manure in soil

$$= \frac{\text{Per cent atom excess in the sample} \times 100}{\text{Per cent atom excess in the green manure}}$$

3.2.5 Statistical analysis

The statistical analyses were done according to the methods suggested by Panse and Sukhatme (1978).

Results and Discussion

RESULTS AND DISCUSSION

4.1 Experiment 1. Evaluation of different green manures and cover crops in coconut basins

The results obtained in the study are presented mainly under the following sections

1. Biomass accumulation
2. Nutrient composition
3. Nutrient accretion
4. Soil nitrogen dynamics after the incorporation of green manures and cover crops
5. Available phosphorus content
6. Available potassium content

4.1.1 Biomass accumulation

Data on biomass accumulation are presented in Table 4. Green manure crops like *Sesbania aculeata, Crotolaria striata, Cassia tora* and cover crops like *Calapagonium mucanoides, Pueraria phaseoloides* and *Mimosa invisa* were established well under coconuts in the basins. Among the green manures *Cassia tora* showed the maximum biomass accumulation of 18.5 kg of fresh matter per basin followed by *Crotolaria striata* (15.08 kg) and *Sesbania aculeata* (13.67 kg). On dry weight basis, *Crotolaria striata* produced the maximum biomass (3.77 kg per basin) followed by *Cassia tora* (3.07 kg) and *Sesbania aculeata* (2.73 kg). *Sesbania speciosa* and *Crotolaria juncea* were failed to establish well in coconut basins.

Table 4. Biomass accumulation and nutrient accretion from green manures

Treatments	Biomass accumulation		N accretion g per basin	P accretion g per basin	K accretion g per basin
	Fresh weight kg per basin	Dry weight kg per basin			
Sesbania acculeata	13.66 b	2.73 b	92.92 b	10.39 b	87.46 b
Sesbania speciosa	6.91 a	1.72 a	55.26 a,b	5.18 a	48.36 a,b
Crotolaria juncea	5.50 a	1.10 a	23.10 a	3.52 a	19.80 a
Crotolaria striata	15.08 b	3.77 c	158.47 c	15.09 c	75.46 b
Cassia tora	18.50 b,c	3.07 b,c	76.75 b	13.20 b,c	98.24 b
Pueraria phaseoloides	23.00 c	4.60 c	202.40 d	15.18 c	101.20 b
Calapagonium mucanoides	16.50 b	3.30 b,c	132.00 c	9.90 b	99.00 b
Mimosa invisa	18.25 b,c	3.65 b,c	135.05 c	10.22 b	76.65 b
CD (0.05)	0.96	5.27	33.81	3.58	30.06

Among the cover crops pueraria accumulated the maximum biomass both on fresh weight (23.0 kg per basin) and dry weight basis (4.6 kg per basin) followed by Mimosa and then calapagonium. However all the cover crops performed well in coconut basins.

Usually biomass production of green manure crops varied widely according to the species of the legume, environmental conditions etc. Age is a key factor controlling biomass accumulation (Singh *et al.*, 1992).

In the present investigation the neglected green manures such as *Cassia tora, Crotolaria striata* and all the cover crops tested were proved to be good for growing in the coconut basins on the basis of biomass accumulation. All these crops have taken relatively longer time for their vegetative growth. *Crotolaria striata* took 105 days to come to the flowering stage. All the cover crops and *Cassia tora* have taken 95 and 70 days respectively for flowering. With longer vegetative growth period, more dry matter accumulation as well as hardening of the tissues occur. This explains the high dry matter accumulation by *Crotolaria striata* compared to *Cassia tora*. The popular green manures such as *Sesbania aculeata* and *Crotolaria juncea* took only 60 days vegetative growth period. Eventhough *Sesbania speciosa* was allowed to grow for more than 120 days, it produced comparatively low biomass, may be because of its higher light requirement and morphological features. The same reason may be attributed to the very poor performance of *Crotolaria juncea*. These plants were reported to put forth higher vegetative growth and dry matter accumulation in rice fallows (Singh *et al.*, 1991) where light is not a limiting factor.

4.1.2 Nutrient composition

The nutrient composition of various green manures and cover crops on dry matter basis is presented in Table 5. The nitrogen content was found to vary from 2.1 to 4.4 per cent with the highest value in Pueraria and the lowest in *Crotolaria juncea*. The phosphorus content varied from 0.28 to 0.43 per cent with the highest value associated with *Cassia tora* and the lowest with *Mimosa invisa*. The potassium content varied from 1.8 to 3.2 per cent with the highest value of 3.2 in *Cassia tora* and *Sesbania aculeata*. Just like the nitrogen content, per cent potassium was low in *Crotolaria juncea*. A higher potassium content than the nitrogen content was obtained with *Cassia tora*.

Calcium content ranged from 1.4 to 2.92 per cent with the highest value in *Crotolaria striata*. Magnesium content also showed variations ranging from 0.94 to 3.0 per cent and *Crotolaria striata* was again found to be the richest source of magnesium also. Sulphur content found to vary from 0.23 to 0.84 per cent and the highest value was recorded for *Crotolaria striata*. So these crops can be exploited as sources of sulphur which is becoming universally deficient now a days.

The content of micronutrients like Iron, Zinc, Manganese and Copper are also presented in Table 5. *Crotolaria juncea* and *Pueraria phaseoloides* were found to accumulate more than 400 ppm Iron. Among the two *Sesbania* specii, *Sesbania aculeata* contained manganese as high as 440 ppm while *Sesbania speciosa* contained only 30 ppm. Though *Calapagonium mucanoides* contained higher percentage of major nutrients, the secondary and trace element contents were low. *Crotolaria striata* was found to be a rich source of zinc with 310 ppm, wherein all the other crops the zinc content was low.

Table 5. Nutrient composition of green manures and cover crops

Treatments	N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	C:N
Sesbania aculeata	3.4	0.38	3.2	2.4	2.62	0.38	200	440	40	5	15.50
Sesbania speciosa	3.2	0.30	2.8	2.8	2.90	0.49	90	30	5	5	18.20
Crotolaria juncea	2.1	0.32	1.8	1.4	1.61	0.38	400	220	20	20	15.10
Crotolaria striata	4.2	0.40	2.0	2.92	3.0	0.84	200	170	310	5	16.70
Carsia tora	2.5	0.43	3.2	2.81	2.95	0.28	110	140	10	5	18.10
Pueraria phaseoloides	4.4	0.33	2.2	1.89	1.80	0.83	420	190	20	10	12.20
Calapagonium micanoides	4.0	0.30	3.0	1.88	0.94	0.23	200	40	10	5	10.50
Mimosa invisa	3.7	0.28	2.1	1.50	1.10	0.28	1.40	110	100	5	14.10

4.1.3 Nutrient accretion

The addition of nutrients to soil due to green manaure incorporation is presented in Table 4.

The maximum nitrogen addition was found to be with *Pueraria phaseoloides* followed by *Crotolaria striata, Mimosa invisa* and *Calapagonium mucanoides* and the mean values obtained were 202.40, 158.47, 135.05 and 132.00 g per basin respectively. The lowest quantities of nitrogen were added by *Sesbania speciosa* with 55.26 g per basin and *Crotolaria juncea* with 23.10 g per basin. Maximum nitrogen addition by *Pueraria, Crotolaria striata*, Mimosa and Calapagonium can be attributed to their high nitrogen content along with high biomass accumulation. In *Cassia tora* even though the biomass accumulation was high, nitrogen addition was less, proving its inability to fix atmospheric nitrogen.

The amount of phosphorus and potassium added to the soil from the green manures also showed wide variations. The highest values of phosphorus accretion were associated with *Pueraria, Crotolaria striata* and *Cassia tora*.

Even though the phosphorus content was very much higher in *Cassia tora*, the total phosphorus added to the soil was less compared to Pueraria and *Crotolaria striata* due to its lower biomass accumulation on dry weight basis. *Sesbania aculeata*, Calapagonium and Mimosa released almost equal amounts of phosphorus to the soil. The lowest values was associated with *Sesbania speciosa* and *Crotolaria juncea*, due to their low biomass accumulation.

In the case of potassium, except *Sesbania speciosa* and *Crotolaria juncea* all the other crops released almost equal quantities to the soil. In the case of *Crotolaria juncea* both the potassium content and biomass accumulation were low. But in the case of *Sesbania speciosa* the lower potassium accretion resulted due to the low biomass accumulation alone.

4.1.4 Soil nitrogen dynamics after the incorporation of green manures and cover crops

Ammonium and nitrate nitrogen in 0 to 15 cm and 15 to 30 cm soil depth was determined at 20, 40, 60, 80, 100 and 120 days after incorporation of green manures and expressed as g per basin. The ammonium, nitrate and total mineral nitrogen in 0 to 30 cm depth is graphically presented in Figs. 2, 3 and 4.

4.1.4.1 Release of ammonium - N

The mineralization of ammonium from soil alone as seen in the control plots where no green manure grown or incorporated was as low as 11.5 to 14.0 g per basin in the 0 to 15 cm soil layer during the entire period of observation of 120 days (Table 6).

The release pattern of ammonium from the green manures showed that the green manure nitrogen was rapidly mineralized. Almost all the treatments were significantly different from the control with no green manure, in the release of ammonium - N at 0 to 15 cm soil depth about 20 days after incorporation except *Cassia tora* and *Crotolaria juncea*. Maximum extractable ammonium -N was observed with *Crotolaria striata* with a mean value of 146.37 g per basin. Soils amended with *Sesbania aculeata* and *Pueraria phaseoloides* released 104.68 g and

Table 6. Extractable NH_4-N (g per basin) in 0 to 15 cm soil at different intervals after incorporation of green manures

Treatments	After incorporation					
	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	104.68 c	92.37 b	86.13 e	23.67 c	21.03 c	16.10 b
Sesbania speciosa	44.16 b	73.20 b	28.35 b	25.35 c	20.72 c	16.00 b
Crotolaria juncea	32.56 a,b	26.52 a	22.63 a,b	18.98 b	17.69 b	16.80 b
Crotolaria striata	146.36 d	150.75 d	100.30 f	34.53 d	24.48 d	22.57 d
Cassia tora	24.87 a	22.17 a	42.95 c	25.30 c	21.27 c	20.58c,d
Pueraria phaseoloides	112.18 c	117.88 c	88.37 e,f	32.53 d	26,23 d	19.14 c
Calapagonium mucanoides	55.40 b	73.59 b	56.30 d	35.34 d	29.57 e	22.35 d
Mimosa invisa	51.31 b	113.55 c	43.40 c	35.78 d	22.50 c,d	21.71 d
Control	13.98 a	11.69 a	12.41 a	11.52 a	12.36a	11.87 a
CD (0.05)	18.92	20.02	12.22	4.00	2.31	1.87

112.18 g of extractable ammonium within 20 days followed by *Sesbania speciosa*, Calapagonium and Mimosa which are found to be on par. Maximum release of ammonium - N was found to be with *Crotolaria striata* even after 40 days of incorporation. This was followed by Pueraria and Mimosa. *Sesbania aculeata, Sesbania speciosa* and Calapagonium released similar amounts of ammonium - N to soil. All the treatments other than Cassia and Sunnhemp were found to be significantly superior to the control.

Almost similar trends were observed at 60 days after incorporation, with the highest values associated with *Crotolaria striata* and *Pueraria phaseoloides* followed by *Sesbania aculeata*. All the treatments produced significantly higher amounts of ammonium - N compared to control.

It was noted that the maximum release of extractable ammonium was found to be within 60 days and thereafter it declined rapidly. But at 80, 100 and 120 days after incorporation also, all the green manure amended soils showed significantly higher amounts of ammonium - N compared to control.

Sesbania aculeata among the popular green manures, *Crotolaria striata* among the neglected green manures and *Pueraria phaseoloides* among the cover crops were found to mineralize ammonium - N for a relatively longer period of 60 days and in comparatively greater quantities.

The ammonium - N accumulation in 15 to 30 cm (Table 7) in all the green manure incorporated treatments was relatively lower than in the top layer, however similar quantities were observed in control plot where no green manure was added.

Table 7. Extractable NH_4-N (g per basin) in 15 to 30 cm soil at different intervals after incorporation of green manures

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	26.77 b	20.35 a,b	21.45 b,c	21.33 c	19.36 c	14.03 b
Sesbania speciosa	26.02 a,b	30.20 b	19.73 b	22.16 c	20.82 c,d	13.79 b
Crotolaria juncea	16.08 a,b	15.17 a	17.32 b	14.65 b	13.98 b	14.00 b
Crotolaria striata	22.07 a,b	29.38 b	27.81 c,d	26.43 d	22.11 d	19.91 d
Cassia tora	17.59 a,b	12.93 a	29.52 d	20.77 c	19.25 c	19.11 d
Pueraria phaseoloides	56.83 c	71.37 c	31.98 d	24.77 d	22.82 d,e	16.70 c
Calapagonium mucanoides	30.68 b	35.90 b	24.58 c	28.97 e	25.15 e	20.02 d
Mimosa invisa	27.04 b	29.92 b	24.73 c	26.85 d,e	20.08 c,d	20.58 d
Control	15.79 a	9.90 a	9.93 a	9.84 a	10.00 a	10.50 a
CD (0.05)	10.80	12.85	4.51	2.45	2.58	1.64

The accumulation was also found to be almost similar during the entire course of observation in the lower level. This is probably due to the fact that the incorporation was mainly done in the top 0 to 15 cm soil, and the ammonium mineralized in the lower layer is mainly from the dead and decomposed root fractions which have gone deeper in the soil. Since the roots are possibly with a wider C:N ratio and relatively hardy nature than the above ground portion, the decomposition and subsequent mineralization was slow but steady (John *et al.*., 1989). It is also to be noted that the ammonium - N accumulation was more or less static for the entire period of 120 days.

Pueraria released the maximum amount of ammonium - N at 20, 40 and 60 days after incorporation and after 60 days the values became almost similar to other treatments. *Crotolaria striata*, Calapagonium and Mimosa were also found to release sizable quantities of ammonium - N, followed by *Sesbania aculeata, Sesbania speciosa* and *Cassia tora*. Even after 6 months of incorporation green manure amended soils retained higher status of ammonium - N content at 15 to 30 cm depth compared to control and this was found to be remarkable in Calapagonium, Mimosa, *Crotolaria striata* and *Cassia tora* followed by Pueraria.

Thus the distribution of ammonium - N in 0 to 15 and 15 to 30 cm soil depths was found to vary widely. Significantly higher amounts of ammonium-N was found in the upper layer upto 60 days. From 80 days onwards, the values became more or less similar.

The total ammonium - N content in 0 to 30 cm soil layer followed similar pattern of that in 0 to 15 cm since the ammonium in the lower soil layers were less in the green manure amended treatments than in the upper layer.

All the treatments were found to release significantly higher quantities of ammonium - N to soil, compared to control (Table 8 and Fig.2). In every treatment the maximum amount of ammonium - N was found to be within 40 days and thereafter showed a decreasing trend except in *Cassia tora* which released the maximum amount within 60 days and thereafter the similar decreasing trend was noted as in the case of all the other treatments. *Crotolaria striata* and Pueraria released the highest amounts of ammonium - N and the lowest values were obtained with sunnhemp.

The mineralization of ammonium in green manure incorporated basins were several fold higher except in *Crotolaria juncea* and *Cassia tora* during the first 60 days after incorporation. The ammonium - N accumulation in the *Crotolaria striata* incorporated treatment was about 15 times higher than in the control treatment.

4.1.42 Nitrate - N accumulation

Nitrate - N content in the 0 to 15 cm soil depth of green manure amended treatments was low compared to ammonium-N content (Table 9). Normally in an aerobic soil environment, the nitrate content should be higher than ammonium, if enough substrate is available for nitrification i.e., ammonium - N and since nitrification is a continuous process. This may hold good in an ideal upland soil environment where no plants are grown. In the rhizosphere of a perennial tree like coconut with an active ramifying root system throughout the life, the uptake of favourable nutrient ions will be fast and continuous. Since nitrogen is preferentially taken as nitrate ion

Table 8. Extractable NH_4-N (g per basin) in 0 to 30 cm soil at different intervals after incorporation of green manures

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	131.45 c	112.72 b	107.59 d	45.01 c	40.39 c	30.13 b
Sesvabia speciosa	70.18 b	103.24 b	48.08 b	47.51 c	41.74 c	29.80 b
Crotolaria juncea	48.64 a,b	41.69 a	39.96 b	33.64 b	31.68 b	30.80 b
Crotolaria striata	168.44 d	180.18 d	128.12 e	60.96 d,e	46.60 d	42.48d,e
Cassia tora	42.47 a	35.10 a	72.48 c	46.07 c	40.53 c	39.69 d
Pueraria phaseoloides	169.01 d	189.26 d	120.36 d,e	57.31 d	49.05 d	35.84 c
Calapagonium mucanoides	86.08 b	105.97 b	80.88 c	64.31 e	54.71 e	42.97 e
Mimosa invisa	78.36 b	143.47 c	68.13 c	62.63 e	42.59 c,d	42.29d,e
Control	29.78 a	21.59 a	22.35 a	21.37 a	22.37 a	22.37 a
CD (0.05)	26.57	27.68	13.49	4.82	4.50	3.11

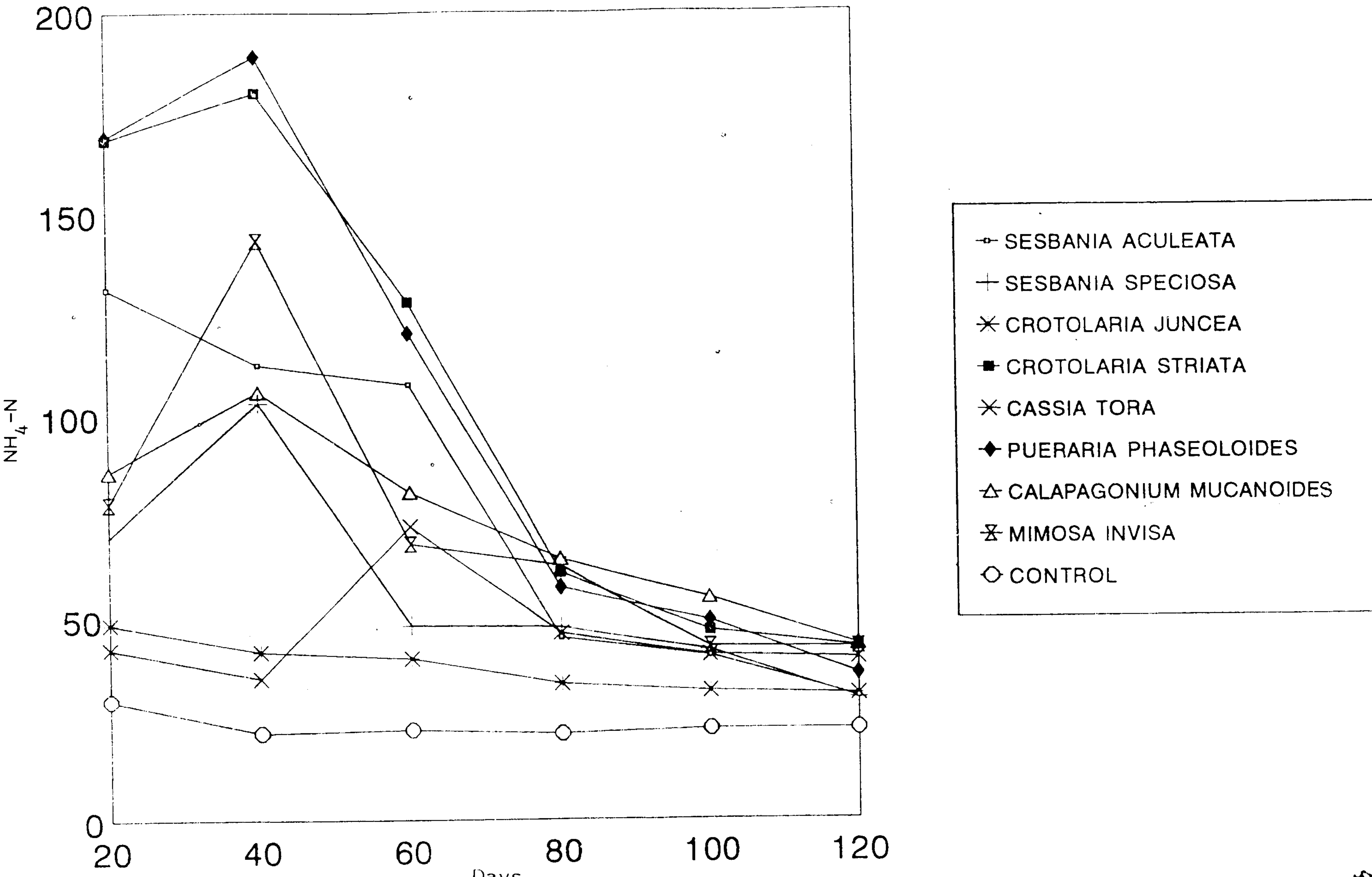

Fig.2. Extractable NH_4-N (g per plant) in 0 to 30 cm soil after incorporation of green manures

Table 9. NO_3-N (g per basin) in 0 to 15 cm soil at different intervals after incorporation of green manures

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	15.77 a,b	31.27 c	24.51 b	15.56 b,c	14.47 a,b	14.16 b
Sesbania speciosa	32.24 b	38.09 c	22.20 b	18.38 c	13.28 a,b	12.19a,b
Crotolaria juncea	17.30 a,b	19.65 b	16.23 a,b	16.44 b,c	14.31 a,b	12.36a,b
Crotolaria striata	61.83 c	53.58 d	22.61 b	14.90 b	19.30 b	16.10 b
Cassia tora	30.22 b	18.34 a,b	20.70 b	15.38 b,c	15.08 a,b	16.52 b
Pueraria phaseoloides	62.28 c	65.47 e	79.12 c	36.11 e	24.18 b	15.72 b
Calapagonium mucanoides	35.23 b	29.31 b,c	27.18 b	15.92 b,c	14.95 a,b	15.58 b
Mimosa invisa	24.93 b	25.49 b,c	25.43 b	24.19 d	19.77 b	16.96 b
Control	9.43 a	8.31 a	9.39 a	9.50 a	9.27 a	9.81 a
CD (0.05)	10.67	10.84	7.71	3.04	6.07	3.49

by upland crops (Herridge and Bergersen, 1988). It is assumed that the nitrate formed from the mineralized ammonium from soil was rapidly taken up by the crop and hence there was little amount for extraction by KCl.

However, all the green manure incorporated treatments maintained a significantly high nitrate - N status comapred to control throughout the experimental period. Excepting *Cassia tora* and Pueraria, highest amounts were recorded at 40 days after incorporation in all the treatments. In Cassia and Pueraria maximum values were noted at 60 days. After that the values showed a decreasing trend and remained more or less same. Pueraria maintained the highest status of nitrate - N in the 0 to 15 cm soil layer, very closely followed by *Crotolaria striata*.

The amount of nitrate - N in 15 to 30 cm layer of soil (Table 10) was found to be almost equivalent to that in the 0 to 15 cm layer. Also it was found to be similar to the amount of ammonium - N in the 15 to 30 cm soil layer. However, treatments like *Crotolaria striata*, Pueraria, Calapagonium and Mimosa were significantly efficient in retaining the nitrate - N status of the soil at a higher level compared to control even after 100 days of incorporation. At the end of the experimental period 120 days *Crotolaria striata*, Calapagonium and Mimosa retained higher Nitrate N content in soil.

Even though the nitrate content in 15 to 30 cm was higher than the upper layer, as against the ammonium content, the quantity of nitrate in 0 to 30 cm depth was much lower than ammonium - N in the same depth (Table 11 and Fig. 3). This is not believed to be due to low nitrification, but due to simultaneous and rapid uptake of formed nitrate from ammonium as explained earlier.

Table 10. NO_3-N (g per basin) in 15 to 30 cm soil at different intervals after incorporation of green manures

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	41.44 d	16.51 a,b	14.56 a,b	14.91 a,b	12.22 b	9.59 a
Sesbania speciosa	15.75 a,b	20.66 b	13.58 a,b	12.49 a,b	11.26 a,b	10.69 a
Crotolaria juncea	13.79 a,b	11.37 a,b	12.05 a,b	12.60 a,b	11.59 a,b	9.88 a
Crotolaria striata	24.68 b	18.50 b	18.66 b	14.22 a,b	18.38 d	15.10 b
Cassia tora	22.09 b	10.26 a	15.13 a,b	12.94 a,b	12.15 b	10.90 a
Pueraria phaseoloides	33.26 c	29.49 c	30.19 c	21.72 b	18.05 d	10.58 a
Calapagonium mucanoides	18.98 b	28.14 c	17.48 b	14.24 a,b	14.95 c	15.12 b
Mimosa invisa	21.33 b	17.60 b	19.67 b	20.39 b	17.02 c,d	16.14 b
Control	10.50 a	10.66 a,b	8.39 a	8.82 a	9.31 a	9.15 a
CD (0.05)	6.60	7.10	8.15	5.33	2.70	2.05

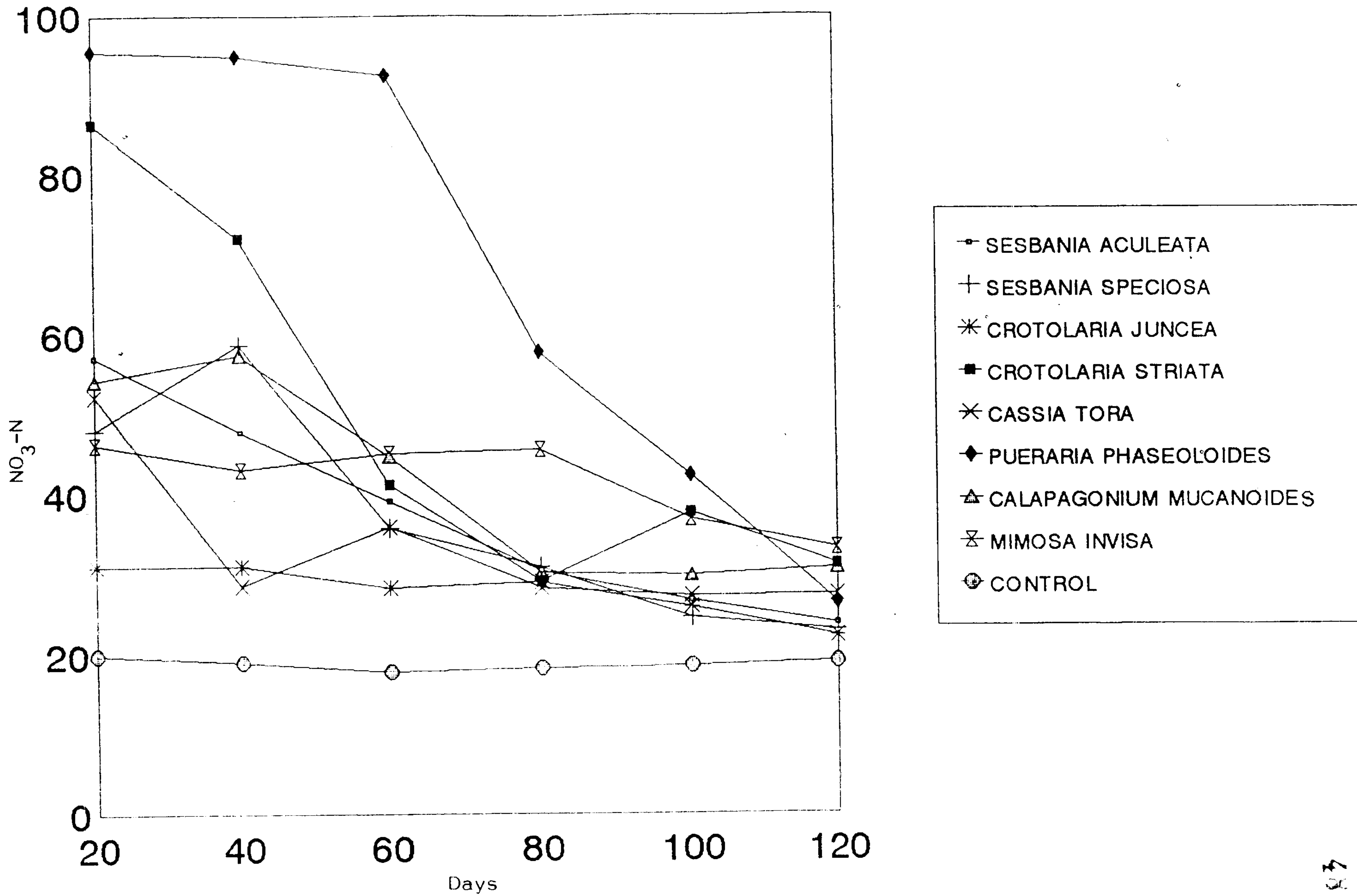

Fig.3. NO_3-N (g per plant) in 0 to 30 cm soil after

Table 11. NO_3-N (g per basin) in 0 to 30 cm in soil at different intervals after incorporation of green manures

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	57.21 b	47.78 b,c	39.07 b	30.47 b	26.70 b	23.75 b
Sesbania speciosa	47.97 b	58.76 c	35.79 a,b	30.87 b	24.55 a,b	22.89a,b
Crotolaria juncea	31.09 a	31.03 a,b	28.28 a,b	29.04 b	25.90 a,b	22.24a,b
Crotolaria striata	86.51 c	72.09 c	41.17 b	29.13 b	37.68 c	31.21 c
Cassia tora	52.31 b	28.61 a	35.84 a,b	28.32 b	27.23 b	27.43b,c
Pueraria phaseoloides	95.54 c	94.97 d	92.65 c	57.84 d	42.24 c	26.30 b
Calapagonium mucanoides	54.22 b	57.45 b,c	44.66 b	30.16 b	29.81 b,c	30.70 c
Mimosa invisa	46.23 b	43.10 b	45.11 b	45.59 c	36.80 c	33.11 c
Control	19.93 a	18.97 a	17.79 a	18.32 a	18.58 a	18.96 a
CD (0.05)	14.22	15.23	18.77	6.25	7.43	4.27

All the treatments except *Crotolaria juncea* released significantly higher amounts of nitrate - N when compared to the control and *Crotolaria juncea* was failed to perform well in the release of nitrate - N. Maximum values were found to be associated with Pueraria closely followed by *Crotolaria striata*. Calapagonium, Mimosa and *Sesbania aculeata* were also proved to be superior in the release of nitrate - N to soil whose effects are almost on par.

4.1.4.3 Total mineral nitrogen content in soil

The quantity of mineral nitrogen (NH_4 + NO_3) extracted from the green manure amended soils at 0 to 15 cm depth is given in Table 12. Ammonium-N content in soil can be considered as an index of mineralization of nitrogen from green manure, but not the nitrate - N or total mineral N since ammonium-N is the initial product of mineralization and its production mainly depends on substrate characteristics such as C:N ratio, hardiness etc. but nitrification is controlled mainly by soil environmental conditions and quality of substrate for nitrification. The quantity of nitrate present in soil also largely determined by uptake, leaching etc.

From the results it was clear that major portion of the nitrogen released is distributed in the upper layers of the soil. All the treatments were found to be significantly superior to control throughout the experimental period of four months. All the treatments except *Crotolaria juncea* and *Cassia tora* showed similar trends in nitrogen release. Upto 40 days the amount of nitrogen release showed an increasing trend and thereafter it decreased and become almost stabilished by about 100 days of incorporation. However, *Crotolaria juncea* released maximum amount of nitrogen within 20 days itself and after that exhibited a decreasing trend. In the case of *Cassia*

Table 12. Mineral N (NH_4 + NO_3) content in 0 to 15 cm soil at different intervals after incorporation of green manures (g per basin)

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	120.45 d	123.64 b,c	110.64 d	39.24 b,c	35.30 b,c	30.26 b
Sesbania speciosa	76.40 c	111.30 b	50.73 b	43.73 c	34.06 b	28.20 b
Crotolaria juncea	49.72 b	46.18 a	38.87 a,b	35.42 b	32.01 b	29.16 b
Crotolaria striata	208.19 f	204.34 d	122.92 d	49.43 d	43.79 c	38.67 d
Cassia tora	55.10 b,c	40.51 a	63.66 b,c	40.68 c	36.35 b,c	37.10c,d
Pueraria phaseoloides	174.46 e	183.35 d	150.83 e	68.65 f	50.41d	34.86 c
Calapagonium mucanoides	90.63 c	102.90 b	83.38 c	51.26 d	44.53 c	37.93c,d
Mimosa invisa	76.21 c	139.05 c	68.83 b,c	59.97 e	42.28 c	38.68 d
Control	23.42 a	20.00 a	21.84 a	21.02 a	21.64 a	21.68 a
CD (0.05)	24.20	26.92	20.66	4.99	7.34	3.67

tora the highest value was obtained on 60th day and thereafter it declined. Upto 40 days of incorporation maximum values were obtained with *Crotolaria striata* closely followed by Pueraria and after 40 days the trend became reversed. Then the highest values were for Pueraria. The lowest values were noted with *Crotolaria juncea*.

The data on nitrogen content in soil at 15 to 30 cm depth are presented in Table 13. The quantity of nitrogen released in the 15 to 30 cm soil layer was found to be less than that distributed in the upper layer. But almost all the treatments maintained a significantly higher content of nitrogen in comparison with the control plot except *Crotolaria juncea*. Its effect was not significant in the earlier stages, but significant effects were obtained from 80 days onwards. In *Cassia tora* the effects became significant from about 60 days of incorporation. Highest values were found to be for cover crops like Pueraria, Calapagonium, closely followed by Mimosa and *Crotolaria striata*.

The total amount of nitrogen mineralized in the 0 to 30 cm soil layer of the green manure amended plots is presented in Table 14 and Fig. 4. All the green manure crops except *Crotolaria juncea* released significantly higher amounts of nitrogen to soil compared to the no green manure amended plot and even this treatment showed significant difference from control from the 80th day onwards.

Sesbania aculeata released the maximum amount of nitrogen within 20 days itself and thereafter the values declined and become stabilised from 80 days onwards.

The crop possibly contain higher water soluble fraction (Reber and Schara, 1971) and low C:N ratio causing rapid mineralization of nitrogen. But

Table 13. Mineral N ($NH_4 + NO_3$) content in 15 to 30 cm soil at different intervals after incorporation of green manures (g per basin)

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	68.21 c	36.86 a,b	36.02 b,c	36.24 c	31.58 c	23.63 b
Sesbania speciosa	41.78 b	50.86 b	33.31 b	34.65 c	32.09 c	24.49 b
Crotolaria juncea	29.87 a,b	26.54 a	29.37 a,b	27.26 b	25.57 b	23.89 b
Crotolaria striata	46.75 b	47.89 b	46.48 c	40.66 c,d	40.49 d	35.01 e
Cassia tora	39.69 a,b	23.19 a	44.66 b,c	33.71 b,c	31.41 c	30.01 d
Pueraria phaseoloides	90.09 d	100.87 c	62.17 d	46.50 d	40.87 d	27.28 c
Calapagonium mucanoides	49.67 b	64.05 b	42.06 b,c	43.21 d	40.09 d	35.74 e
Mimosa invisa	48.38 b	47.52 b	44.40 b,c	47.24 d	37.11 d	36.72 e
Control	26.29 a	20.56 a	18.33 a	18.67 a	19.31 a	19.66 a
CD (0.05)	14.38	17.13	11.62	6.20	4.16	2.34

Table 14. Mineral N ($NH_4 + NO_3$) content in 0 to 30 cm soil at different intervals after incorporation of green manures (g per basin)

Treatments	20 days	40 days	60 days	80 days	100 days	120 days
Sesbania aculeata	188.33 d	160.51 b	146.66 c,d	75.48 c	67.09 b	53.89 b
Sesbania speciosa	118.18 b,c	162.16 b	83.87 b	78.38 c	66.29 b	52.69 b
Crotolaria juncea	79.73 a,b	72.72 a	68.25 a,b	62.68 b	57.58 b	53.05 b
Crotolaria striata	254.95 e	252.27 c	169.40 d	90.10 d	84.28 c,d	73.69 d
Cassia tora	94.79 b	63.71 a	108.32 b,c	74.39 c	67.76 b	67.12 c
Pueraria phaseoloides	264.55 e	284.23 c	213.01 e	115.15 e	91.29 d	62.14 c
Calapagonium mucanoides	140.30 c	163.43 b	125.54 c	94.47 d	84.63 c,d	73.67 d
Mimosa invisa	124.59 b,c	186.58 b	113.23 b,c	107.22 e	79.39 c	75.26 d
Control	52.05 a	40.56 a	40.14 a	39.69 a	40.96a	41.20 a
CD (0.05)	36.79	38.86	29.51	9.63	10.22	5.00

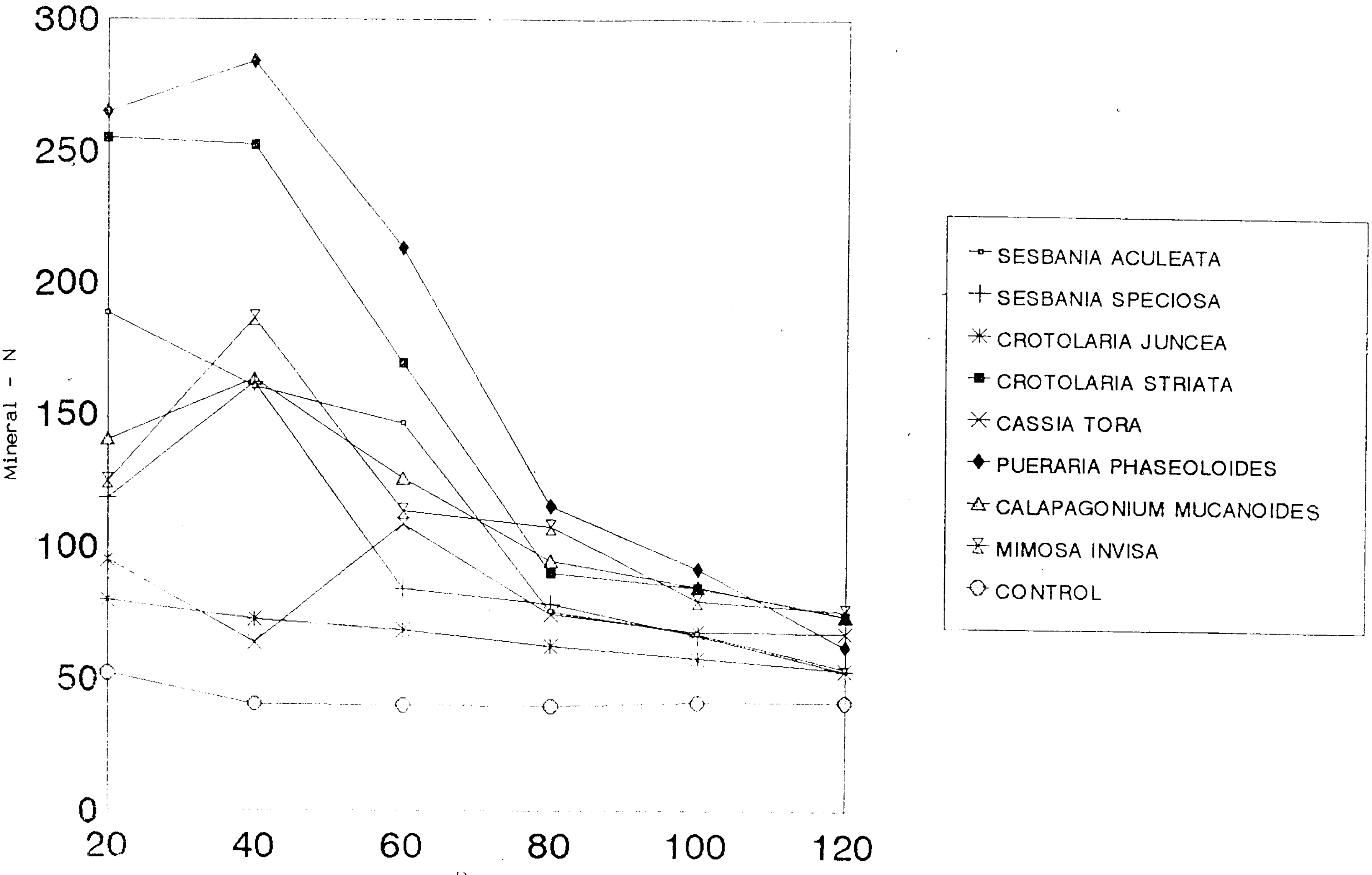

Fig.4. Mineral N (NH_4 + NO_3) in 0 to 30 cm soil after incorporation of green manures (g per basin)

Sesbania speciosa released the maximum amount within 40 days and thereafter decreased and again became almost stabilised. This may be due to the more hardy nature of the crop as well as its high C:N ratio.

Crotolaria juncea released most of its nitrogen within 20 days itself. The same reason as in the case of *Sesbania aculeata* can be attributed here. However *Crotolaria striata* showed almost similar quantities of nitrogen release upto 40 days and then showed a slight decline followed by a decreasing trend. The decomposition and release of nitrogen usually proceeds very rapidly in the initial phase and then attains a much slower pace (Wilson and Hargove, 1986; Singh *et al.*, 1988; Jensen, 1989; Wagger, 1989). The rapid release phase may be due to the decomposition of easily decomposible portions like leaves. After that the decomposition of harder tissues occur which takes place slowly but steadily. Also *Crotolaria striata* possessed comparatively high C:N ratio and so showed a constant rate of mineralization after the initial rapid release phase.

Cassia tora released the maximum amount of nitrogen within 60 days because of the high C:N ratio and hardy nature. All the cover crops showed similar pattern of nitrogen mineralization and the maximum values are obtained within 40 days and then exhibited a trend of decline.

Crops with high biomass accumulation and nitrogen content like *Puerar-ia phaseoloides* and *Crotolaria striata* were proved to be grown in coconut basins for green manuring.

4.1.5 Available phosphorus content in soil

The phosphorus content at 120 days after incorporation of the green manures in the coconut basins when no green manure was grown or incorporated was as low as 73.40 g per basin while all the green manure incorporated treatments contained significantly higher values (Table 15).

All the treatments were found to be significantly superior to control in the release of phosphorus. The highest quantity of phosphorus was released from *Crotolaria striata* and it was more than three fold as that of control. This was closely followed by *Pueraria phaseoloides* which also released phosphorus three times as that of control. The available phosphorus content of the *Cassia tora* incorporated basin was about 206.40 g which was more than 250 per cent increase compared to control. The lowest values were obtained with *Crotolaria juncea* and *Sesbania speciosa* possibly due to their low biomass accumulation.

Thus it was found that the green manures liberated their phosphorus into the soil in plant available forms upon mineralization. The higher accumulation of phosphorus in these crops may be due to the fact that the legume plants have the ability to utilise insoluble phosphates through the well developed tap root system, and when used as green manures, upon mineralization release phosphorus in available forms (Gu and Wen, 1981; Singh, 1984). Also the organic acids formed during the course of decomposition of green manaures interact with soil components, thereby considerably enriching the pool of available phosphorus (Bin, 1983). The higher phosphorus content observed in green manure incorporated treatments may also be due to the enhanced mineralization of native soil phosphorus.

Prabhakar *et al*. (1972) reported that the addition of *Glyricidia maculata* green manure increased the availability of native soil phosphorus by 26 to 37 per cent. But here we have got an increase ranging from 167 per cent to 341 per cent.

Table 15. Available P content of soil (g per basin) at 120 days after green manure incorporation

Treatments	0 to 15 cm depth	15 to 30 cm depth	Total P
Sesbania aculeata	77.19 bc	91.53 c	168.73 c
Sesbania speciosa	62.40 b	63.67 b	126.07 b
Crotolaria juncea	62.57 b	60.22 ab	122.80 b
Crotolaria striata	166.93 d	84.06 bc	250.99 e
Cassia tora	93.92 c	111.47 c	206.39 d
Pueraria phaseoloides	158.54 d	65.77 b	224.32d,e
Calapagonium mucanoides	79.05 bc	50.39 ab	129.44 b
Mimosa invisa	91.68 c	59.30 ab	150.98b,c
Control	34.51 a	38.89 a	73.40 a
CD (0.05)	18.20	23.71	36.20

This may be due to the differences in the morphological features of the crops tried in the experiment compared to *Glyricidia maculata* and also due to the higher phosphorus content in the crops, possibly. Glyricidia is usually used as green leaf manure and only the tops are used for incorporation, but in the crops tried here all parts of the plants were used for incorporation and this might have resulted in the higher availability of phosphorus.

4.1.6 Available potassium content

Incorporation of various green manures and cover crops increased the availability of potassium in soil (Table 16). This increase was found to be very significant in 0 to 15 cm soil layer where the crops are incorporated and also the total potassium content of soil. *Sesbania aculeata, Sesbania speciosa, Cassia tora, Pueraria phaseoloides* and *Calapagonium nucanoides* were found to release significant amounts of potassium to soil compared to other treatments. About 60 to 90 per cent increase was observed in the availability of potassium in these treatments compared to control. Gu and Wen (1981) reported that leguminous green manure plants, because of their typical root characteristics, possess a strong ability to absorb the difficultly available potassium from the soil.

4.2 Experiment 2. Mineralization of green manure - ^{15}N

The mineralization of green manure - N in red and laterite soils was studied in an incubation experiment. *Sesbania aculeata* - a popular succulent green manure, *Crotolaria striata* - a neglected hardy green manure and *Pueraria phaseoloides* - a common cover crop were labelled with ^{15}N and incubated after incorporation at two per cent by weight of soil under aerobic condition for 60 days.

Table 16. Available K content of soil (kg per basin) at 120 days after green manure incorporation

Treatments	0 to 15 cm	15 to 30 cm	Total K
Sesbania aculeata	1.29 cd	0.98 b	2.28 c
Sesbania speciosa	1.29 cd	0.95 b	2.25 c
Crotolaria juncea	0.93 b	0.78 ab	1.72 b
Crotolaria striata	1.24 cd	0.86 ab	2.11 bc
Casia tora	1.55 d	0.88 b	2.43 c
Pueraria phaseoloides	1.43 d	1.08 b	2.51 c
Calapagonium mucanoides	1.22 cd	0.91 b	2.13 c
Mimosa invisa	1.17 c	0.88 b	2.06 bc
Control	0.68 a	0.63 a	1.32 a
CD (0.05)	0.21	0.22	0.39

4.2.1 Green manure characateristics

The analysis of green manaure added to the soil for incubation is presented in Table 17. The N content of the three green manures showed wide variations. Pueraria contained only 1.53 per cent while Sesbania and Crotolaria had N contents of 2.45 and 2.82 per cent, respectively. Consequently, the C:N ratio of these green manures also varied considerably from 14:1 to 23:1 which might have a profound influence on the further N mineralization pattern. The differences in N content may mainly be due to the stage at which the plants are harvested. Sesbania and Crotolaria were harvested at 60 days and 90 days after sowing respectively. They had reached their flowering stage by this time. When Pueraria was harvested at 90 days, it was still in its vegetative growth stage and did not get enough time to reach its maturity and that resulted in low N status.

The ^{15}N enrichment also varied with per cent atom excess of 10.46 for Pueraria, 12.45 for Sesbania and 13.38 for Crotolaria. Since 20 atom per cent excess ammonium sulphate was used for nitrogen supply for growing the green manure in sand culture, it should be assumed that the plants might have used other sources of N, probably for nitrogen fixation. Pueraria is known to be the best nitrogen fixer, to the extent of 300 to 400 kg ha^{-1} and sesbania 100 to 200 kg ha^{-1} (FAO, 1983). However Crotolaria is a poor biological nitrogen fixer. It is to be assumed that Pueraria and Sesbania might have utilized the fixed nitrogen, which was evident from the root nodules observed at harvest which led to a lower ^{15}N enrichment.

Table 17. Analysis of green manures used for incubation study

Green manure crop	N content (per cent)	C:N ratio	Total N added to soil (mg)	^{15}N enrichment per cent atom excess
Sesbania aculeata	2.45	15:1	49.0	12.45
Crotolaria striata	2.80	14:1	56.4	13.38
Pueraria phaseoloides	1.53	23:1	30.6	10.46

4.2.2 Nitrogen release from the green manures

The data on mineralization of $^{15}NH_4$ from the green manure and $^{15}NO_3$ accumulated due to the nitrification of mineralized $^{15}NH_4$ in red and laterite soils are given in Table 18 and 19 respectively. The N release in terms of $^{15}NH_4$ extracted during different periods of incubation was the highest for Crotolaria followed by Sesbania. Eventhough comparable at certain periods of observation the differences were significant for most of the observation periods irrespective of the soil types. N release from Pueraria was significantly less than the above green manures at all the times of observations. Nitrogen added through various green manures into the soil was different as seen from Table 17. Crotolaria and Sesbania added 84 and 60 per cent more N, respectively, than that of Pueraria. This points to the fact that the mineralization from the green manure is a function of total N of the material added to the soil.

The C:N ratio of the material added to the soil is also responsible for varying mineralization rates. When the carbon content of a plant material shows little variation, the N content is very much depending on the growth habit, stage of the crop, N uptake etc. and consequently the C:N ratio varies. The C:N ratio of Sesbania and Crotolaria were narrow and the same of 23:1 observed in the case of Pueraria was not in favour of the mineralization process. Frankenberger and Abdel-majid (1985) reported the C:N ratio 19:1 as the upper limit favouring mineralization. Singh *et al.* (1992) also reported that organic residues with wide C:N ratio often have a slow rate of decomposition.

Table 18. Mineral ^{15}N extracted from red soil amended with ^{15}N labelled greenmanure at different intervals of incubation

	Days after incorporation					
	1	5	10	15	30	60
	Ammonium - ^{15}N mg per 100 g soil					
Sesbania aculeata	1.06	17.90	18.12	10.68	14.69	5.01
Crotolaria striata	0.48	14.52	32.01	11.70	27.27	10.47
Pueraria phaseoloides	0.85	5.02	5.36	5.07	3.41	1.35
CD (0.05)	NS	2.94	3.91	4.91	7.54	2.18
	Nitrate - ^{15}N mg per 100 g soil					
Sesbania aculeata	0.11	5.14	2.64	2.94	3.32	3.26
Crotolaria striata	0.07	5.50	3.60	4.06	2.46	5.31
Pueraria phaseoloides	0.03	1.07	1.08	0.73	0.92	0.58
CD (0.05)	NS	1.84	0.55	0.48	0.65	1.05

Table 19. Mineral ^{15}N extracted from laterite soil amended with ^{15}N labelled greenmanure at different intervals of incubation

	Days after incorporation					
	1	5	10	15	30	60
	Ammonium - ^{15}N mg per 100 g soil					
Sesbania aculeata	0.81	6.54	12.89	6.02	3.97	1.91
Crotolaria striata	1.05	10.49	12.80	9.68	4.75	2.38
Pueraria phaseoloides	0.95	4.13	4.52	1.77	1.92	1.14
CD (0.05)	NS	3.31	4.85	4.85	1.87	NS
	Nitrate - ^{15}N mg per 100 g soil					
Sesbania aculeata	0.11	3.44	3.62	0.71	0.68	0.65
Crotolaria striata	0.05	3.32	4.91	0.82	0.71	0.70
Pueraria phaseoloides	0.04	1.07	0.59	0.48	0.51	0.48
CD (0.05)	NS	1.18	1.40	NS	NS	NS

The $^{15}NH_4$ -N release from all the three green manures reached the peak by 10th day of incubation and then declined in both the soil types. However, in red soils the mineralization showed a second peak on 30th day. The first peak observed on the 10th day irrespective of the green manures and soil types may be due to the fast decomposition of easily decomposible tissues like leaves. Beri *et al.* (1989) reported that about 40 per cent mineralization was taking place in the first two weeks of incubation since the green manaure crops contain probably higher hot water soluble fraction in leaves. The second peak was observed with the decomposition of tissues which are more resistant to decomposition and controlled heavily by soil characteristics.

The possible fate of NH_4-N in soil incubation is its conversion to nitrate through nitrification, losses through ammonia volatalization and fixation in the form non-extractable by KCl. There is enough room for assuming the loss of mineralized $^{15}NH_4$-N through volatalization or fixation in soil. Since the decline in the quantity of extractable $^{15}NH_4$ after 10 to 15 days incubation is not in proportion to the quantity of $^{15}NO_3$ formed as seen in Table 18 and 19. Makarov and Grerashchenko (1981) suggested that ammonia volatalization loss can be occurred with increasing rate of ammonium salts formed or increased production of ammonium from mineralization of organic sources. Manguiat and Broadbent (1977) reported that clay fixation may reduce availability of ammonium and limit nitrification irrespective of the green manures and soil types. Under aerobic and anaerobic soil conditions, organic nitrogen is converted to ammonium-N. Under aerobic conditions it can be oxidised to nitrate. Though the incubation was done under aerobic situation, the soil water contents varied from drying to full saturation at times. Loss of nitrogen through sequential nitrification and denitrification is referred to be high when soil undergoes alternate wetting and drying (Reddy and Patrick, 1975). In upland soil condition, which is supposed to be aerobic, there is frequently an intra-aggregate air filled porosity surrounding intra-aggregate water filled porosity (Craswell and Martin, 1974) which results in more or less anerobic zones, permitting denitrification. Denitrifying activity is highly correlated with water extractable organic carbon (Burford and Bremner, 1975) and addition of green matter which is a source of extractable organic carbon also might have contributed to denitrification and loss of nitrate subsequently.

4.2.3 Green manure - N mineralization as influenced by soil types

Eventhough the trend in the decomposition and mineral N accumulation was similar for Sesbania and Pueraria it greatly varied in absolute quantities in red and laterite soils. For Crotolaria, both the trend and quantity of mineral N accumulated varied in these two soil types (Table 20). The mineralization of green manure N took place at a lower rate in laterite soils, in general. This is more evident from the graphical representation of percentage of ^{15}N release to the total N added by the various green manures (Fig. 5, 6 and 7). The initial total N status (Table 20) or the available N status in terms of NH_4-N + NO_3-N on the first day of incubation (Table 21) may not be the reason for different mineralization pattern as usually thought since both the total N and available N are less in red soil where mineralization is more and fast. The available N status of control soil where no labelled green manaure was added also showed little variation between laterite and red soils during different observation periods (Table 21). Hence it is assumed that the other physico-

Table 20. Total mineral ^{15}N ($^{15}NH_4$ + $^{15}NO_3$) extracted from red and laterite soils amended with ^{15}N labelled green manure at different intervals of incubation (mg per 100 g soil)

Soil	Green manure	Days after incorporation					
		1	5	10	15	30	60
Red soil	*S. aculeata*	1.17	23.12	20.76	13.62	18.01	8.77
	C. striata	0.55	20.02	35.61	15.76	29.73	15.78
	P. phaseoloides	0.88	6.09	6.44	5.80	4.33	1.93
Mean		0.87	16.41	20.94	11.73	17.36	8.66
CD (0.05)		NS	5.18	9.32	4.38	7.10	5.38
Laterite soil	*S. aculeata*	0.92	9.98	16.51	6.73	4.65	2.56
	C. striata	1.10	13.81	17.71	10.50	5.46	3.06
	P. phaseoloides	0.99	5.20	5.11	2.25	2.43	1.62
Mean		1.00	9.62	13.11	6.49	4.18	2.41
CD (0.05)		NS	2.69	3.12	2.58	NS	NS

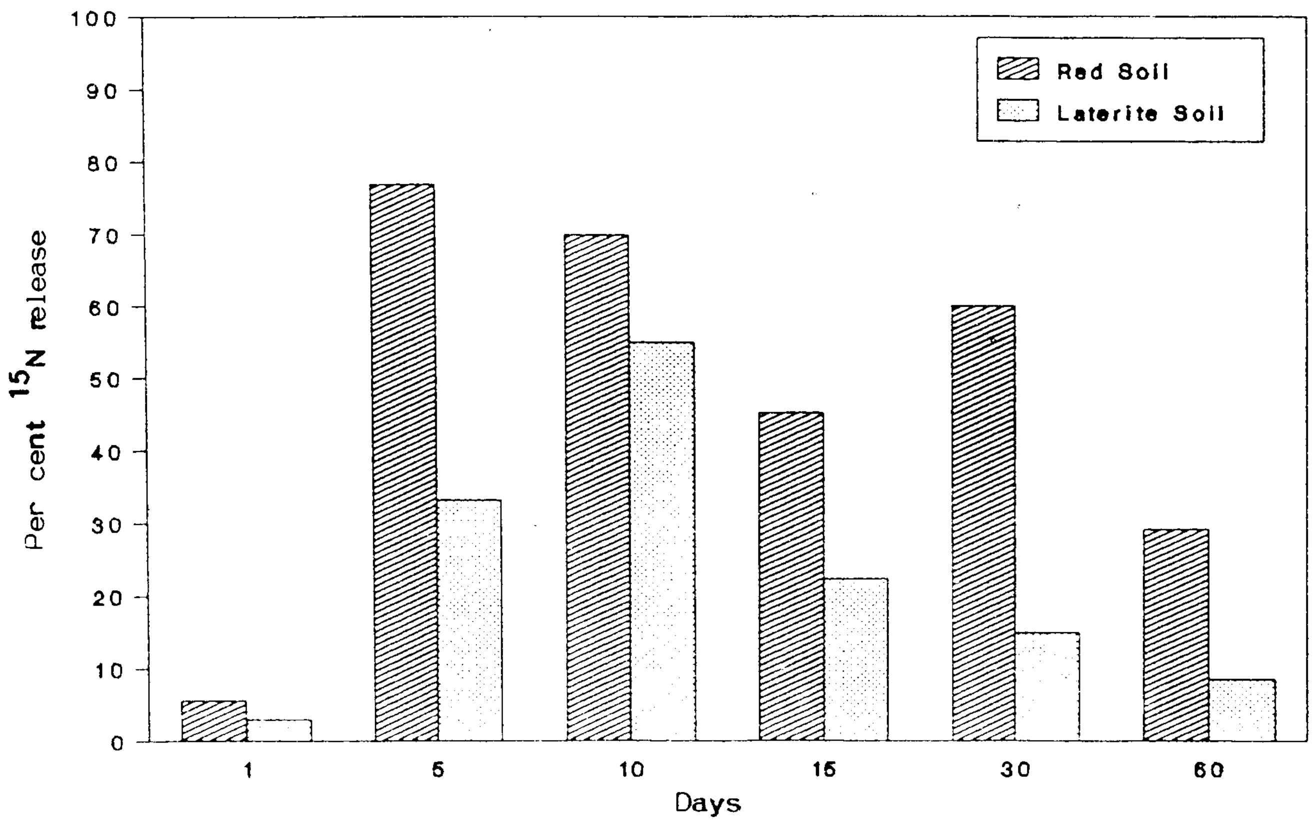

Fig.5. Percentage of ^{15}N release from Sesbania aculeata in red soil and laterite soil at different intervals of incubation

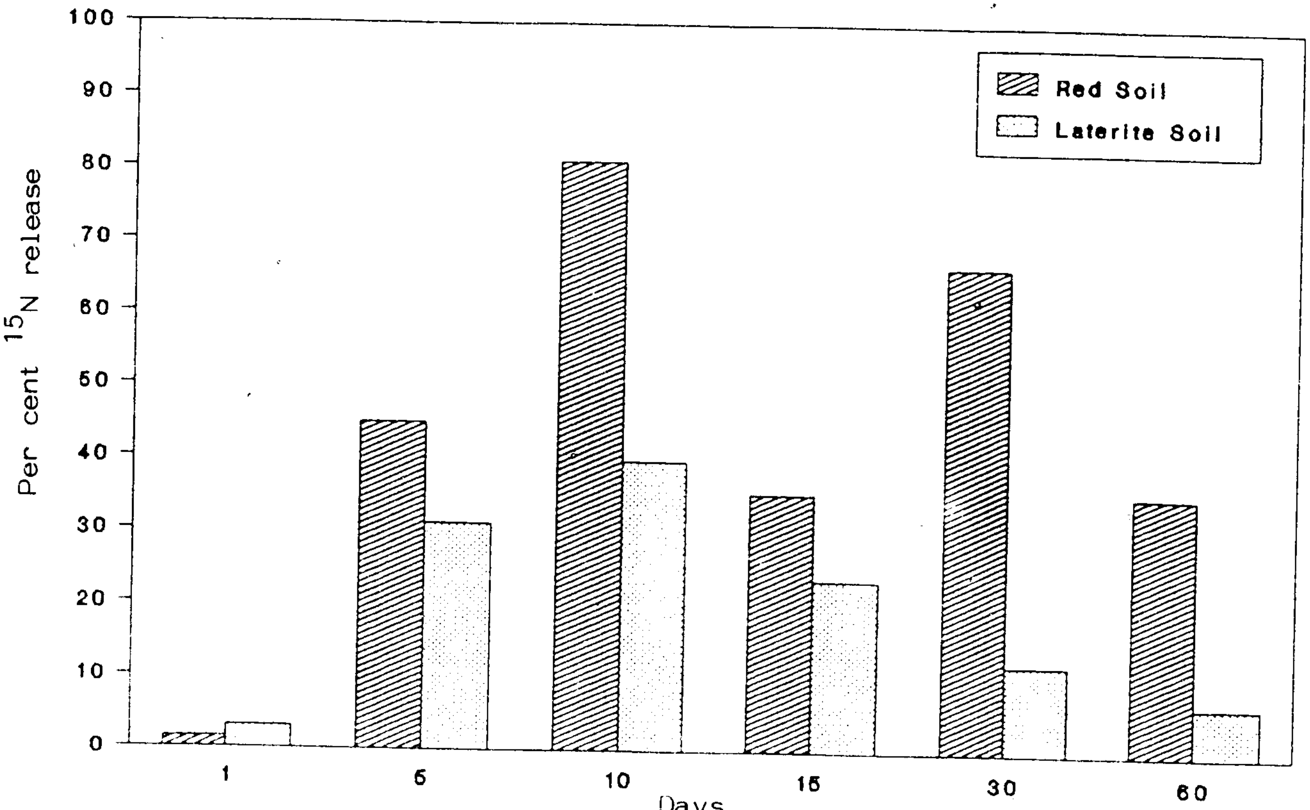

Fig.6. Percentage of ^{15}N release from Crotolaria striata in red soil and laterite soil at different intervals of incubation

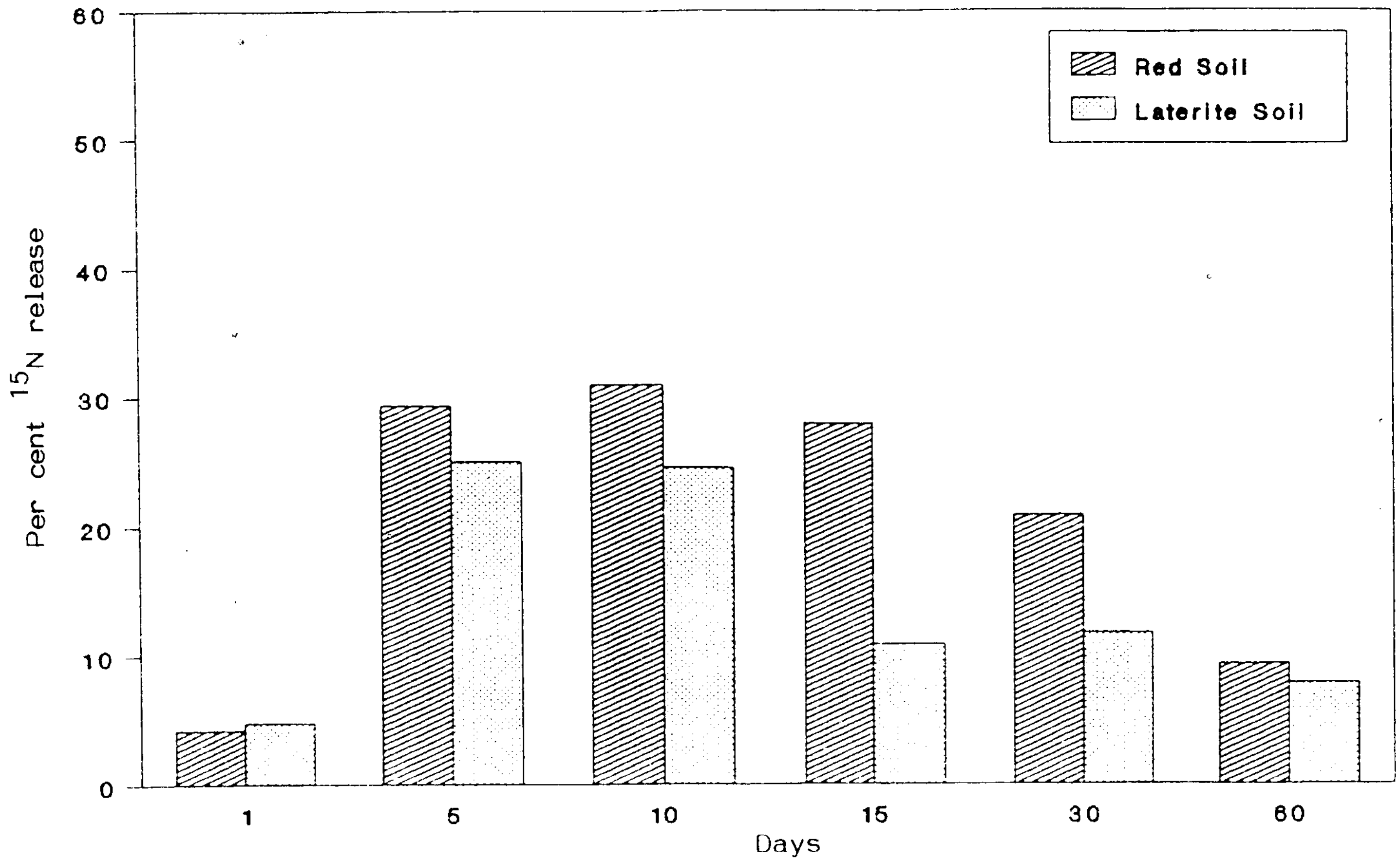

Fig.7. Percentage of ^{15}N release from Pueraria phaseoloides in red soil and laterite soil at different intervals of incubation

Tabie 21. Mineral N extracted from red and laterite soils not amended with green manure at different intervals of incubation

Soil	Mineral N (ppm)	Days after incubation					
		1	5	10	15	30	60
Red soil	NH_4-N	4.5	4.8	5.6	4.1	3.9	4.4
	NO_3-N	1.3	2.5	2.6	2.6	2.3	2.5
	Total	5.8	7.3	8.2	6.7	6.2	6.9
Laterite soil	NH_4-N	5.5	5.8	5.3	5.0	3.9	4.8
	NO_3-N	2.5	2.9	2.2	4.4	3.2	8.1
	Total	8.0	8.7	7.5	9.4	7.1	12.9

chemical characteristics are more important in controlling mineralization and maintaining mineral N status of soil amended with green manures. These two soil types differ much in characteristics like pH, clay content etc.

Red soils used in this study has comparatively higher pH value and lower clay content than laterite soils. The decomposition of green manures is slow in soils with low pH values (Lin and Wen, 1990). There are various reports that organic residues decompose more slowly in soils with high clay contents (Allison, 1973; Sorensen, 1975 and Zhu *et al.*, 1984). The difference in pH and clay content might have contributed to the higher rate of mineralization in red soils than in laterite soils.

The $^{15}NO_3$ content in the laterite soil was relatively less than in red soil (Table 18 and 19). Ammonium may be present in dissolved form in soil solution, in exchangeable form adsorbed to soil colloids and non-exchangeable or fixed form in the interlayers of silicated clay minerals. Manguiat and Broadbent (1977) reported that clay fixation may reduce the availability of ammonium and limit nitrification. Laterite soil used in this study had higher clay content and that might have limited nitrification. Mathew (1986) and Zachariah (1980) reported a total lack of nitrification process in laterite soil. Further Rekha (1993) observed very low rate of nitification taking place in laterite soil.

Summary

SUMMARY

Experiments were conducted under field and laboratory conditions to evaluate the performance of various green manure crops grown in coconut basins and the mineralization of green manure N.

Experiment-1

Eight green manure crops were grown in coconut basins and their growth and N mineralization after incorporation into soil was compared with a control. Green manure crops like *Sesbania aculeata, Sesbania speciosa* and *Crotolaria juncea* represented the popular green manure crops, *Crotolaria striata* and *Cassia tora* represented the neglected green manure crops and *Pueraria phaseoloides, Calapagonium mucanoides* and *Mimosa invisa* represented the popular cover crops. At the peak flowering stage of various green manure crops, the plants were harvested, cut into small pieces and then incorporated in the respective basins.

Green manure crops like *Sesbania aculeata, Crotolaria striata, Cassia tora* and cover crops like *Calapagonium mucanoides, Pueraria phaseoloides* and *Mimosa invisa* were established well under coconuts in the basins. On dry weight basis *Crotolaria striata* produced the maximum biomass of 3.77 kg per basin among the green manure crops and *Pueraria* accumulated the maximum biomass of 4.6 kg per basin among cover crops.

The N content in the various treatments was found to vary from 2.1 to 4.4 per cent with the highest value in Pueraria and the lowest on *Crotolaria juncea*. The P content varied from 0.28 to 0.43 per cent with the highest value associated

with *Cassia tora* and the lowest with *Mimosa invisa*. The K content varied from 1.8 to 3.2 per cent with the highest value of 3.2 in *Cassia tora* and *Sesbania aculeata*. All the green manure crops tried were found to contain moderate amounts of micronutrients.

The maximum nitrogen addition to the soil was found to be with Pueraria followed by *Crotolaria striata* and the mean values obtained were 202.40 and 158.47 g per basin, respectively. *Crotolaria juncea* added only 23.10 g N per basin. The highest values of phosphorus accretion were associated with *Pueraria phaseolodes*, *Crotolaria striata* and *Cassia tora*. In the case of potassium, except *Sesbania speciosa* and *Crotolaria juncea* all the other crops released almost equal quantities to soil.

Ammonium and nitrate-N in 0 to 10 cm and 15 to 30 cm soil depth was determined at 20, 40, 60, 80, 100 and 120 days after incorporation of green manures.

Sesbania aculeata among the popular green manures, *Crotolaria striata* among the neglected green manures and *Pueraria phaseoloides* among the cover crops were found to mineralize ammonium-N in the 0 to 15 cm soil layer for a relatively longer period of 60 days and in comparatively greater quantities. The ammonium-N accumulation in the 15 to 30 cm soil layer was found to be low. Pueraria released the maximum amount of ammonium N upto 60 days of incorporation and after that the value became almost similar. The total ammonium-N content in 0 to 30 cm soil layer followed similar pattern of that in 0 to 15 cm. *Crotolaria striata* and Pueraria released the highest amounts of ammonium-N and the lowest values were obtained with *Crotolaria juncea*.

Pueraria maintained the highest status of nitrate-N in the 0 to 15 cm soil layer, very closely followed by *Crotolaria striata*. Treatments like *Crotolaria striata, Pueraria, Calapagonium* and *Mimosa* were significantly efficient in retaining the nitrate-N status of the soil in 15 to 30 cm layer at a higher level compared to control. With regard to the total nitrate-N, Pueraria was found to be the most efficient closely followed by *Crotolaria striata*.

The quantity of mineral N (ammonium + nitrate) extracted from the green manure amended soils was also determined upto 40 days of incorporation, maximum extractable mineral N was obtained with *Crotolaria striata* in the 0 to 15 cm soil layer closely followed by Pueraria and after 40 days the trend became reversed. The quantity of N released in the 15 to 30 cm soil layer was found to be less than that distributed in the upper zones. Highest values were found to be for cover crops like Pueraria and Calapagonium closely followed by Mimosa and *Crotolaria striata*. All the green manure crops except *Crotolaria juncea* released significantly higher amounts of nitrogen to the soil in 0 to 30 cm layer compared to the no green manure amended plot.

The highest quantity of available phosphorus was observed in *Crotolaria striata* and it was more than three fold as that of control. *Sesbania aculeata, Sesbania speciosa, Cassia tora*, Pueraria and Calapagonium were found to release significant amounts of potassium to soil compared to other treatments.

It is to be concluded that crops with high biomass accumulation and nutrient release like *Pueraria phaseoloides* and *Crotolaria striata* were proved to be the best to be grown in coconut basins for green manuring.

Experiment-2

An incubation experiment was conducted to study the mineralization of green manure-N in red and laterite soils. *Sesbania aculeata* - a popular green manure, *Crotolaria striata* - a neglected hardy green manure and *Pueraria phaseoloides* - a common cover crop were lebelled with ^{15}N and incubated after incorporation at 2 per cent by weight of soil under aerobic condition for 60 days.

Crotolaria contained 2.82 per cent N while Sesbania and Pueraria contained only 2.45 and 1.53 per cent, respectively. The C:N ratio of these crops showed variations ranging from 14:1 to 23:1.

The ^{15}N enrichment also varied with per cent atom excess of 10.46 for Pueraria, 12.45 for Sesbania and 13.38 for Crotolaria.

The N release in terms of $^{15}NH_4$ extracted during different periods of incubation was highest for Crotolaria followed by Sesbania. N release from Pueraria was significantly less than the above green manures at all times of observation. Crotolaria and Sesbania added 85 and 60 per cent more N respectively than that of Pueraria. The $^{15}NH_4$-N release from all the three green manure reached the peak by tenth day of incubation and then declined in both soil types. However, in red soils, the mineralization showed a second peak on 30th day also.

The $^{15}NO_3$-N contents were low compared to $^{15}NH_4$-N showing low rates of nitrification. This may be due to losses of ammonium by volatalization or clay fixation or the conditions may not be favourable for nitrification. Another reason that can be attributed is loss of formed nitrate by denitrification.

The mineralization of green manure nitrogen took place at a lower rate in laterite soil, in general. The difference in pH and clay content might have contributed to the higher rate of mineralization in red soils than in laterite soils.

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* Originals not seen

Appendices

Appendix I

Weather data (weekly average) for the experimental period

Standard Week No.	Month and Date	Total rainfall (mm)	No. of rainy days	Temperature Max. °C	Temperature Min. °C	Relative humidity Forenoon%	Relative humidity Afternoon%	Sun shine hours	Evaporation mm/day
23	Jun 4-10	236.6	6	29.6	23.3	95	80	1.8	3.5
24	Jun 11-17	237.9	7	29.2	23.8	95	80	1.8	3.5
25	Jun 18-24	85.5	4	30.4	24.5	94	73	4.4	3.8
26	Jun 25-Jul1	186.4	5	29.2	23.6	94	82	2.9	3.3
27	July 2-8	188.9	6	28.6	22.7	95	78	2.0	3.1
28	July 9-15	167.8	7	28.7	22.6	92	83	1.8	3.1
29	July 16-22	128.1	6	28.9	22.9	94	76	2.8	2.9
30	July 23-29	101.0	6	28.0	23.1	94	80	2.9	3.1
31	July 30-Aug 5	96.4	6	29.1	23.7	95	76	3.6	3.8
32	Aug 6-12	54.9	4	29.9	23.5	95	75	4.6	3.9
33	Aug 13-19	66.3	6	29.2	23.1	93	78	3.3	3.7
34	Aug 20-26	61.9	4	29.8	23.2	96	74	5.6	4.0
35	Aug 27-Sept 2	33.6	2	29.8	23.5	95	73	6.5	3.4
36	Sept 3-9	23.7	2	29.4	23.0	93	75	3.9	3.05
37	Sept 10-16	11.5	1	30.7	23.1	93	69	7.5	3.45
38	Sept 17-23	23.2	3	31.7	23.4	94	63	8.3	4.1
39	Sept 24-30	14.9	1	31.0	23.2	91	65	6.7	3.9
40	Oct 1-6	149.8	6	29.8	23.4	93	82	3.8	2.9
41	Oct 7-13	181.5	5	29.3	23.2	95	78	2.1	2.5
42	Oct 14-20	102.7	4	31.2	23.2	90	74	4.9	2.8
43	Oct 21-27	83.4	2	31.9	23.5	92	72	6.3	2.8
44	Oct 28-Nov 4	3.2	0	32.5	24.2	80	63	7.1	3.8
45	Nov 5-11	58.3	3	30.4	23.9	84	70	4.0	3.5
46	Nov 12-18	12.7	2	31.8	23.0	91	66	5.6	3.0
47	Nov 19-25	1.2	0	31.8	23.1	72	54	7.6	4.6
48	Nov 26-Dec2	0.8	0	31.4	24.3	77	60	5.8	5.7
49	Dec 3-9	17.0	2	31.2	22.7	84	62	3.4	3.4
50	Dec 10-16	0.0	0	32.5	21.9	75	47	5.1	5.05
51	Dec 17-23	1.0	0	31.0	23.8	75	59	5.5	5.6
52	Dec 24-31	0.0	0	31.6	23.5	72	47	6.1	6.1
1	Jan 1-7	0.0	0	32.6	23.6	69	44	10.0	7.5
2	Jan 8-14	0.0	0	32.2	22.7	73	43	9.0	7.3
3	Jan 15-21	19.4	1	33.6	23.7	83	49	7.7	4.9
4	Jan 22-28	0.0	0	32.8	22.0	65	32	9.2	9.7
5	Jan 29-Feb 4	0.0	0	33.9	21.0	81	37	9.8	5.9
6	Feb 5-11	0.0	0	34.6	23.8	17	43	7.8	6.3
7	Feb 12-18	1.7	0	34.4	23.1	86	45	8.2	4.7
8	Feb 19-25	0.0	0	35.7	23.0	83	36	7.8	6.1
9	Feb 26-Mar 4	0.0	0	35.8	22.5	56	20	10.2	8.8
10	Mar 5-11	0.0	0	37.2	21.8	71	20	10.1	7.2
11	Mar 12-18	0.0	0	37.4	23.7	83	36	9.8	6.8
12	Mar 19-25	1.2	0	35.2	25.4	90	55	8.8	5.8
13	Mar 26-Ap 1	19.8	1	35.4	25.4	86	57	8.3	5.6
14	Ap 2-8	37.1	3	35.8	23.5	85	54	8.3	5.1
15	Ap 9-15	79.8	4	34.8	23.7	90	58	6.1	4.9
16	Ap 16-22	27.6	[illegible]	34.3	24.5	89	61	8.5	4.4
17	Ap 23-29	20.7	1	34.6	25.3	86	63	7.0	4.5
18	Ap 30-May 6	0.0	0	34.3	25.0	85	58	10.2	5.1
19	May 7-13	11.6	1	34.1	25.2	84	58	9.0	4.6
20	May 14-20	82.2	2	34.0	24.6	92	62	7.5	4.5
21	May 21-27	3.5	0	33.9	25.3	89	62	7.6	4.3
22	May 27-Jun3	171.8	7	30.2	22.8	95	80	0.0	2.6

Appendix-2

Layout of the Experiment

*32 Control	*46 Sesbania aculeata	*60 Cassia tora	*74 Calapagonium	*88 Pueraria	*102 Control
*33 Crotolaria juncea	*47 Sesbania speciosa	*61 Crotolaria juncea	*75 Sesbania speciosa	*89 Sesbania aculeata	*103 Crotolaria striata
*34 Crotolaria striata	*48 Pueraria	*62 Pueraria	*76 Control	*90 Sesbania speciosa	*104
*35 Mimosa	*49 Calapa-gonium	*63 Mimosa	*77 Mimosa	*91 Crotolaria juncea	*105
*36 Cassia tora	*50 Crotolaria striata	*64 Sesbania aculeata	*78 Cassia tora	*92 Calapagonium	*106

* palm number

BIOMASS PRODUCTION OF GREEN MANURE CROPS AND MINERALIZATION OF ORGANIC NITROGEN IN COCONUT BASINS

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation on the biomass accumulation of green manure crops and mineralization of organic nitrogen in coconut basins was conducted at the College of Horticulture, Vellanikkara, during 1993-94. The experiment was aimed at evaluating the performance of various green manures and cover crops grown in coconut basins based on their biomass accumulation, nutrient accretion and nitrogen dynamics in the soil after incorporation. The mineralization pattern of green manure in red and laterite soils was studied in a laboratory incubation study using ^{15}N labelled green manure. The salient results of the investigation are abstracted below.

Crotolaria striata which represented the neglected green manures and *Pueraria phaseoloides* which represented the cover crops produces the maximum dry matter in coconut basins. The popular green manure *Crotolaria juncea* failed to grow and put forth good biomass accumulation under coconut. The highest N content was found to be with Pueraria. *Cassia tora* was found to be the richest source of P. The maximum K content was reported in *Cassia tora* and *Sesbania aculeata*. *Pueraria phaseoloides* and *Crotolaria striata* released the maximum quantity of nitrogen to the soil.

The ammonium - N accumulation was found to be high in the upper layer of 0 to 15 cm soil when compared to the 0 to 30 cm soil layer. *Crotolaria striata* and Pueraria released the highest amounts of ammonium - N. In the release of nitrate - N, Pueraria was found to be the most efficient closely followed by *Crotolaria striata*. In the case of total mineral N (ammonium + nitrate) content the highest quantity was extracted with *Crotolaria striata* followed by Pueraria.

In the incubation experiment to study the pattern of mineralization green manure N, the N release in terms of $^{15}NH_4$ extracted during different periods of incubation was the highest for *Crotolaria striata* followed by *Sesbania aculeata*. The mineralization of green manure ^{15}N took place at a lower rate in laterite soil when compared to red soil.