NUTRIENT CONTENT AND DECOMPOSITION OF LEAF LITTER OF *Acacia mangium* WILLD. AS AFFECTED BY SEASON AND FIELD CONDITIONS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Forestry

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Vellanikkara, Thrissur
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1995

DECLARATION

I hereby declare that this thesis entitled ***Nutrient content and decomposition of leaf litter of Acacia mangium Willd as affected by season and field conditions*** *is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society*

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✿ DEDICATED TO PARENTS ✿

It's their trust that

I strive to achieve today

and in their mirth lie

my tomorrows....

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Introduction

INTRODUCTION

Some of the common land use practices such as intensive use of inorganic fertilizers, unscientific manurial and fertilization practices, cropping systems and lack of proper soil conservation measures have adversely affected the fertility status, structure, and other physico-chemical properties of the soil which eventually lead to degradation of fertile land and making it unproductive The adoption of some of the simple soil conservation measures like organic mulching and use of organic manures particularly leaves, could not only conserve the soil but also improve its productivity

Litter production and the decomposition are the two primary mechanisms through which the nutrient pool in the forest ecosystem is maintained A large quantity of leaf litters are produced in tropical forests Leaf litter from the trees and shrubs are reported to retain a considerable portion of most of the plant nutrients When the leaf falls on the ground and gets incorporated into the soil, will decompose releasing most of the nutrients This will act as a potential source for both macro and micro nutrients to other plants

Unlike commercially manufactured products, leaf litter does not carry any label giving specification regarding its chemical composition and quality This could be the hinderance in situations where leaf litter incorporation play a paramount role in the crop production programmes especially in small scale and low input technology systems The practice of leaf litter application is having an added advantage as it is largely based on local and accessible resources Extensive use of these materials will certainly improve the nutrient status of the soil without any deleterious effect on the physico-chemical properties of the soil The study on the rate of decomposition of leaf litter, nutrient release pattern and improvement of nutrients due to mineralisation from decomposing litter mass is expected to throw some light in recommending a manurial package in various agroecosystems

Acacia mangium Willd is one of the fast growing nitrogen fixing leguminous tree species It is one of the most promising species in tropical agroforestry systems Of late, this tree species has assumed lot of importance in extensive planting programmes both in homesteads as well as avenues The timber is also reported to be quite comparable with other accepted timbers with regard to the quality

The present study was conducted to determine the rate of litter decomposition of *Acacia mangium* during south west monsoon and north east monsoon seasons The study also aims at assessing the nutrient release pattern and addition of nutrients to the soil through the process of litter decomposition

Review of Literature

REVIEW OF LITERATURE

Physical and chemical properties of the soil can be improved by incorporation of leaf litters produced by trees and shrubs which when added to soil will improve both major and minor nutrients through the process of mineralisation Studies on mineralisation have indicated that the substrate quality, climatic variables and soil organisms are the most important factors influencing the process of decomposition The literature on some of the important factors pertaining to the decomposition of leaf mass of various tree species are reviewed and presented here under

2.1 Leaf litter decomposition

The tropical broad leaved trees are reported to retain a considerable portion of the nutrient capital incorporated in the leaf biomass (Whitmore, 1984 and Vogt *et al* , 1986) Decomposition of litter and the release of nutrients are therefore an important aspect in maintaining the fertility status of the soil (Jordan and Herrera, 1981, Vitousek, 1981 and Anderson and Swift, 1983)

It is a well established that the use of leaf biomass by farmers in developing countries has not only increased the crop yield by many folds, but also improved the physico-chemical attributes of the soil

2.1.1 Litter decomposition studies in forest ecosystem

Litter fall and decomposition are the two primary mechanisms by which a stable nutrient content of the forest ecosystem is maintained The litter on the forest floor is reported to act as an input - output system for nutrients (Das and Ramakrishnan, 1985) The rates at which the litter falls and subsequently decays regulate the energy flow, primary productivity and nutrient cycling in forest ecosystems (Waring and Schlesinger, 1985) Litter dynamics studies are reported to be very important in the nutrition budgeting in tropical forest ecosystems where vegetation depends on the recycling of nutrients contained in the plant detritus (Singh, 1968, Cole and Johnson, 1978 and Prichet and Fisher, 1987)

A number of studies were seen to be done on various aspects of litter dynamics in tropical and temperate forest ecosystem This includes the studies by Madge (1965),Venkataraman *et al* , (1983), Pande and Sharma (1986), Gill *et al* , (1987), Pascal (1988), Sugur (1989), Harmon *et al* , (1990), Kumar and Deepu (1992) and Sankaran *et al* , (1993)

Litter decomposition is the primary mechanism by which organic matter and nutrients are returned to the soil for the reabsorption by the plants (Aber and Melillo, 1980) Nutrients in the decomposing organic matter are released to the ecosystem by a variety of physical and biological processes (Ebermayer, 1976)

2.1.2. Litter decomposition studies in agroecosystem

The addition of nutrients in an agroecosystem through the process of decomposition of leaf litter is an important factor to be considered for nutrient budgeting The tree component in any agroecosystem plays an important role in biomass production In properly designed agroforestry systems, the loss in organic matter through the agricultural crop component is compensated by a gain through the tree component Farmers in tropical developing countries are applying various soil amendments such as leaf litter or leaf mulch, green manures, crop residues etc to improve the soil fertility

Studies conducted on decomposition of leaves of six multipurpose tree species in maize field at Chipata, in Zambia by Mwiinga *et al* (1994) revealed significant differences in the rate of decomposition among the species Among the six species tried, *Gliricidia sepium* decomposed at a faster rate followed by *Leucaena leucocephala, Sesbania sesban, Cassia siamea, Pericopsis angolensis* and *Flemingia congesta*

Kunhamu (1994) conducted studies on the nutrient content and decomposition of leaf biomass of selected woody species in selected home gardens of Vellanikkara, Trichur The study showed significant differences in the rate of decomposition of different species He reported that among the major nutrients present in the decomposing leaves, potassium mineralised faster compared to other elements

It is apparent that the trees used in agroforestry systems vary widely in their quality and rates of decomposition Leaves of *Leucaena leucocephala* decomposed within few weeks while those of *Cassia siamea* at an intermediate rate The litters of *Gmelina arborea* *Acacia mangium* and *Eucalyptus* recorded relatively slower rate of decomposition (Wilson *et al* 1986)

Yamoah *et al* (1986) conducted a leaf decomposition study using the prunings of various tree species under uniform conditions of climate and soil at Ibadan, Nigeria The decomposition rate was found to be maximum for *Leucaena leucocephala* followed by *Gliricidia sepium* *Cassia siamea* and *Flemingia congesta* Arias (1988) compared the decay rates of common tree component in various agroecosystems in Colombia The half life of litter was 60 days for *Albizia carbonaria* 80 days each for *Gliricidia sepium* and *Sesbania grandiflora* 120 days each for *Erythrina* sp and *Cajanus cajan* and 170 days for *Cassia grandis* In the case of albizia, sesbania and gliricidia over 80 per cent of N P and K were released within 170 days

Decomposition studies in a tropical agroforestry system revealed that during 274 day of exposure of litter in the field, the mass loss in *Leucaena* sp , *Populus deltoides*, *Prosopis juliflora and Eucalyptus sp* was 86 3 75 6, 69 0 and 60 5 per cent respectively (Bharadwaj *et al* 1992)

2.1.3 Rate of decomposition

A wide variety of species have been evaluated in terms of the relative rate of decomposition Earlier studies revealed that litter of different species do not decompose at the same rate even under similar environmental conditions (Alexander, 1977, Kunhamu, 1994 and Mwiinga *et al* , 1994)

2 1 3 1 Effect of ecological and environmental factors on the rate of decomposition

The rate of decomposition of leaf biomass varies with the quality of the plant material and prevailing environmental conditions The decomposition rates are reported to be higher ranging from 0 45 to 1 15 per cent per day in tropical forests (Olson, 1963 and Cornforth, 1970), whereas litter decay rate in temperate forest is reported to be at a slower rate The lowest rates of decomposition have been reported for California pine forests ranging from one to three per cent per annum (Olson, 1963) However, in general, the decomposition rates in coniferous forests are reported to range from 11 to 30 per cent per annum (Mikola, 1954 and Crosby,1961) Even in temperate forests, the rate of decomposition is found to be relatively higher for broad leaf litter as compared to conifer litter (Bray and Gorham, 1964)

Hopkins (1966) compared the rates of leaf decomposition under varying environmental conditions While it is taking only

0 1 to 0 6 years far complete decomposition in moist semideciduous and moist semi evergreen forests in tropical environment, it is taking more or less one year in temperate deciduous forests (Ovington, 1962), 1 6 years in subtropical forests, three to five years in coniferous forests of Britain (Jenney *et al* , 1949) and as many as 28 to 60 years in high mountain oak and pine forests of California (Ovington, 1962)

Upadhyay and Singh (1989) conducted decay studies using litters of *Quercus langinosa* and *Pinus roxburghii* and reported that after a period of one year, the per cent weight remaining was 48 7 and 32 1 respectively for *P roxburghii* and *Q langinosa*, indicating the fact that the leaves of subtropical and temperate trees decomposes slowly even at the tropical condition owing to their inherent resistance to microbial activity

Lee and Young (1985) compared the decay rates of *Shorea curtisii* and *Pinus carabaea* under evergreen dipterocarp forests and pine forests in Malayasia After 16 weeks of observation, weight loss was 39 and 19 5 per cent for shorea in dipterocarp and pine forests respectively, whereas the respective figures for pine was 13 6 and 10 3 per cent Singh (1969) reported that generally three to five months were required for complete decomposition of leaf litter The decomposition studies conducted in moist deciduous forests of Western Ghats of peninsular India indicated that the leaf litter of various tree species decomposed within five to eight months (Kumar and Deepu, 1992)

It is already reported that the rate of decomposition of the organic matter incorporated into the soil is also governed by various ecological and environmental factors These factors that influence the decomposition can be grouped as abiotic and biotic factors

2 1 3 1 1 Abiotic factors

Soil moisture, atmospheric temperature and soil temperature are reported to be the paramount abiotic factors controlling the rate of decay under natural conditions (Van Der Dritt, 1963, Singh and Gupta, 1977, Singh and Joshi, 1982 and Moore, 1986)

(a) Soil moisture

Soil moisture is one of the important factors to be considered in biomass decomposition studies Madge (1965) found a positive influence of soil moisture in controlling the activities of soil organism, particularly arthropods Gupta and Singh (1977) found highest disappearance at the rate of 36.25 to 52 85 per cent from July to October, when there was maximum rainfall They also observed a weight loss of only 14 78 to 25 5 per cent during drier periods Moore (1986) reported that the decay rate is a linear function of water potential and approached maximum at a soil temperature of about 40^0 C A high rate of litter decay during rainy season in tropical condition has also been observed by Singh *et al*, (1980)

Sankaran *et al* (1993) reported that the maximum weight loss in acacia leaf litter occurred in September to November during north east monsoon period in Kerala, India Sankaran (1993) conducted studies of decomposition of leaf litter of *Paraserianthus falcataria*, *Eucalyptus tereticornis* and *Tectona grandis* in Kerala, and concluded that rainy season provides congenial condition for rapid breakdown of leaf litter

Decomposition studies in a deciduous broad leaved forest indicated that soil moisture conditions have a greater influence on the rate of decomposition compared to chemical composition of the litter (Ishii *et al* , 1982) A linear relationship between mean annual rainfall and decay constant was established by Hutson and Veitch (1985)

Under saturated conditions, the decomposition is dependent on anaerobic organisms which are found to be less efficient compared to aerobics (Yoshida, 1975 and Patrick, 1982) de Boois (1974) found a slower rate of decomposition both under the situations of high moisture content (more than 100%) and low moisture content (less than 30%)

Pascal (1988) observed a low rate of decomposition throughout the dry period in Attapadi forests of Kerala. He reported that with first pre-monsoon showers the decay rate was doubled (k values ranged from 0.12 to 0.31) and with the onset of monsoon the rate of decomposition decreased once again to the level before the rains (0.14). The decomposition rate at the end of the rainy period and before the dry season, indicated that the microbial activity was renewed abruptly to reach the maximum (0.63) which is twice the rate of the pre-monsoon period.

(b) Atmospheric and Soil temperature

Olson (1963) reported the presence of low content of carbon in highly productive tropical forests and high content in cool temperate forests. He further pointed out that in subalpine forests, temperature tended to affect the biological activity, finally resulting in lower rates of biomass decomposition.

Rate of decomposition in warm tropical rain forests was reported to be 8.2 t ha^{-1} yr^{-1} (Wanner, 1970) whereas, in temperate region, the rate was estimated to be less than 1.2 t ha^{-1} yr^{-1} (Douglas and Tedrow, 1959). Floate (1970) observed that the amount of Co_2 evolved over a period of 12 weeks was reduced from an average of 40 per cent of the original carbon content at a temperature of 30^0 C to 25 per cent at 10^0 C and 12 per cent at 5^0 C.

The studies conducted by Inagawa (1972) revealed the importance of temperature on the rate of decomposition in relation to the species and type of leaves Soil temperature is an important factor controlling the growth and microbial activity which are finally responsible for decomposition of organic matter The mesophilic bacteria, actinomycetes and fungi require a temperature below 45^0 C for their optimum activities while thermophilic bacteria require a temperature range of 45^0 C to 60^0 C (Alexander, 1977)

The combined effect of high temperature and moisture is more pronounced than the temperature alone (Jenney *et al* , 1949) In tropical climate they found a heavy weight loss in alfalfa leaves due to high temperature and moisture conditions Singh and Joshi (1982) reported that temperature and moisture have paramount role in enhancing the rate of decomposition and these two factors could be considered as critical environmental parameters resulting high rates of decomposition in sand dune regions of Rajasthan The microbial activity is favoured during summer due to high moisture and temperature thus accelerating the rate of decomposition (Witkamp and Van Der Dritt, 1961)

2.1.3.1.2 Biotic factors

Soil fauna and flora are the biological mediators for soil organic matter transformations The action of these biological mediators on organic matter present in the soil is primarily responsible for the biochemical modifications of organic materials

a) Soil fauna

The action of soil fauna may have a significant influence on the decomposition of litter entering into the soil ecosystem The action may be the physical mixing of the litter within the soil profile, inoculation of the plant litter with decomposer populations, adjustment of the soil physical properties to levels more conducive for organic matter decomposition, physical disintegration of organic matter, direct metabolism of the organic components and stimulation of decomposer populations through interactions which may finally increase or decrease the decomposition rate (Tate, 1987)

Bocock (1964) found that litter decomposition by earth worms and millipedes was more rapid during the initial five months of decomposition These animals accounted 40 per cent of the decomposition of *Fraxinus excelsio* litter Seastedt and Crossley (1983) reported that the soil fauna is not only stimulating the litter decomposition rate but their activity also resulted in increased nutrient concentration of the decomposing litter The animal groups such as earthworms, insects and snails bring about mechanical reduction They bite and eat the organic matter and thus pulverize the material (Rangaswamy and Bagyaraj, 1993)

Butler and Buckerfield (1979) reported that termites have metabolised 63 per cent of maize lignin to CO_2 within 6 to 69 days They also found that the decomposition of lignin occurred in the termites and not externally in their faeces

b) Soil microbes

Soil microbes play a paramount role in the decomposition of litter applied to the soil In the early stages of decomposition, heterotrophic bacteria are highly active. The organic matter has bound energy, and this energy is taken up, at least in part, by the heterotrophic group In the course of breakdown, various intermediary substances are formed The other bacteria, actinomycetes and fungi which are capable of attacking the intermediate products become active and they utilise CO_2 to synthesize various carbon compounds They oxidise sulphur, ammonia etc to obtain energy for the build-up process there by reducing the original organic matter (Rangaswamy and Bagyaraj, 1993)

Sankaran (1993) studied the decomposition pattern in teak, albizia and eucalyptus and isolated the organisms responsible for decomposition He reported that main decomposers were belonging to the group of fungi, bacteria and actinomycetes

2.1 3.2 Effect of species on the rate of decomposition

Litter production and decomposition dynamics in moist deciduous forests of India were studied by Kumar and Deepu (1992) and found that among the six species investigated, litter of *Pterocarpus marsupium* decomposed rapidly Litters of *Tectona grandis, Dillenia pentagyna* and *Terminalia paniculata* recorded slower rate of decomposition compared to *Grewia tiliaefolia* and *Xylia xylocarpa* However, a very fast decay rate was reported for *Tectona grandis* in the dry forests of Western Nigeria by Egunjobi (1974) The complete mineralisation of litter was found to occur within six months

Lisanework and Michelsen (1994) studied the litterfall and nutrient release by decomposition in the Ethiopian highland and found that the litter decomposition of *Eucalyptus globulus* and *Juniperus procera* was faster compared to *Cupressus lusitanica* Bahuguna *et al* (1990) conducted decomposition studies on *Shorea robusta* and *Eucalyptus camaldulensis* plantations at Dehra Dun and reported that at the end of 12 months, *Shorea robusta* showed 65 per cent weight loss whereas *Eucalyptus camaldulensis* lost 85 per cent of the initial weight They concluded that high decay rates in eucalyptus was due to high initial leachability of potassium However, Munshi *et al* (1987) reported that litter of *Shorea robusta* in a deciduous forest in Bihar took 144 days for complete decomposition

Singh *et al* (1993) observed a faster rate of decomposition for *Shorea robusta* and *Tectona grandis* as compared to that of eucalyptus and poplar forests and they reported that the faster rate could be attributed to physical and chemical properties of the leaf litter

O' Connel (1990) conducted laboratory incubation studies using the litter of *Eucalyptus marginata* and *Eucalyptus diversicolor* and found a faster rate of decomposition in case of *Eucalyptus diversicolor* Wylie (1987) found a marked variation in decay rates with respect to species in wet lands of south east Missouri

Litter bag studies in a low land tropical rain forest in North Eastern Queensland, Australia showed that break down rates were maximum for *Eucalyptus alba* followed by *Araucaria cunninghami* and *Pinus carebaea* The first two litter types were found to be highly attracted by arthropods Of the commonly used regression models fitted to the data, exponential models gave a satisfactory fit for all except the resistant litter of *Pinus carebaea* where asymptotic model was found to be more appropriate (Spain and Feuvre, 1987)

Upadhyay and Singh (1989) conducted litter bag studies over two years in five forest ecosystems in U P The species included *Shorea robusta, Mallotus philippensis* and *Rhododendron arboreum* In general, annual weight loss ranged from 47 to 100 per cent for various species They found a significant difference between the species and sites and they concluded that mean annual temperature, altitude and lignin content were the main factors regulating the weight loss and nutrient mineralisation

Sankaran *et al* (1993) studied the decay rates of leaf litter of *Acacia auriculiformis* and observed a significant difference in the rate of decomposition between the sites A faster rate of decomposition was noticed in fertile site compared to degraded areas

Rout and Gupta (1987) studied the leaf biomass decomposition by measuring CO_2 evolution rates from the soil using three deciduous tree species and two shrubs and correlated the decay rates with various chemical constituents of the litter They found a differences in the rates of decomposition among the species and concluded that the concentration of lignin, nitrogen and C N ratio had significant effect on decomposition The study conducted by Kunhamu (1994) in home gardens of Vellanikkara revealed that the rate of decomposition varied with species The lignin concentration of leaf biomass influenced the rate of decomposition

2.1.3.3 Effect of stand age on the rate of decomposition

Bargali *et al* (1993) studied the pattern of decomposition and nutrient release from decomposing litter in eucalyptus plantations of different ages and found a significant difference in decomposition with respect to age and time The rate of decomposition was faster in one year old plantation and the rates decreased with the progress in age The rate of decomposition was significantly correlated with initial nutrient concentration

Edmonds (1979) examined the decomposition rates and changes in nutrient content of needles in a stand of Douglas fir of age sequence of 11, 24, 75 and 97 years in Western Washington Litter bags were collected after 3,6,12 and 24 months The maximum rate of decomposition was observed in the stand of 24 year old

2 1.3 4 Effect of litter quality on the rate of decomposition

The chemical composition of the leaf litter determines the quality of substrate The composition of the decomposing material has long been recognised as a critical factor determining the rates of decomposition (Waksman and Jenney, 1927, Meentemayer, 1978 and Kretzschmar and Ladd, 1993)

2.1 3.4.1 Water soluble substances

Water soluble materials present in the leaf biomass provide readily available energy source for decomposers and therefore said to be highly influential during the initial stages of decomposition (Melin, 1930) Boyd (1970) reported that the initial rapid mass loss phase which was frequently observed in litter decomposition studies was mainly due to the solubalization and subsequent leaching of simple organic substances

Jenney *et al* (1949) found a high initial rate of weight loss of alfalfa leaves followed by lower rates and hence concluded that it could be due to more leaching during initial stages The quantity of water soluble substances in organic matter vary with species The content of water soluble materials in the leaves of *Fraxinus excelsior* was 32 per cent, while, in *Quercus petraea* it was only 18 per cent (Gilbert and Bocock, 1960)

In the Hubbard Brook forest, the intense leaching of soluble organic materials resulted in marked difference in the weight losses of litters of yellow birch sugar mapple and beech leaves by the end of first month (Gosz *et al* , 1973) Lossaint (1953) studied the litter decay of nine species and showed that higher the content of nitrogen and water soluble matter including calcium, the more rapid will be the rate of decomposition

Studies conducted by Berg and Landmark (1987) on the decomposition of scot pine and lodgepole pine revealed that mass loss rates were positively correlated with concentration of water soluble substances and nitrogen and negatively with those of lignin

2 1 3.4 2 Initial nitrogen

Nitrogen content of the plant material has been found to be an important factor controlling the rate of decomposition in most of the species (Cowling and Merril, 1966 and Aber and Melillo, 1980) Jamaludheen (1994) in his studies established a positive relationship between the rate of decomposition with initial nitrogen content of the leaf litter

Kumar and Deepu (1992) stated that nitrogen content of the detritus could be taken as a better predictor of the decay rate constant Constantinides and Fownes (1994) suggested initial nitrogen as the best determinant for the decomposition dynamics of the litter

Fresh plant material vary considerably in their nitrogen content Tropical tree leaf biomass has a higher N content compared to temperate tree leaf biomass (Nye, 1961) Nitrogen content of deciduous leaves is relatively higher than that of conifers (Alway *et al* , 1933) Bahuguna *et al* (1990) found that the higher initial nitrogen content of eucalyptus litter lead to faster decomposition compared to sal which had low initial nitrogen

2.1.3.4 3 Carbon . nitrogen ratio

The C N ratio of plant residue plays a crucial role in biomass decomposition Plant litters with high initial content and low C N ratios are known to decompose rapidly (Singh and Gupta 1977, and Meentemayer, 1978) Fog (1988) established that plant materials with high C N ratio do not provide sufficient nitrogen for metabolism of decomposer populations particularly under condition of rapid microbial activity Barry *et al* (1989) conducted extensive studies using eight species to identify the best predictors of litter decay rates In all the species, they tried to correlate the initial N content, the C N ratio and lignin nitrogen ratio with rate of decomposition They concluded that C N ratio and nitrogen content were the best predictors of mass loss rate

Bondar (1975) conducted a laboratory study in Ukraine to compare the chemical processes in decomposition of scots pine litter at C N ratios of 20, 15 and 10 He observed the highest degree of decomposition at C N ratio of 10 Alexander (1977) reported that C N ratio of 20 1 or narrower will be sufficient to supply nitrogen for the decomposing micro organisms and also to release nitrogen for plant use

Knapp *et al* (1983) suggested that decomposition was regulated by N during the initial period and by C during a prolonged period

2.1.3.4.4 Lignin

Several studies have indicated that compared to nitrogen, the initial lignin content of the litter has more control over the rate of decomposition (Bollen, 1953, Fogel and Cormark, 1977 and Melillo *et al* , 1982)

Tian *et al* (1992) found negative correlations between decomposition rate constants and percentage of lignin content of the plant residues Effect of lignin and nitrogen on the decomposition of litter in nutrient poor ecosystems was studied by Berndse *et al* (1987) They found that lignin content in the decomposing mass had negative correlation with decomposition rate under conditions when both carbon and nitrogen were limiting

Martin *et al* (1980) demonstrated the importance of lignin as a source of structural units by using ^{14}C labelled organic substances They found that the majority of the lignin carbons were incorporated into more resistant or aromatic portions of soil humus The polysaccharide carbon was metabolised and utilized as energy sources for decomposing microflora for synthesis of cellular proteins

2.1.3.4 5 Lignin : nitrogen ratio

The decomposition of uniformly ^{14}C labelled lignin mixed with brown or white rotted beech leaf litter was investigated in laboratory condition by Scheu (1993) The study revealed that the low mineralisation of lignin was due to high mineral nitrogen leaching from the system He concluded that lignin inhibition was due to the excessive nutrient supply from the decomposing material

Pandey and Singh (1982) studied the effect of chemical composition of litter on the decomposition of biomass of oak-conifer forests in Himalaya They found that the influence of lignin on the rate of decomposition increased with time whereas, that of nitrogen decreased

Melillo *et al* (1982) investigated the decomposition rate in hardwood forests in New Hampshire and observed that the decay rate constants were ranging from 0 08 to 0 47 The decay rates were found to be negatively correlated with initial lignin nitrogen ratio The amount of biomass remaining showed an inverse linear relation with their nitrogen content, which in turn was negatively correlated with the initial lignin concentration

Kumar and Deepu (1992) found that high lignin nitrogen ratio was associated with lower rate of mineralisation Similarly, Edmonds (1987) also observed a negative relationship between rate of decomposition and initial lignin nitrogen ratio when compared to lignin alone.

2.1.3.4.6 Ligno cellulose index

Melillo et al (1989) tried to relate the ratio of lignin concentration to the concentration of lignin plus acid soluble carbohydrates in the litter as an indicator of susceptibility of plant materials to microbial attack and this was referred to as ligno cellulose index (LCI) They concluded that different leaf materials of different LCI's incorporated into the soil reach a common LCI value ranging from 0 7 to 0 8 Till the attainment of this range, decay rate is a function of initial litter quality and other factors of decomposition

2 1.3.4.7 Polyphenol

Leaf tissues contain a variety of polyhydroxy phenols constituting considerable portion of their dry weight Edwards and Heath (1963) found strong evidences establishing the influence of these substances on controlling the rate of decomposition De Moral and Muller (1969) found that the high content of polyphenol in eucalyptus leaves hindered the rate of decomposition Vallis and Jones (1973) observed less mineralisation rate in two species having varied content of polyphenol though they were having uniform lignin nitrogen ratio • They attributed a lower rate of decomposition to the higher quantity of polyphenols present in the decomposing matter

2.1.4 Patterns of biomass decomposition

In general, decomposition of litter follows a biphasic pattern (Berg and Staff, 1981, Kumar and Deepu, 1992, Sankaran *et al* , 1993 and Kunhamu, 1994) The decomposition dynamics involve a rapid initial rate of disappearance followed by a subsequent lower rate The rapid phase involves the metabolization of readily digestable water soluble compounds such as simple sugars, proteins, aminoacias and polysaccharides (Alexander, 1977 and Rangaswamy and Bagyaraj, 1993) During the later slower phase, the compounds resistant to bio degradation was found to be metabolized (Brady, 1984)

Singh *et al* (1993) observed a typical biphasic pattern of biomass decomposition of the four species studied for a period of one year Sal lost 87 per cent of the original biomass and this was followed by teak (72%), poplar (50%) and eucalyptus (50%) The weight loss of sal was rapid during the first 3 to 6 months Almost a similar trend was observed in teak also There was a slow rate of decomposition of eucalyptus as compared to other species Poplar exhibited a steady rate of decay during the first six months

Kunhamu *et al* (1994) studied the decomposition dynamics of *Acacia auriculiformis* and reported that 90 per cent of the litter disappeared within six months and the residual mass was remaining upto 16 months

Olson (1963) tried to predict the decay rates of various species using mathematical models These models could be used to predict the rate of decomposition of leaf litter added to soil

2.2 Nutrient release pattern

Generally the rate of decomposition governs the nutrient release pattern, but various nutrients are found to be released at different rates and showed differential release patterns (Swift *et al* , 1979 and Kunhamu, 1994)

Attiwill (1968) studied the rate and extent of loss of dry matter, P, Mg, Ca, K and Na during the decomposition in *Eucalyptus obliqua* forest in Australia Maximum loss was seen for Na followed by

K, Ca, Mg and P and this was attributed to the differential behaviour of these elements in terms of mobility and leachability

Edmonds (1980) examined the decomposition rates and changes in the nutrient content of needles and leaf litters of Douglas fir, Western hemlock, Pacific silver fir and red alder under various ecosystems He found a varied pattern of loss of elements with regard to ecosystems In general, all the species recorded maximum mineralisation of K followed by Mg, Ca, P, N and Mn in red alder, Mg, Ca, P, Mn and N in Douglas fir, Ca, Mg, N, Mn and P in Western hemlock and Mg, Ca, Mn, P and N in Pacific silver fir

In scots pine, P was found to be the most limiting element for microbial activity during the initial phase There appeared to be little initial leaching from the litter and the differential behaviour of these elements could largely be explained by their extent of solubility and concentration in litter in relation to the needs of micro organisms Generally, potassium and magnesium were found to be released at rates similar to the weight loss of organic matter (Staaf and Berg, 1982) They also found that nutrients in the decomposing litter were retained (to a weight loss of about 75 per cent) in the order of Mn followed by Ca, K, Mg, S, N and P During the first 18 months, there was a net increase in N and P, followed by a net decrease emphasising the fact that P is the most limiting element for microbial activity

In tropical sal forest, Shukla and Singh (1984) found that Ca content of the litter declined throughout the year while P content released almost in a steady state

The nutrient release patterns in *Eucalyptus obliqua* and *Pinus radiata* were studied by Baker and Attiwill (1985) In pine, N was immobilised for two years while eucalyptus litter showed a net N release after one year Moreover, within first three months, about 20 per cent of the P was mineralised and after which there was only a little change Potassium and sodium reduced rapidly during the initial stages The calcium and magnesium losses were found to be quite comparable with losses in organic matter content

Sharma and Ambasht (1987) studied the decomposition of *Alnus nepalensis* in Eastern Himalaya and found that the initial labile fraction of nutrient in decomposing biomass declined in the sequence of K followed by P, Ca, and N In their study, K showed a short half life (2 4 months) followed by P (2 7 months) whereas nitrogen had a half life of 21 months Bahuguna *et al* (1990) studied the nutrient release patterns in plantations of sal and eucalyptus under similar eco-climatic and edaphic conditions and observed that Mg recorded the highest elemental mobility in sal followed by K, P, Ca and N where as in eucalyptus, K was having faster mobility followed by Mg, P, Ca and N

Variation in the nutrient releases pattern among the species was also observed by Stohlgren (1988) He noticed the immobilisation of nitrogen in all the species at varying degrees Phosphorous was strongly immobilised in two species viz , sequoia and white fir Potassium and magnesium were quickly released in all the species Calcium was immobilised in sugar pine, while quickly released in incent cidar leaf litter A strong linear or negative exponential relationship was found to exist between initial concentrations of N, P, K and Ca and per cent of original biomass remaining

Bargali *et al* (1993) investigated the nutrient release patterns in decomposing leaf litters of eucalyptus They found an increase in nitrogen and phosphorus content and towards the end of the study the nutrient concentrations were twice compared to the initial content Potassium was actively leached resulting in lower concentrations as compared to the content in the original litter

Bockheim *et al* (1991) observed an increase in the concentrations and absolute amount of N, Ca, S, Zn, Mn, Fe, Cu and Al in decomposing litter mass of jack pine, paper birch, trembling aspen and northern pine oak after one year of decomposition They also observed a decreased concentration of P, K, Mg and B in the decomposing leaf litter Two way analysis of variance tests revealed significant difference in dry matter content and concentration of most of the elements and this was stated to be a function of species and time

Berg and Staaf (1981) reported that the changes in N, P, Ca and S in the decomposing biomass followed a three phase process They established cubic function to relate initial loss, accumulation and final release phase of these nutrients in the decomposing leaf litter Lisanework and Michelsen (1994) studied the nutrient release by decomposition in three plantations in Ethiopian high land and found that the loss of K was fastest followed by Mg and Ca Interestingly, the rate of loss of N was similar to that of P

Mwiinga *et al* (1994) studied the N mineralisation pattern in decomposing leaf litters of six multipurpose tree species and noticed that during the first week the amount of N released from *Gliricidia sepium* and *Leucaena leucocephala* foliages was high compared to *Sesbania sesban, Pericopsis angolensis, Cassia siamea* and *Flemingia congesta* After four weeks of decomposition *Gliricidia sepium, Sesbania sesban, Pericopsis angolensis, Flemingia congesta* and *Cassia siamea* had released respectively 107, 104, 72, 57, 50 and 42 kg N ha^{-1}

Attempts were made to monitor the nutrient flux in the decomposing leaf biomass of sal, teak, pine and eucalyptus (Pande and Sharma, 1988) In general, all the species exhibited maximum release of Ca followed by K, N, Mg and P

Materials and Methods

MATERIALS AND METHODS

3.1 Study site

3.1.1 Location

The present study was conducted in College of Forestry, Kerala Agricultural University, Vellanikkara, Trichur during the period 1993-95 The sites included a mixed dense home garden and an open area located at Vellanikkara, Trichur district The location lies at 10° 31'N latitude and 76° 10'E longitude at an elevation of 22 m above MSL The details of the climatic and soil conditions are furnished below

3.1.2 Climate

The experimental area enjoys a warm humid tropical climate and had received a total rainfall of 3521.9 mm during 1994 and 2597 6 mm till the end of September in 1995 The bulk of the rain is received during the south-west monsoon season The wettest months are June, July and August The mean monthly maximum temperature recorded at the nearby agrometeorological laboratory (300 m away) varied from 28 8°C (July) to 36 2°C (March) and the mean monthly lowest temperature varied from 18 6°C (December) to 21 6°C (August) during 1994 In 1995, the mean monthly maximum temperature varied from 29 9°C (July) to 47 6°C (March) where as mean monthly lowest temperature varied from 20 0°C (January) to 22 5°C (August)

3.1.3 Soil

The soil at the experimental location is oxisols The predominant parent material is metamorphic rock of gneiss series The average soil pH was found to be 5 8 The soils and sub soils were porous and extremely well drained

3.1.4 Field experiment

The study involved the assessment of rates of leaf litter decomposition, nutrient release from decomposing leaf litter and nutrient added to soil through the process of mineralisation of nutrients from the incorporated leaf litter of *Acacia mangium* Willd The experiment was conducted during two seasons viz , (i) south west monsoon season (commenced in June 1994) and (ii) north east monsoon season (commenced in October 1994) under two field conditions The descriptions of the fields are given below

3.1.4.1 Home garden

The experiments for the above two seasons were laid out in typical home garden of about two acres, where different varieties of horticultural crops were planted and maintained in a very intense manner (Plate 1) The area was dominated by coconut and arecanut A wide variety of tree crops such as mango, nutmeg, tamarind, annona, guava, drumstick, curry leaf etc were irregularly interplanted in available spaces Fruit crops like banana, papaya and crops like amorphophallus, colocasia, turmeric, ginger etc were dominant components of the ground vegetation The field also supported a variety of tree species like *Tectona grandis, Ailanthus triphysa, Bombax ceiba, Dalbergia latifolia* etc which were mainly confined to the plot boundary Pepper vines were trained on most of the trees The erythrina-pepper association was also very common

Most of the horticultural crops were said to be maintained as per the recommendations of the Kerala Agricultural University In these plots, two weedings were carried out in the year, one at the onset of south-west monsoon and the other in the month of October Soil working was done during November Soil fertility was maintained mainly by adding farm yard manure and compost

3 1 4 2 Open area

An open area of about one acre was selected for the experiment (Plate 2) This area was completely devoid of vegetation

3 1.4.3 Experimental design

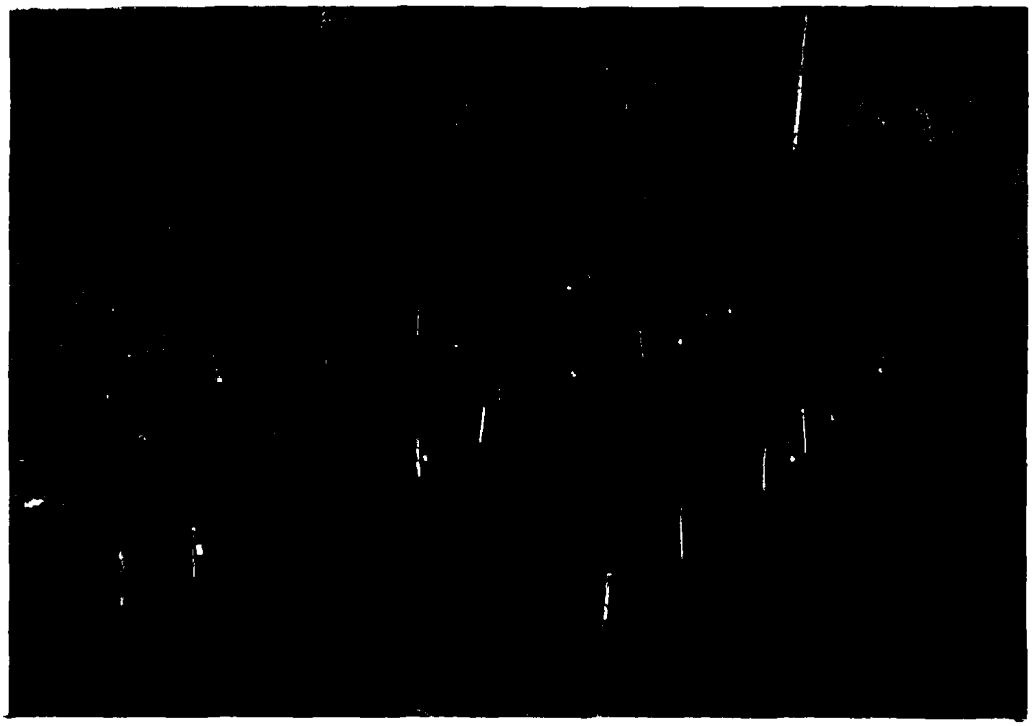
A 2^2 factorial experiment in completely randomised design was followed with season as factor and field conditions as levels

3.2. Leaf litter decomposition

For studying the rates of leaf litter decomposition in different seasons and field conditions mesh bag technique

Plate 1 Panoramic view of the home garden selected for the study

Plate 2 Panoramic view of the open area selected for the study



(Bocock and Gilbert, 1957) was employed Leaf litter of *Acacia mangium* Willd was collected from grown up trees planted and maintained in the arboretum of College of Forestry Representative samples were drawn for the estimation of moisture and initial concentrations of major nutrients The litter was air dried for 72 hours before incorporating into soil.

Each sample containing 50 g of leaf litter was filled in nylon bags (mesh size 2 mm x 2 mm) of size 30 cm x 25 cm The sides of the bags were properly sealed (Plate 3). Seventy two bags were laid out in three replications for each season and field condition Total number of bags used for the study was 288 Litter bags were placed randomly in the field on 1st June, 1994 to study the effect of south west monsoon season and on 1st October 1994 to study the effect of north east monsoon season on litter decomposition Litter bags were placed on the surface of the soil and a thin layer of soil was spread over the bags to avoid misplacements and the bags were labelled properly

One bag from each replication was sampled at fortnightly interval during the study period Sampled bags were taken to laboratory, extraneous materials, arthropods, earthworms, fine roots and other soil particles were separated manually and residues were cleaned in running water by repeated washing

Plate 3 Nylon litter bag used for the decomposition study

3

The content of the bags were transferred to paper bags and oven dried at 70°C for 72 hours till constant weights were obtained The final residue mass was weighed by using a precision balance

3.3 Chemical analysis of leaf litter and detritus

Fresh leaf litter samples and residues after drying were powdered in Willey mill The fine powder was used for the estimation of C, N, P, K, Ca, Mg and S The lignin content was also estimated in fresh samples and residues The standard procedures adopted for the chemical analysis are furnished below

3.3.1 Total carbon

The total carbon content was found out by igniting the samples at 550°C (Gaur, 1975)

3.3.2 Nitrogen

Nitrogen content in fresh leaf litter and residues retrieved at monthly intervals was determined by digesting 0 1 g of samples in 5 ml of concentrated sulphuric acid using digestion mixture (sodium sulphate copper sulphate in 10 4 ratio) and nitrogen in the digest was determined by Kjeldhal's method (Jackson, 1958)

3.3.3 Phosphorus

A known quantity (one gram) of the powdered leaf sample was digested in diacid mixture (Nitric acid perchloric acid in 3 1 ratio) and the digest was made upto 100 ml A known quantity of aliquot was taken to determine the phosphorus content by following chlorostannus reduced molybdophosphoric blue colour method in sulphuric acid system (Jackson, 1958) and the colour intensity was read at 660 nm in UV spectrophotometer

3.3.4 Potassium

A known quantity of aliquot from the diacid extract was taken to read potassium content using Flame Photometer (Jackson, 1958)

3.3.5 Calcium

An aliquot of 1 ml of the diacid extract was mixed with 1 ml of stronortium chloride solution (1000 ppm) and volume was made upto 25 ml Calcium content in the sample was read using Atomic Absorption Spectrophotometer

3.3.6 Magnesium

One ml of stronortium chloride was added to an aliquot of 0 1 ml of the diacid extract and made upto 25 ml The magnesium concentration was read directly by using Atomic Absorption Spectrophotometer

3.3.7 Sulphur

Sulphur content in the samples was estimated by turbidometry using $BaCl_2$ The turbidity was read at 400 nm in UV spectrophotometer

3.3.8 Lignin

The lignin content was estimated by following the procedure suggested by Sadasivan and Manikam (1992) One gram of powdered sample was refluxed with acid detergent solution and the content was filtered and washed with hot water and acetone The left over was dried in an oven at 100°C for overnight and the weight was taken after cooling in a desiccator The weighed material was mixed with 50 ml of 72 per cent H_2SO_4 and added with 1 g of asbestos powder and allowed to remain for 3 hours with intermitant stirring The content was diluted, filtered with pre-weighed Whatman No 1 filter paper and washed repeatedly to remove acid component The residue in the filter paper was dried, weighed and was subjected to ashing in a muffle furnace at 550°C for 5 hours The contents were cooled in a desiccator The ash was weighed and lignin content was calculated

3.4 Soil analysis

Representative soil samples were collected from the study area before and after the placement of litter bags The samples were taken just below the retrieved litter bags at monthly intervals till the end of the study The soil moisture content of the study area was estimated at fortnightly whereas the pH, N, P, K and organic C content in the soil was estimated for monthly samples The Ca, Mg and S content was estimated before the commencement and after the completion of the study Periodic observations on soil temperature was recorded The standard procedures adopted for the analysis of soils are furnished below

3.4.1 Soil pH

The pH of the soil was determined with the help of digital pH meter

3.4.2 Organic carbon

Organic carbon content of the soil was estimated by the method suggested by Jackson (1958)

3.4.3 Total nitrogen

The total nitrogen content of the soil was determined by digesting 1 g of soil in 5 ml of sulphuric acid in presence of digestion mixture (Na_2SO_4 $CuSO_4$ Selenium in 10 4 1 ratio) and the N content in the digest was determined by Microkjeldhal method (Jackson, 1958)

3.4.4 Available phosphorus

Available P in the soil was extracted by using Bray-I solution and P content was then assayed colorimetrically using chlorostannus reduced molybdophosphoric blue colour method in sulphuric acid system (Jackson, 1958)

3.4.5 Exchangeable potassium

Exchangeable potassium in the ammonium acetate extract of soil was estimated flame photometrically (Jackson, 1958)

3.4.6 Exchangeable calcium

Exchangeable calcium in the ammonium extract of the soil was determined by Versenate method using calcon as indicator (Jackson, 1958)

3 4.7 Exchangeable magnesium

Ammonium acetate extract of the soil was used to estimate exchangeable Mg content following Versenate method using Erichrome Black-T as indicator (Jackson, 1958)

3.4.8 Available sulphur

Sulphur content was estimated in turbidometry using barium chloride and gum acacia (Jackson, 1958)

3.5 Statistical analysis

The observations recorded on leaf litter decomposition and absolute nutrient content of residual mass at various periods were analysed statistically by using the methods suggested by Panse and Sukhatme (1978) after $\log_e$ transformation of the data The rate of decomposition was statistically correlated with weather parameters and soil properties

The decay rate coefficient were worked out for the constant potential weight loss by the following formula suggested by Olson (1963)

$$X/X^0 = e^{kt}$$

Where X - the weight remaining at time 't

X^0 - the original mass

e - base of the natural logarithm

k - decay rate coefficient

t - time

Half lives ($t_{0\ 5}$) of decomposing litter were estimated from k values using the standard equation (Bockheim *et al* , 1991)

$$t(0\ 5) = \ln(0\ 5)/-k$$
$$= -\ 0\ 693/-k$$

Absolute nutrient content of the decomposing leaf was calculated using the formula suggested by Bockheim *et al* (1991)

$$\%\ \text{Absolute nutrient remaining} = (C/C_0) \times (DM/DM_0) \times 10^2$$

Where, C = concentration of element in the leaf litter at the time of sampling

C_0 = initial concentration of element in the leaf litter

DM = mass of dry matter at the time of sampling

DM_0 = initial dry matter of leaf litter kept for decomposition

Various regression models suggested by William (1992) were tried to characterise nutrient mineralisation over time

Results

RESULTS

The rate of leaf litter decomposition, the nutrient release pattern and the improvement of soil by the addition of nutrients from the decomposing leaf litter were studied under two different field conditions during two seasons viz , south west monsoon season (first season) and north east monsoon season (second season) The salient findings of the studies are described hereunder

4.1 Leaf litter decomposition

4.1.1 Rate of decomposition

The observations recorded at fortnightly intervals on the decomposition of leaf litter of *Acacia mangium* Willd under different field conditions during the two seasons are tabulated in Table 1 In general, the rate of decomposition was very fast under all the study situations and was completed within 20 fortnights

4.1.1.1 Rate of decomposition as affected by seasons

The data relating to the leaf litter mass remaining at the end of each month during the study period for the two different seasons are tabulated in Table 2

The residual mass at the end of the first month showed a significant difference between the two seasons The rate of mineralisation was faster during the second season The litter mass

Table 1 Changes in the litter mass remaining at fortnightly intervals

Fortnight	South west monsoon season				North east monsoon season			
	Home garden		Open area		Home garden		Open area	
	Residual mass (g)	Relative mass (%)	Residual mass (g)	Relative mass (%)	Residual mass (g)	Relative mass (%)	Residual mass (g)	Relative mass (%)
0	23 82	100 00	23 82	100 00	16 97	100 00	16 97	100 00
1	17 97	75 45	21 40	89 84	6 97	41 10	6 03	35 56
2	16 74	70 28	14 69	61 66	7 73	45 56	7 70	45 37
3	9 19	38 57*	8 49	35 62*	8 37	49 34*	0 36	2 21
4	9 14	39 52	3 94	16 54	4 05	23 87	0 96	5 68
5	7 09	29 75	1 03	4 31	1 69	9 98	0 07	0 43
6	3 11	13 06	5 41	22 70	2 13	12 52	0 66	3 87
7	3 23	13 58	1 59	6 65	3 56	20 99	0 26	1 53
8	0 74	3 11	2 59	10 85	0 48	2 82	0 12	0 73
9	2 14	8 99	1 40	5 86	1 92	11 31	0 09	0 53
10	2 64	11 09	1 26	5 29	1 79	10 56	0 06	0 33
11	1 15	4 83	1 47	6 18	0 33	1 92	0 05	0 31
12	0 08	0 32	0	0	1 24	7 30	0 29	1 72
13	0 33	1 39	0 42	1 76	0 29	1 69	0 07	0 43
14	1 77	7 42	0 01	0 04	0 56	3 31	0 11	0 65
15	0 13	0 54	0 11	0 47	0 68	4 01	0 26	1 53
16	0 52	2 20	0 20	0 85	0 03	0 16	0 10	0 58
17	0 03	0 13	0	0	0 14	0 81	0 24	1 41
18	0 01	0 05	0	0	0 05	0 31	0 05	0 31
19	0 03	0 12	0 02	0 07	0 04	0 22	0 01	0 07
20	0	0	0	0	0	0	0	0

* Values having similar superscript do not differ significantly

P <0 05 CV 16 40 SEM± 4 84

Table 2 Changes in litter mass remaining (%) under different seasons and field conditions at monthly intervals (pooled data)

Study situation	Relative residual mass (%)									
	1	2	3	4	5	6	7	8	9	10
Season I	65 97	28.03	17 88	6 98	8 19	0 17	3 73	1.52	0.03	0.00
Season II	45 47	14.78	8 20	1 77	5 45	4 51	1.98	0.37	0.29	0.00
CD (0 05)	19 67	NS	NS	NS	NS	3 18	NS	NS	0 25	NS
SEM±	8.53	-	-	-	-	1 38	-	-	0.11	-
Home garden	57.92	31.70	12 79	2 96	10.83	3 81	5 37	1.18	0 16	0.00
Open area	53 52	11.11	13 29	5 79	2 81	0 87	0 34	0 72	0 16	0.00
CD (0 05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEM±	-	-	-	-	-	-	-	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

remaining at the end of first month was more in the first season (65 97%) compared to second season (45 47%) In both seasons by the end of the second month, nearly 70 per cent of the initial litter mass was decomposed During the same period the quantity of residual litter was very low in the second season (14 78%) Around 90 per cent of the initial litter mass was decomposed in the second season after three months At the end of the fourth month of the study, the residual mass remaining in the litter bags were 6 98 per cent of the initial mass in first season while it was 1 77 per cent in the second season At the end of seventh month the mass loss during the second season was more rapid compared to first season Similarly, the residual mass at the time of eighth month sampling was high in first season (1 52%) compared to second season (0 37%) However, the litter residues sampled at the end of sixth and ninth month from the second season study plots showed more quantity of residues in the bags than the first season and also was found to be statistically significant

4.1.1.2 Rate of decomposition as affected by field conditions

The data furnished in Table 2 also indicate the effect of field conditions on the rate of decomposition In general, the rate of decomposition was found to be faster in open condition After one month of application, the residual mass remaining in the home garden was relatively high (57 92%) compared to open area (53 52%) At the end of the second month also the residual mass remaining in the litter bags collected from the home garden was found to be relatively high (31 70%) compared to open area (11 11%) However, the difference was not statistically significant Around 95 per cent of the initial litter mass decomposed after four months of exposure to decomposition in both the field conditions After fifth month, the amount of mass remaining in home garden and open area was found to be respectively 10 83 per cent and 2 81 per cent A more or less similar trend was discernible till the end of the study

4.1 1 3 Rate of decomposition as affected by the interaction of season and field conditions

The data presented in Table 1 show the residual litter mass remaining at the end of each fortnight under various study situations

The data obtained at monthly intervals were subjected to statistical analysis and this indicate that the interaction effect was not significant in any of the above months At the end of first month of the first season, the residual mass remaining in the home garden was relatively more (70.28%) compared to the open area (66 66%) During the same period, the bags kept in open area in second season recorded the least residual mass of 45 37 per cent Similar trend was observed in the second month also However, at the end of the third month, the residual litter mass was more in the open area of the first season (22 70%). During the sixth month of sampling the litter mass remaining in the home garden during the second season was relatively high (7 30%) and the least mass was found in litter bags of open area during first season (0 01%) After nine months of incorporation of leaf litter, the litter mass remaining in the litter bags from the open area of the second season was found to be more (0 31%) whereas decomposition was completed in open area of the first season By the end of the tenth month, the residual mass collected from various situations approached zero

The residue mass collected at the end of third month, sixth month and ninth month are depicted in Plates 4 to 15

4.1.2 Pattern of decomposition

In general, the decomposition followed a biphasic pattern under all the situations and fields Litter decomposition pattern under various situations are depicted in Fig 1 Initially the decomposition was rapid followed by a slower phase In all the situations, about 90 per cent of the initial litter mass was decomposed during the initial rapid phase which lasted for three months Remaining quantity of the litter mass took nearly seven more months for complete decomposition

4.1.3 Factors affecting rate of decomposition

4.1.3.1 Effect of litter quality on the rate of decomposition

The effects of litter quality on the leaf litter decomposition under various study situations are described below

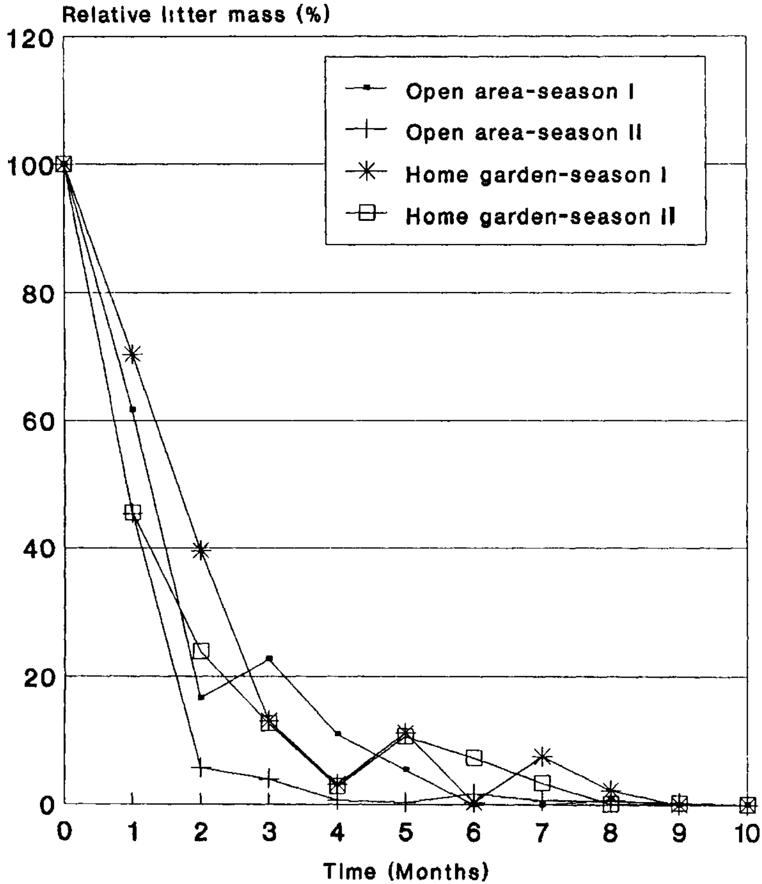
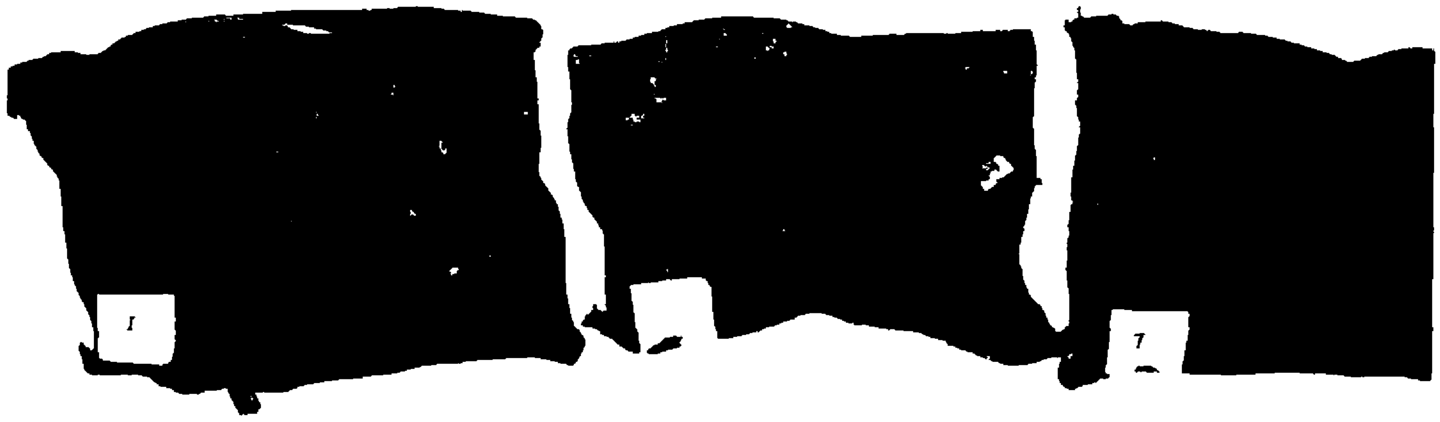


Fig. 1 Rate of decomposition of litter mass in different study situations

Plate 4 Litter residues retrieved after three months from open area during first season

Plate 5 Litter residues retrieved after three months from open area during second season



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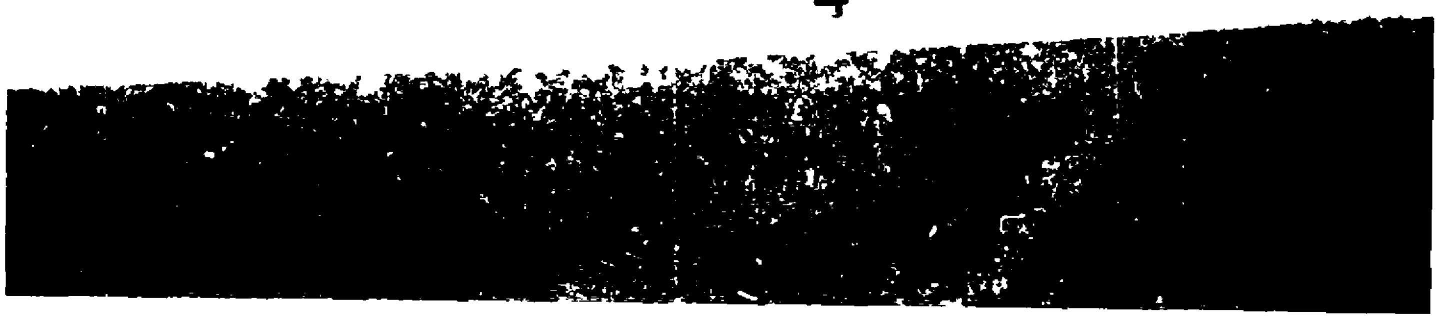


Plate 6 Litter residues retrieved after six months from open area during first season

Plate 7 Litter residues retrieved after six months from open area during second season

6

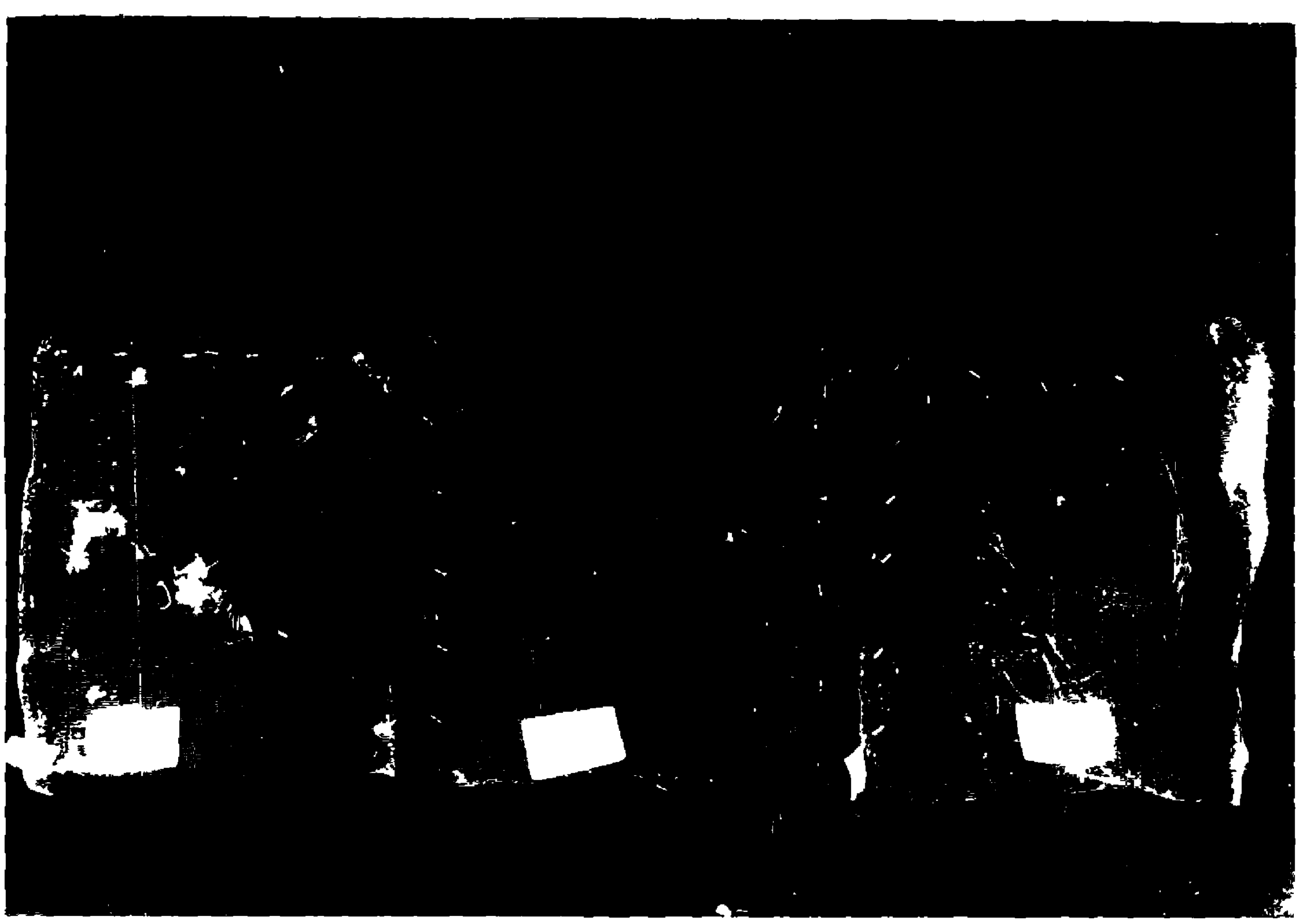
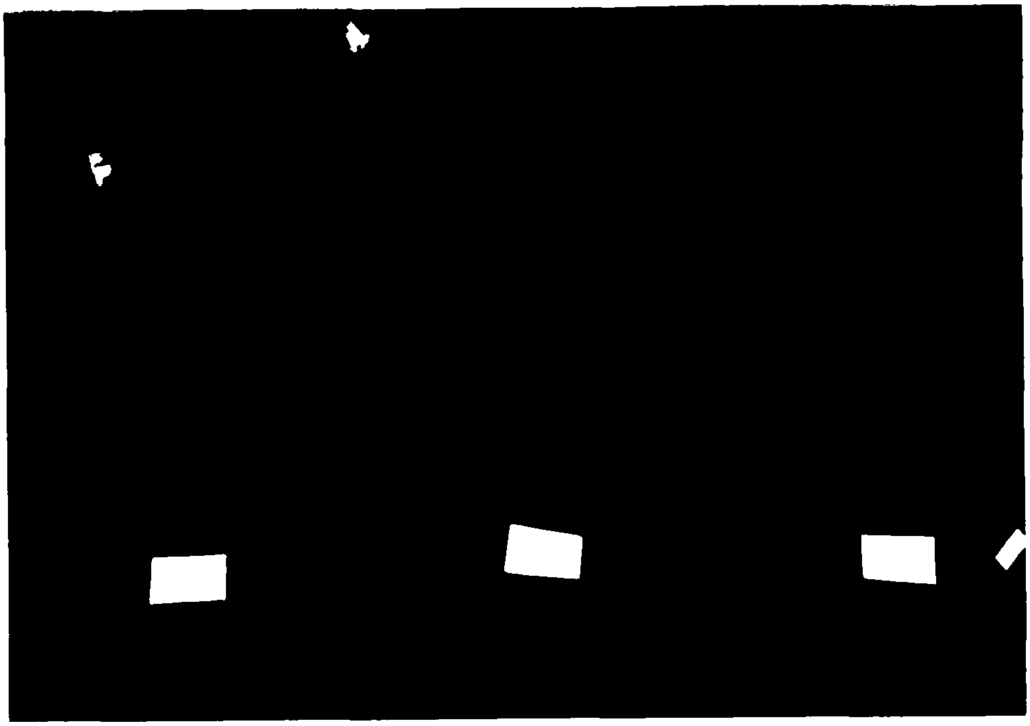


Plate 8 Litter residues retrieved after nine months from open area during first season

Plate 9 Litter residues retrieved after nine months from open area during second season



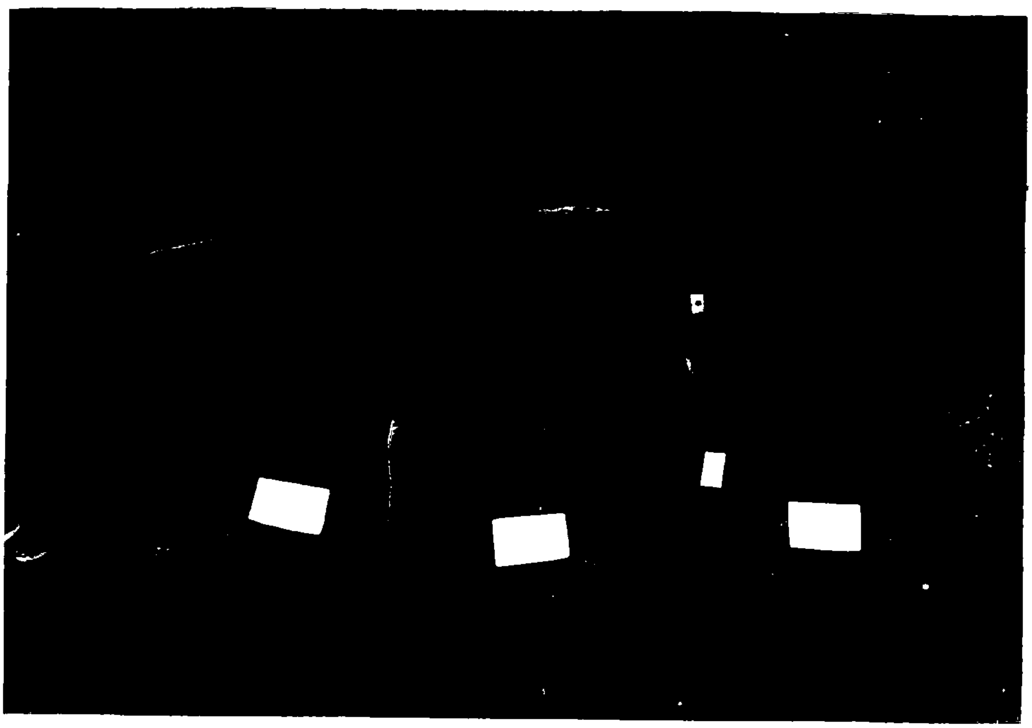


Plate 10 Litter residues retrieved after three months from home garden during first season

Plate 11 Litter residues retrieved after three months from home garden during second season

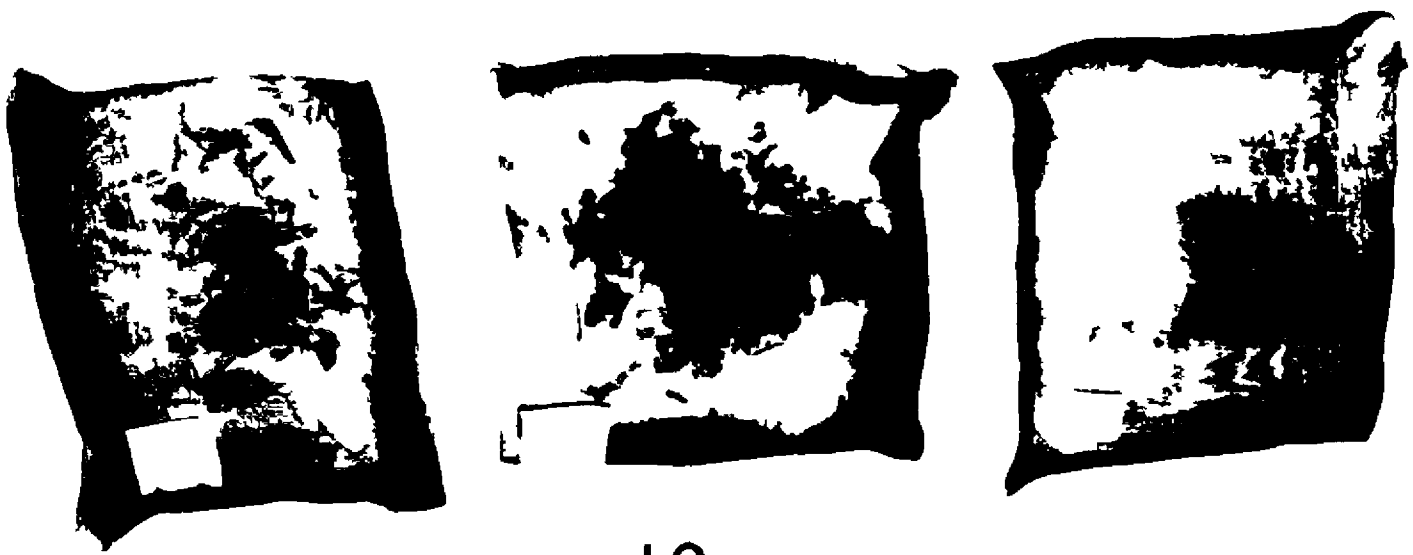


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Plate 12 Litter residues retrieved after six months from home garden during first season

Plate 13 Litter residues retrieved after six months from home garden during second season

12

Plate 14 Litter residues retrieved after nine months from home garden during first season

Plate 15 Litter residues retrieved after nine months from home garden during second season

4.1.3.1.1 Nitrogen content and C·N ratio

The data pertaining to total carbon, nitrogen content and C N ratio of the leaf litter and their changes during the study are tabulated in Table 3 The decomposition was faster during the second season where litter was having lower initial C N ratio (31 07) compared to the first season (37 87) The C N ratio of litter kept in the open area during the south west monsoon season declined initially and reached peak (55 35) in the fourth month and subsequently declined again In the case of litter residues from the home garden during the same period, C N ratio declined initially for first two months, showed almost a steady state for next two months and then declined in further months In the case of litters applied in north east monsoon season, the C N ratio initially showed a decline followed by an increasing trend in the home garden and attained its peak (36 76) by the end of fifth month (Fig 2)

4.1 3 1 2 Lignin content and lignin nitrogen ratio

The results of the chemical analysis for the lignin content of fresh leaf litter and residues sampled at monthly intervals are presented in Table 4 The initial lignin content was low in the second season's litter (15 90%) compared to first season (21 90%) The content of lignin in the residual mass exhibited an increasing trend over time At the end of the study, during the first season, lignin content in the residual mass reached to a peak in home

Table 3 Changes in the content of carbon, nitrogen and C N ratio of residues sampled at monthly intervals

Months	South west monsoon season								North east monson season							
	Residual mass (g)	Home garden			Residual mass (g)	Open area			Residual mass (g)	Home garden			Residual mass (g)	Open area		
		C	N	C N		C (%)	N (%)	C N		C (%)	N (%)	C N		C (%)	N (%)	C N
0	23 82	91 91	2 43	37 87	23 82	91 91	2 43	37 87	16 97	93 96	3 02	31 07	16 97	93 96	3 02	31 07
1	16 74	83 21	2 61	31 84	14 69	86 09	2 61	32 94	7 73	86 25	2 89	29 81	7 70	89 72	3 08	29 13
2	9 41	77 40	2 43	31 90	3 94	75 87	2 24	33 87	4 05	83 82	2 93	28 64	0 96	88 05	2 80	31 45
3	3 11	74 55	2 24	33 28	5 41	74 62	2 05	36 34	2 13	86 76	2 61	33 20	NA	NA	NA	NA
4	0 74	52 87	1 68	41 81	2 59	77 49	1 40	55 35	0 48	77 85	2 52	30 89	NA	NA	NA	NA
5	2 64	41 81	1 59	26 35	1 26	52 50	1 54	34 09	1 79	75 47	2 05	36 76	NA	NA	NA	NA

NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 3 Changes in the content of carbon, nitrogen and C N ratio of residues sampled at monthly intervals

Months	South west monsoon season								North east monson season							
	Residual mass (g)	Home garden			Residual mass (g)	Open area			Residual mass (g)	Home garden			Residual mass (g)	Open area		
		C	N	C N		C (%)	N (%)	C N		C (%)	N (%)	C N		C (%)	N (%)	C N
0	23 82	91 91	2 43	37 87	23 82	91 91	2 43	37 87	16 97	93 96	3 02	31 07	16 97	93 96	3 02	31 07
1	16 74	83 21	2 61	31 84	14 69	86 09	2 61	32 94	7 73	86 25	2 89	29 81	7 70	89 72	3 08	29 13
2	9 41	77 40	2 43	31 90	3 94	75 87	2 24	33 87	4 05	83 82	2 93	28 64	0 96	88 05	2 80	31 45
3	3 11	74 55	2 24	33 28	5 41	74 62	2 05	36 34	2 13	86 76	2 61	33 20	NA	NA	NA	NA
4	0 74	52 87	1 68	41 81	2 59	77 49	1 40	55 35	0 48	77 85	2 52	30 89	NA	NA	NA	NA
5	2 64	41 81	1 59	26 35	1 26	52 50	1 54	34 09	1 79	75 47	2 05	36 76	NA	NA	NA	NA

NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 4 Changes in the lignin content and lignin nitrogen ratio of residues sampled at monthly intervals

Months	South west monsoon season								North east monson season							
	Residual mass (g)	Home garden			Residual mass (g)	Open area			Residual mass (g)	Home garden			Residual mass (g)	Open area		
		Lignin (%)	N (%)	L N		Lignin (%)	N (%)	L N		Lignin (%)	N (%)	L N		Lignin (%)	N (%)	L N
0	23 82	21 90	2 43	9 02	23 82	21 90	2 43	9 02	16 97	15 90	3 02	5 26	16 97	15 90	3 02	5 26
1	16 74	40 57	2 61	15 52	14 69	24 43	2 61	9 40	7 73	33 90	2 89	11 72	7 70	21 23	3 08	6 89
2	9 41	41 75	2 43	17 21	3 94	42 80	2 24	19 11	4 05	41 35	2 93	14 13	0 96	36 50	2 80	13 04
3	3 11	43 00	2 24	19 20	5 41	37 50	2 05	18 26	2 13	40 40	2 61	15 46	NA	NA	NA	NA
4	0 74	43 50	1 68	25 89	2 59	40 30	1 40	28 79	0 48	NA	2 52	NA	NA	NA	NA	NA
5	NA	NA	NA	NA	NA	NA	NA	NA	1 79	43 10	2 05	20 99	NA	NA	NA	NA

NA - Decomposition was almost completed - sample was not sufficient for analysis

garden (43 5%) and in open area (40.3%) During the second season, the lignin content of litter residues collected from the above two fields were respectively 43 1 per cent and 36 5 per cent

The ratio between lignin and nitrogen content had shown an increasing trend from the beginning to the end Initial lignin.nitrogen ratio for litter was 9 02 and 5 26 respectively during the first and second season The lignin nitrogen ratio had its peak at the end of the study (Fig 3)

4.1.3.2 Effect of weather parameters on the rates of decomposition

The weather data during the study period are furnished in Appendix I Attempts were made to relate the important weather variables such as mean monthly rainfall, temperature and relative humidity with rate of decomposition In majority of the cases, the relationship between these parameters with rate of decay was found to be statically feeble

4 1.3 3 Effect of soil factors on the rates of decomposition

The decomposition of organic matter incorporated into the soil is a function of various edaphic factors An attempt was made to understand the role of edaphic factors on the rate of decomposition and the salient findings are summarised below

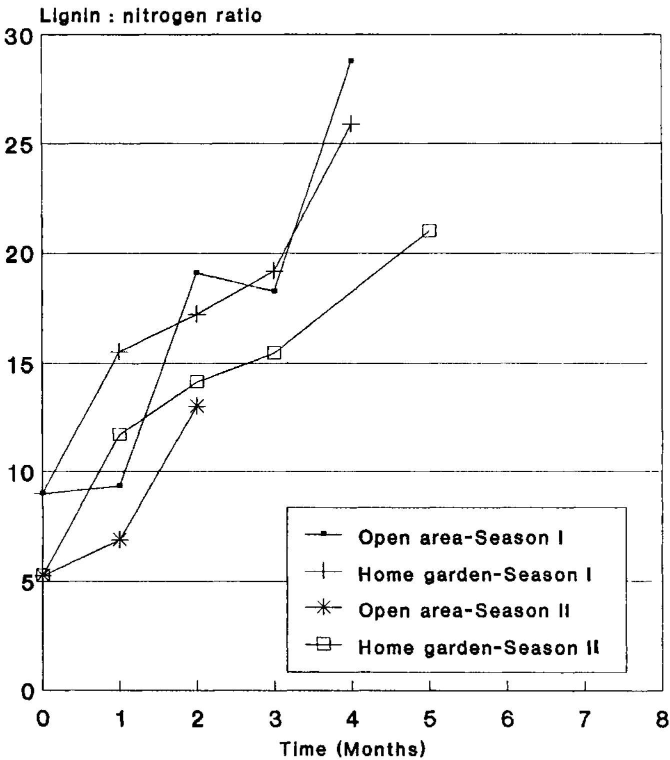

Fig. 3 Changes in lignin:nitrogen ratio
in the decaying litter mass

4.1 3.3.1 Soil temperature

The observations recorded on the soil temperature at fortnightly intervals are presented in Table 5 During the study period an attempt was made to asses the effect of soil temperature on the rate of litter decomposition The regression showed a poor r^2 value of less than 0 314

The maximum soil temperature was recorded during the drier periods During rainy days, the diurnal fluctuation was less compared to non rainy days In home garden the soil temperature was low (maximum 34^{0}C) compared to open area (maximum 50 4^{0}C) In all the situations the soil temperature during dry periods was higher

4.1.3.3.2 Soil moisture

Soil moisture content of the study area was recorded at fortnightly intervals and the relevant data is furnished in Table 6 The soil moisture content was higher during rainy days compared to non rainy days During the dry season, soils of open area were found to record a very low moisture content (2 06%) compared to that of home gardens (7 87%) where the crops were irrigated once in a week In the present study, the soil moisture and the rate of decomposition was not found to be significantly correlated

Table 5 Changes in the soil temperature of the study area at fortnightly intervals

Fortnight	South west monsoon season				North east monsoon season			
	Home garden		Open area		Home garden		Open area	
	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)
1	25.5	30.0	25.4	31.0	25.8	30.8	26.0	30.7
2	25.0	31.2	25.4	31.4	26.0	32.0	25.6	33.2
3	24.0	28.6	24.6	28.6	26.0	31.0	26.0	34.3
4	25.2	28.6	25.6	28.7	25.0	30.9	26.2	31.5
5	26.0	30.6	26.3	31.4	24.8	30.8	25.9	31.3
6	25.8	30.8	26.0	30.7	24.0	30.6	25.2	33.6
7	26.0	32.0	25.6	33.2	25.3	33.0	24.8	38.5
8	26.0	31.0	26.0	34.3	24.4	33.2	25.3	41.5
9	25.0	30.9	26.2	31.5	25.6	32.9	23.7	40.7
10	24.8	30.8	25.9	31.3	25.8	32.1	25.7	41.2
11	24.0	30.6	25.2	33.6	25.5	31.5	26.1	44.0
12	25.3	33.0	24.8	38.5	27.0	33.0	25.1	44.2
13	24.4	33.2	25.3	41.5	27.5	33.5	27.0	45.9
14	25.6	32.9	23.7	40.7	27.0	33.0	28.6	46.3
15	25.8	32.1	25.7	41.2	27.5	32.5	29.0	47.9
16	25.5	31.5	26.1	44.0	28.5	33.5	29.5	50.4
17	27.0	33.0	25.1	44.2	28.0	34.0	29.9	46.4
18	27.5	33.5	27.0	45.9	28.0	33.0	28.3	40.5
19	27.0	33.0	28.6	46.3	27.5	33.5	28.0	39.5
20	27.5	32.5	29.0	47.9	26.5	33.0	26.7	35.5

Table 6 Changes in the soil moisture content of the study area at fortnightly intervals (%)

Fortnight	South west monsoon season		North east monsoon season	
	Home garden	Open area	Home garden	Open area
0	16.83	17.19	15.42	17.42
1	24.72	26.57	22.76	18.78
2	29.66	21.36	27.19	16.52
3	32.62	29.27	19.85	15.60
4	33.19	29.54	10.52	8.08
5	29.03	19.77	8.70	5.66
6	26.78	24.25	21.82	3.49
7	18.72	13.92	7.87	5.52
8	19.54	9.94	9.67	2.06
9	25.33	17.53	8.56	3.02
10	23.87	14.52	10.03	4.29
11	21.07	15.18	11.43	3.81
12	10.22	9.07	12.34	2.24
13	8.04	3.26	12.55	8.88
14	12.26	4.03	12.02	8.77
15	10.38	3.15	21.76	32.59
16	4.89	2.53	17.19	13.97
17	18.69	3.05	24.27	27.93
18	8.65	3.02	33.52	27.82
19	10.03	4.29	27.35	28.87
20	11.43	3.81	27.24	27.41

Table 6 Changes in the soil moisture content of the study area at fortnightly intervals (%)

Fortnight	South west monsoon season		North east monsoon season	
	Home garden	Open area	Home garden	Open area
0	16.83	17.19	15.42	17.42
1	24.72	26.57	22.76	18.78
2	29.66	21.36	27.19	16.52
3	32.62	29.27	19.85	15.60
4	33.19	29.54	10.52	8.08
5	29.03	19.77	8.70	5.66
6	26.78	24.25	21.82	3.49
7	18.72	13.92	7.87	5.52
8	19.54	9.94	9.67	2.06
9	25.33	17.53	8.56	3.02
10	23.87	14.52	10.03	4.29
11	21.07	15.18	11.43	3.81
12	10.22	9.07	12.34	2.24
13	8.04	3.26	12.55	8.88
14	12.26	4.03	12.02	8.77
15	10.38	3.15	21.76	32.59
16	4.89	2.53	17.19	13.97
17	18.69	3.05	24.27	27.93
18	8.65	3.02	33.52	27.82
19	10.03	4.29	27.35	28.87
20	11.43	3.81	27.24	27.41

4.1.4 Decomposition model

The quantity of residues present in the litter bags is a function of several factors such as time elapsed, soil moisture, and soil temperature Mathematical models were developed to assess the effect of these factors on the rate of decomposition

Based on the quantity of residual mass left in the litter bags at the end of each fortnight, decay coefficient (k) was estimated for different study situations (Appendix II) The decay coefficient was highest for the open area during the first season (0 392) and lowest for the home garden during the second season (0 303)

To determine the pattern of decomposition over a period of time during various situations regression equations were fitted, by relating the per cent of residues remaining in the litter bags with the time elapsed (Fig 4) The exponential equation $X/X^0 = e^{kt}$ was fitted for three situations where r^2 values were more than 0 650 The exponential equation fitted to the open area of the second season had less feasibility (r^2 = 0 264)

By relating the per cent of residues left in the litter bags at the end of each fortnight, and corresponding soil moisture and soil temperature values, mathematical equations were developed In all cases the model gave a good fit with multiple R value of more than 0 740 (Table 7)

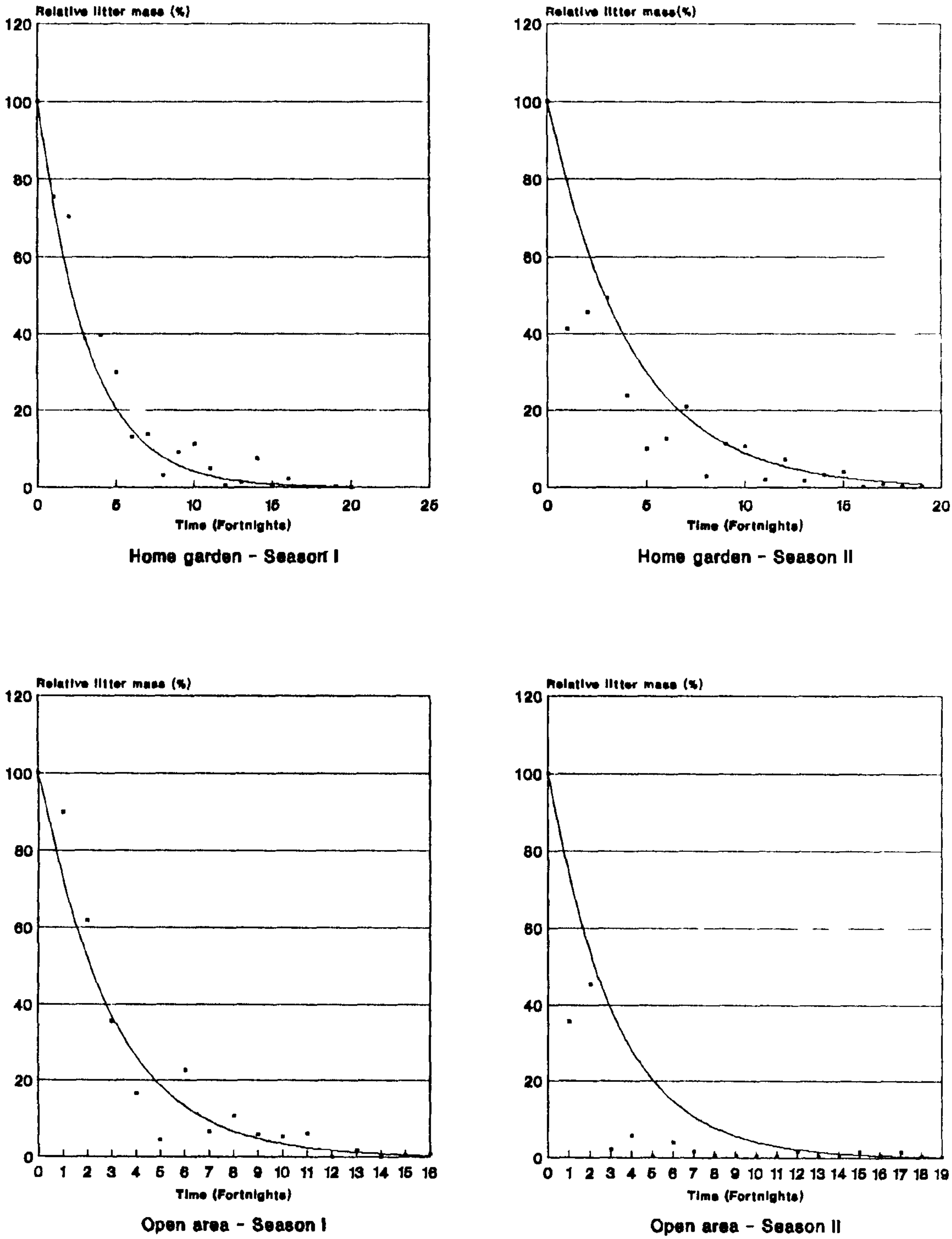

Fig. 4 Decay models of litter mass in different study situations

Table 7 Mathematical models for prediction of residual mass in relation to time elapsed, soil temperature and soil moisture

Study situation		Equation	R value	S.E.E.	n
Season I	Home garden	$Y = 0.039608\ X_2 + 1\ 1066\ X_3 - 0\ 86478\ X_1 - 19.466752$	0.824	3.385	20
	Open area	$Y = 0.16464\ X_2 + 2.0837\ X_3 - 1.607\ X_1 - 47.294$	0 850	3.305	19
Season II	Home garden	$Y = 0.11691\ X_2 + 0.07861\ X_3 - 0.35401\ X_1 + 0\ 311113$	0 740	1.566	19
	Open area	$Y = 0.11566\ X_2 + 1.2323\ X_3 - 0.64658\ X_1 - 29.39028$	0.946	0 963	19

Season I - South west monsoon season
Season II - North east monsoon season

Y - Relative mass remaining (%)
X_1 - Fortnight
X - Soil moisture (%)
X_3 - Mean soil temperature (°C)
n - Number of observations

4.2 Nutrient release pattern

4.2.1 Changes in nutrient concentrations

The observations on the nutrient concentrations in the initial and residual litter mass retrieved at monthly intervals under various study situations are tabulated in Table 8

4.2.1.1 Nitrogen

The content of nitrogen present in leaf litter collected during two seasons was found to be different Nitrogen content was highest in the leaves collected after south west monsoon season (3 02%) while the litter collected during pre-south west monsoon recorded relatively lower concentration (2 42%)

Litter which was incorporated into the soil during south west monsoon season showed gradual increase in nitrogen concentration in the residues at the end of first month From the second month onwards a considerable reduction in N concentration was noticed (Fig 5) The nitrogen content in the residues continued to decline upto to the end of fifth month in home garden recording the minimum value (1 59%). Further, it showed a gradual increase till the end of the study. In the residues collected from open area the nitrogen concentration recorded its minimum value of 1 40 per cent in fourth and sixth month samples After six months the N content increased gradually till the end

Table 8 Changes in the nutrient content of the residual mass retrieved at monthly intervals

Situation		Time (month)	Residual mass (g)	Nutrient concentration (%)					
				N	P	K	Ca	Mg	S
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Season I	Home garden	0	23.82	2.43	0.058	0.79	0.70	1.15	0.47
		1	16.74	2.61	0.029	0.10	0.99	0.66	0.93
		2	9.41	2.43	0.020	0.10	0.66	0.70	0.75
		3	3.11	2.24	0.031	0.07	0.78	0.58	0.42
		4	0.74	1.68	0.008	0.08	0.73	0.73	0.65
		5	2.64	1.59	0.010	0.07	0.23	0.71	1.65
		6	0.08	1.96	0.010	0.07	0.23	0.71	1.65
		7	1.77	2.10	0.010	0.07	0.49	0.71	1.62
		8	0.52	2.24	0.012	0.07	0.48	0.68	1.58
	Open area	0	23.82	2.43	0.058	0.79	0.70	1.15	0.47
		1	14.69	2.61	0.033	0.07	0.64	0.78	0.86
		2	3.94	2.24	0.016	0.08	0.63	0.63	1.03
		3	5.41	2.15	0.003	0.09	0.49	0.71	1.09
		4	2.59	1.40	0.000	0.09	0.27	0.73	1.27
		5	1.26	1.54	0.000	0.08	0.19	0.63	1.65
		6	0.01	1.40	NA	NA	NA	NA	NA
		7	0.04	1.54	NA	NA	NA	NA	NA
		8	0.85	1.96	NA	NA	NA	NA	NA

Contd.....

Table 8 contd....

(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Season II	Home garden	0	16.97	3.02	0.074	0.88	0.82	1.15	0.88
		1	7.73	2.89	0.060	0.70	1.66	0.78	0.99
		2	4.05	2.94	0.063	0.48	1.03	0.84	1.04
		3	2.13	2.61	0.064	0.59	0.76	0.88	0.42
		4	0.48	2.52	0.062	0.31	0.70	0.78	1.02
		5	1.79	2.05	0.058	0.37	0.78	1.11	1.36
		6	1.24	1.68	0.070	0.04	0.86	0.73	1.13
		7	0.56	2.10	0.062	0.10	0.70	0.73	0.49
		8	0.03	1.68	NA	NA	NA	NA	NA
		9	0.05	1.40	NA	NA	NA	NA	NA
	Open area	0	16.97	3.02	0.074	0.88	0.82	1.15	0.88
		1	7.70	3.08	0.059	0.18	3.30	0.83	0.98
		2	0.96	2.80	0.062	0.08	0.65	0.75	0.97
		3	0.66	2.99	0.062	0.06	0.85	0.73	0.39
		4	0.12	1.96	NA	NA	NA	NA	NA
		5	0.06	1.96	NA	NA	NA	NA	NA
		6	0.29	2.10	NA	NA	NA	NA	NA
		7	0.11	2.10	NA	NA	NA	NA	NA
		8	0.10	1.68	NA	NA	NA	NA	NA

Season I - South west monsoon season

Season II - North east monsoon season

NA - Decomposition was almost completed - sample was not sufficient for analysis

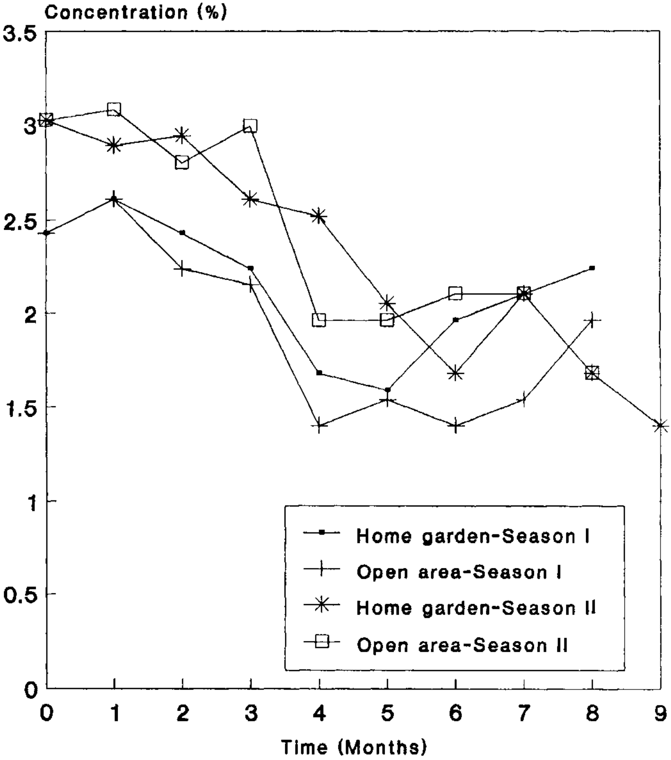

Fig. 5 Changes in nitrogen concentration in the decaying litter mass

The trend in nitrogen content of the residues retrieved at various intervals from the north east monsoon application plots are depicted in Fig 5 During the first month of sampling, the N content in the residues from home garden decreased gradually whereas in the open area it increased to 3 08 per cent In the second month of sampling, the N content in the residues of the home garden showed a considerable increase while in open area it showed a gradual decrease During the third month sampling, N content in the residues of open area showed a slight increase and reached to its lowest value of 1 68 per cent at the end of the eight month with slight fluctuations in between Similarly, the N content of the residues from home garden also showed gradual decrease from third month onwards and reached its lowest value of 1 40 per cent at the end of eighth month

4.2.1.2 Phosphorus

Phosphorus content in the leaf litter collected during the first season was very low (0 058%) compared to second season (0 074%) The changes in phosphorus content of the residual mass retrieved at monthly intervals at depicted in Fig 6

The residual mass obtained from the study situation during the first season showed a gradual decrease in P content in the first month of sampling (in home garden 0 03% and in open area 0 03%) The residues showed further decrease in P content in the second month of sampling The P content in the residues from home garden showed a slight increase during the third month of sampling (0 03%) where as in open area, a further reduction was noticed (0 003%) In the fifth month of sampling, the P content in the residues from home garden was 0 01 per cent whereas in open area the P content was practically nil The P content in the residues obtained from the home garden reached 0 012 per cent at the end of the study with slight fluctuations in between

The residues of the litter mass from the north east monsoon season's study situation showed a gradual decrease in the P content during the first month In the second month of sampling, a gradual increase in P content was noticed in both the situations The P content in the residues from the home garden at the end of the third month was 0 060 per cent, while the residues from the open area recorded 0 062 per cent of P The residues from home garden recorded its lowest P value in the fifth month of sampling (0 058%) It could also be seen from the table that P content of the residues from both the situations was 0 062 per cent at the end of the study period

4.2.1.3 Potassium

The potassium content of fresh leaf litter collected during the first and second season was found to be 0 79 per cent and 0 88

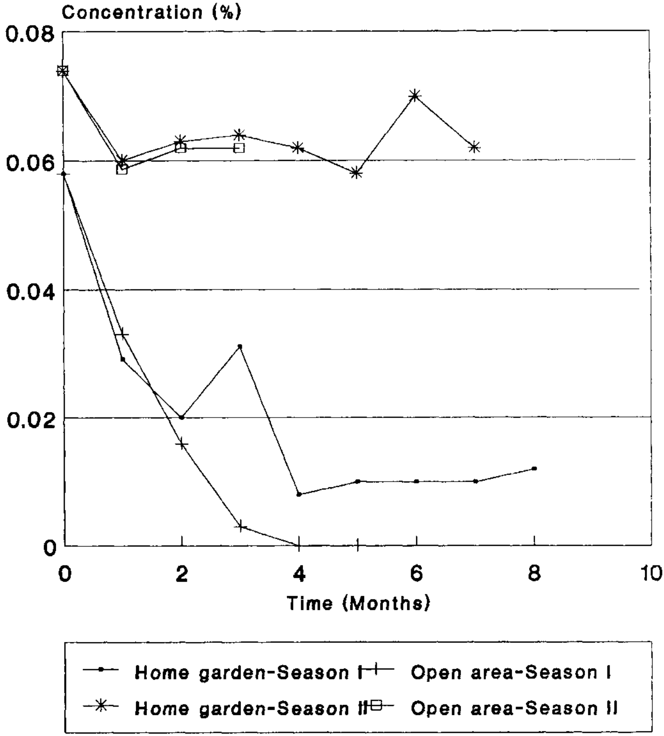

Fig. 6 Changes in phosphorus concentration in the decaying litter mass

per cent respectively The dynamics of K concentration in decaying litter sampled at monthly intervals are also illustrated in Fig 7

The potassium content of the residues obtained from the two study situations during the first season showed drastic reduction in the first month In the second month of sampling, slight increase was noticed in both the cases The potassium content in the residues obtained from home garden reached its lowest value at the end of third month (0 07%) The K content of the residues at the end of the study reached 0 07 per cent in home garden and 0 08 per cent in open area

Potassium content of the residues sampled during the second season from the two study situations showed a decreasing trend in the first month During the first month itself, the K content in the residues from open area was reduced drastically from 0 88 per cent to 0 18 per cent However, in home garden the reduction was gradual from 0 88 per cent to 0 70 per cent In open area it continued to decline and reached its lowest value of 0 06 per cent at the end In home garden the K content reduced gradually and reached its minimum value (0 04%) in the sixth month and at the end of the study, the K content was 0 10 per cent

4.2 1.4 Calcium

The calcium content of the fresh leaf litter was highest during the north east monsoon season (0 82%) Changes in calcium

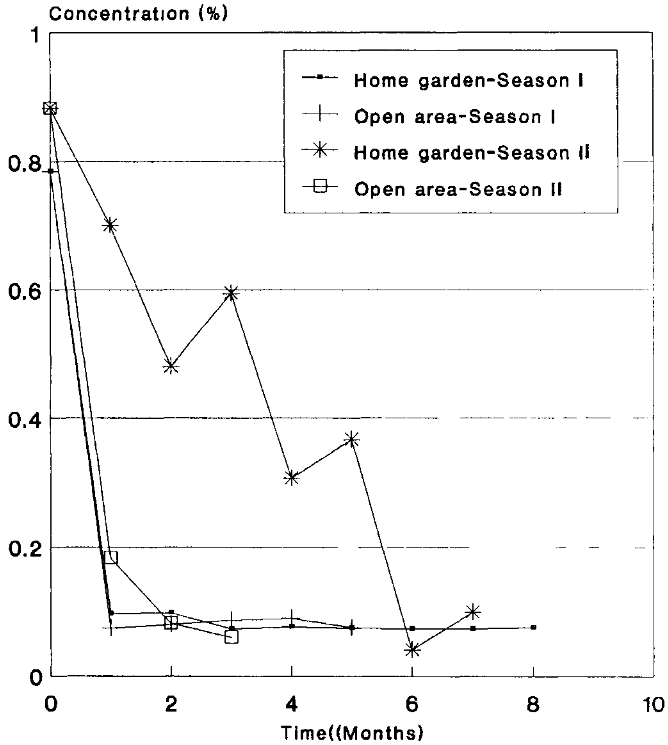

Fig. 7 Changes in potassium concentraion in the decaying litter mass

content of decaying litter mass kept under various situations are depicted in Fig 8

The content of calcium in the residual mass retrieved after first month of incorporation during the first season from the home garden was found to be increased (0 99%) whereas in open area, it showed a pronounced reduction (0 64%) Decrease in Ca content was observed in both the situations upto fifth month of sampling The Ca content in the residues retrieved from the open area was lowest in the fifth month (0.19%) whereas in home garden, the residues recorded a Ca content of 0 23 per cent

At the end of the first month, the Ca content in the residues retrieved during the second season was increased drastically and reached its highest value of 2 30 per cent in open area and 1 66 per cent in home garden In the next month of sampling, the Ca content was reduced slightly In home garden, the calcium content of the residue was lowest in the fourth and seventh month sampling (0 70%), whereas in open area the lowest content (0 65%) was recorded during the second month At the end of the study, the Ca content in the residues retrieved from the open area and home garden was respectively 0 85 per cent and 0 70 per cent

4.2.1.5 Magnesium

Initial content of magnesium in the leaf litter kept for decomposition in both the seasons was 1 15 per cent The changes

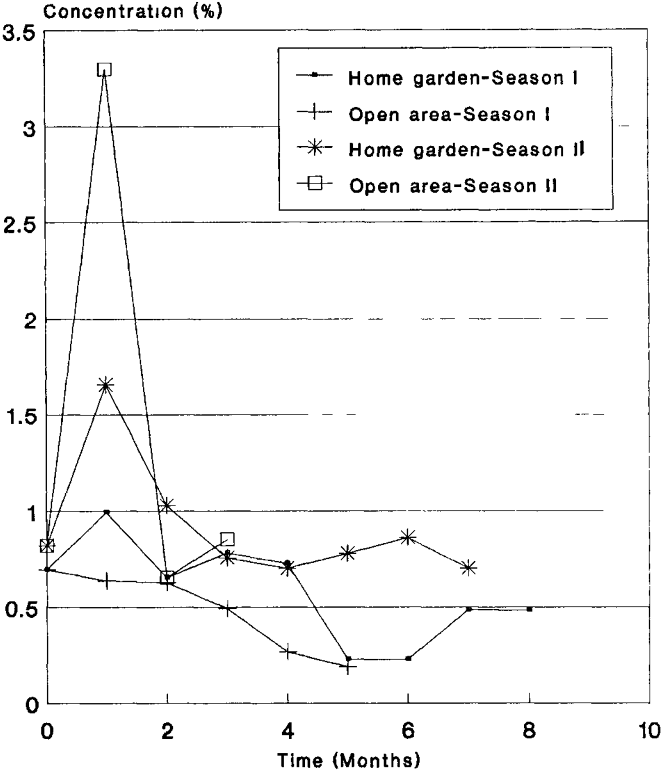

Fig. 8 Changes in calcium concentration in the decaying litter mass

in the Mg concentration after varying periods of exposure to decomposition are depicted in Fig 9

The residues sampled during the first season showed a decrease in Mg content after one month of exposure to decomposition During the second month of sampling, the magnesium content in the residues from home garden increased (0 70%), whereas it was decreased in open area (0 63%) In home garden, from fourth month onwards, the magnesium content was found to be almost steady, while a high degree of fluctuation was noticed in Mg content sampled from open area with respect to sampling period during the first season

During the second season, the Mg content was reduced in the residues sampled in the first month In the second month of sampling, the Mg content in the residues collected from the home garden showed a slight increase (0 84%) over previous month, whereas the residues from open area showed further fall in its content The lowest magnesium content in residues from both the situations was 0 73 per cent

4.2.1.6 Sulphur

Leaf litter collected during the second season had more sulphur content (0 88%) compared to the first season (0 47%) The fluctuations in the sulphur content of the decaying mass over a period of time are diagrammatically represented in Fig 10

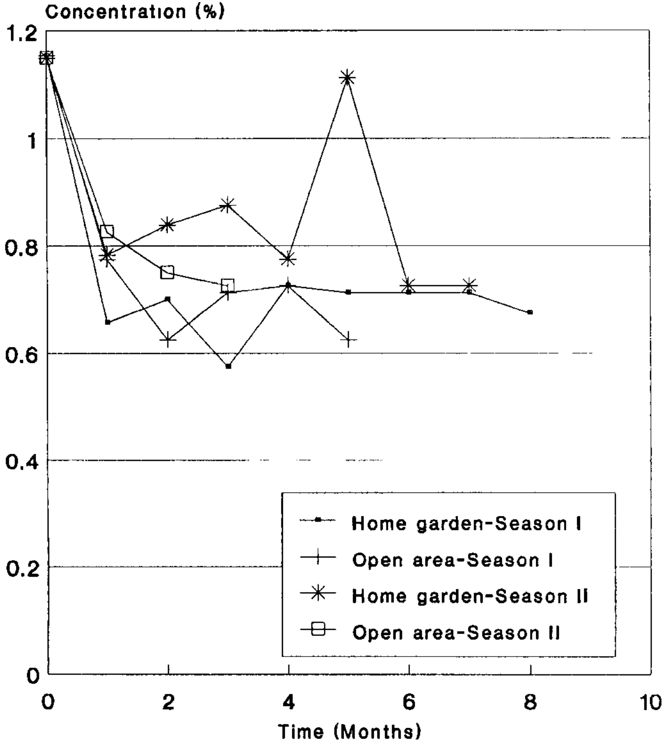

Fig. 9 Changes in magnesium concentration in the decaying litter mass

Residues obtained after one month of exposure to decomposition during the first season showed a gradual increase in the S content The sulphur content of the residues from the home garden decreased during the second month of sampling and reached the lowest value (0 42%) in the third month The residues from the open area registered a gradual increase in sulphur content and reached its peak (1 65%) at the end of the study period

Sulphur content of the residues during the second season also registered an increase in the first month in both the situations In open area, a decrease in sulphur content was noticed in the second month and reached its lowest value (0 39%) at the end The residues from home garden recorded lowest value (0 42%) in the third month and again showed an increase in fourth month and reached to maximum value (1 36%) in the fifth month The sulphur content in the residues collected from the home garden at the end of sampling period was 0 49 per cent

4.2.2 Changes in relative concentration of nutrients

The changes in relative concentration of nutrients in the residual mass sampled at monthly intervals are tabulated in Table 9 and illustrated in Figures 11 to 16

4.2 2.1 Nitrogen

The relative concentration of nitrogen in the decomposing litter during the south west monsoon season showed a slight increase

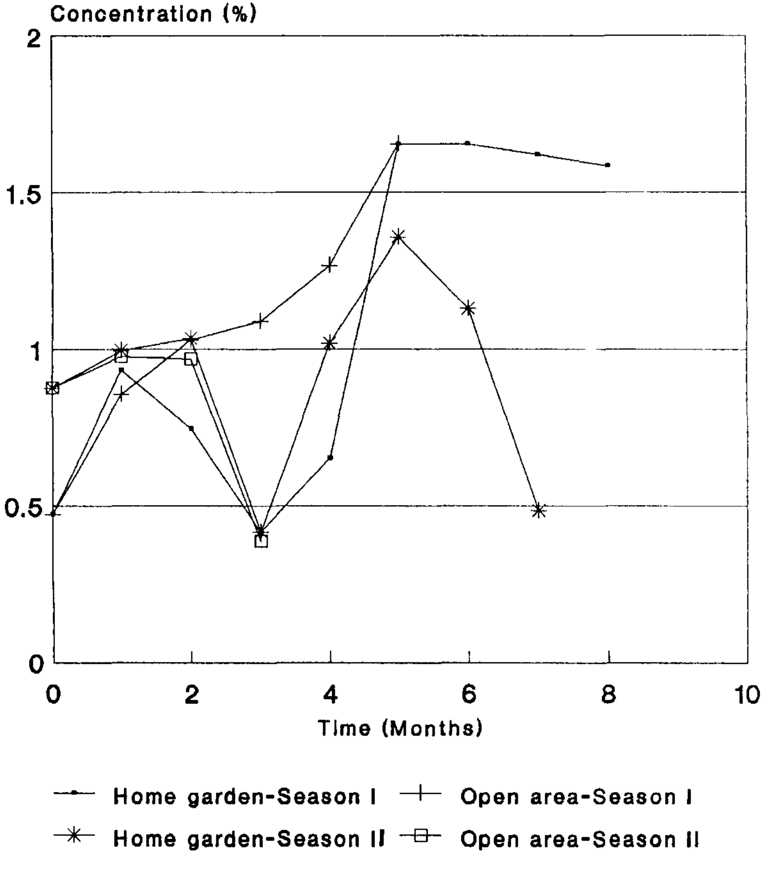

Fig. 10 Changes in sulphur concentration in the decaying litter mass

Table 9 Changes in the relative concentration of the nutrients in the residual mass retrieved at monthly intervals

Situation		Time (month)	Residual mass (g)	Relative concentration (%)					
				N	P	K	Ca	Mg	S
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Season I	Home garden	0	23 82	100 00	100 00	100 00	100 00	100 00	100 00
		1	16 74	107 55	49 43	12 32	128 21	57 05	197 88
		2	9 41	100 00	34 48	12 53	89 88	60 66	157 98
		3	3 11	92 18	53 45	9 27	107 02	49 83	88 14
		4	0 74	69 14	13 79	9 59	99 33	62 83	138 35
		5	2 64	65 38	17 24	9 40	31 11	61 76	350 21
		6	0 08	80 66	17 24	9 39	31 11	61 79	350 21
		7	1 77	86 42	17 24	9 39	66 63	61 76	342 34
		8	0 52	92 18	20 69	9 46	65 90	58 49	335 59
	Open area	0	23 82	100 00	100 00	100 00	100 00	100 00	100 00
		1	14 69	107 55	56 32	9 40	91 86	67 16	181 07
		2	3 94	92 18	27 59	10 12	90 23	54 16	218 22
		3	5 41	84 50	5 17	10 93	70 79	61 76	230 72
		4	2 59	57 61	0 00	11 33	38 17	62 83	268 46
		5	1 26	63 42	0 00	9 54	26 96	54 16	350 35
		6	0 01	57 61	NA	NA	NA	NA	NA
		7	0 04	63 37	NA	NA	NA	NA	NA
		8	0 85	80 66	NA	NA	NA	NA	NA

Contd

Table 9 contd

(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Season II	Home garden	0	16 97	100 00	100 00	100 00	100 00	100 00	100 00
		1	7 73	95 81	81 08	79 33	202 03	68 12	113 65
		2	4 05	97 35	85 14	54 50	125 20	72 84	118 02
		3	2 13	86 53	86 47	67 35	92 07	76 09	47 43
		4	0 48	83 44	83 78	34 81	85 73	67 39	116 31
		5	1 79	67 90	78 38	41 57	95 00	96 75	154 62
		6	1 24	55 63	94 59	4 50	105 24	63 04	128 73
		7	0 56	69 54	83 78	11 22	85 73	63 04	55 30
		8	0 03	55 63	NA	NA	NA	NA	NA
		9	0 05	46 36	NA	NA	NA	NA	NA
	Open area	0	16 97	100 00	100 00	100 00	100 00	100 00	100 00
		1	7 70	101 99	79 73	20 63	289 59	71 74	113 65
		2	0 96	92 72	83 78	9 18	79 62	65 22	110 60
		3	0 66	98 90	83 78	6 69	104 02	6304	44 01
		4	0 12	64 90	NA	NA	NA	NA	NA
		5	0 06	64 82	NA	NA	NA	NA	NA
		6	0 29	69 54	NA	NA	NA	NA	NA
		7	0 11	69 54	NA	NA	NA	NA	NA
		8	0 10	55 63	NA	NA	NA	NA	NA

Season I - South west monsoon season

Season II - North east monsoon season

NA - Decomposition was almost completed - sample was not sufficient for analysis

over its initial value in the first month of sampling (107 56%) under both the study situations In the subsequent months, the relative concentration decreased gradually upto fifth month During the sixth month, the relative content of N in the residues from open area showed further decrease compared to home garden where it was increased gradually till the end of the study

During the north east monsoon season, the relative concentration of N in the residual mass collected from home garden was found to be reduced (95 81%), whereas it slightly increased in open area (101 85%) in the first month of sampling In the second month of sampling, the relative concentration of N in the residues from home garden recorded an increase while in open area it decreased At the end of the experiment study the relative concentration of nitrogen in both the study situations was found to be 55 56 per cent each

4.2.2 Phosphorus

The litter residues collected during the south west monsoon season showed a gradual decrease in their relative P concentration till the end of second month The changes in relative P concentration are depicted in Fig 12 The relative changes in P content of the litter residues from the home garden recorded 53 45 per cent in the third month whereas in the open area its content decreased further to 5 17 per cent In the fourth month, the

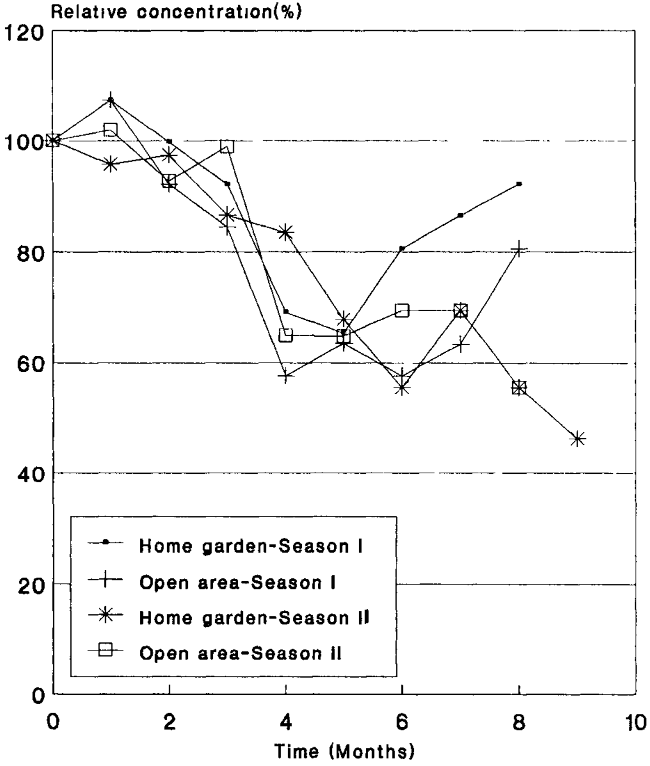

Fig.11 Changes in relative concentration of nitrogen in decaying litter mass

relative P content in the home garden reached its lowest value (1 379%), whereas in open area, it reduced to zero At the end of the study ie at the end of eighth month, the relative changes in P content of the litter mass collected from the open area was absolutely practically nil whereas in home garden the residues contain 20 69 per cent

The relative changes of phosphorus in the residual mass retrieved from home garden and open area during the north east monsoon season study period experienced a decrease in the first month In the second month, the relative changes in P increased in both the situations Relative P content in the residues at the end of the study was 83 78 per cent in both the study situations

4 2.2 3 Potassium

Figure 13 illustrates the relative changes in K concentration at various sampling intervals The trends in relative concentration of potassium in decaying mass was similar to that of potassium concentration The relative K content in the litter mass kept for decomposition during the south west monsoon season reduced drastically in the first month and remained more or less steady in the subsequent periods

During the second season, the litter residues sampled after one month showed a gradual reduction in their relative K content in the home garden and drastic reduction in open area During the

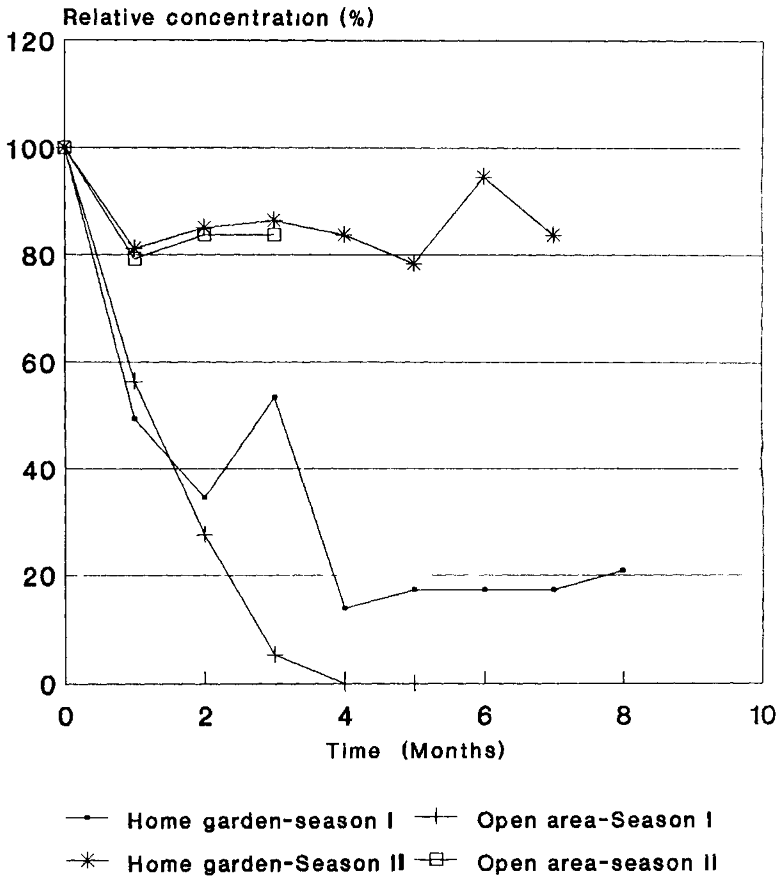

Fig.12 Changes in relative concentration of phosphorus in decaying litter mass

third month, the relative K content in home garden showed a slight increase in relation to open area where it was reduced to 6 69 per cent The relative potassium content in the residues collected from the home garden at the time of last sampling was 11 22 per cent

4 2 2.4 Calcium

The relative changes in the calcium content with respect to initial content over time is diagrammatically represented in Fig 14

After one month of decomposition, the relative content of calcium in the litter kept during south west monsoon period was 128 21 per cent in home garden and 91 86 per cent in open area The relative concentration of calcium in the residues from open area showed a gradual decline and recorded the lowest value of 26 96 per cent towards the end of the study, whereas in home garden it showed fluctuations and finally reached to 65 90 per cent

The relative content of calcium in the litter residues obtained during north east monsoon season was found to increase by two fold in the first month However, in the second month, relative Ca content in the residual mass reduced drastically in both the cases The content in the residues at the end of third month from open area was 104 02 per cent It could also be seen from the data that the relative calcium content in the residues collected from the home garden reached 85 73 per cent at the end of the study with varied fluctuations in between

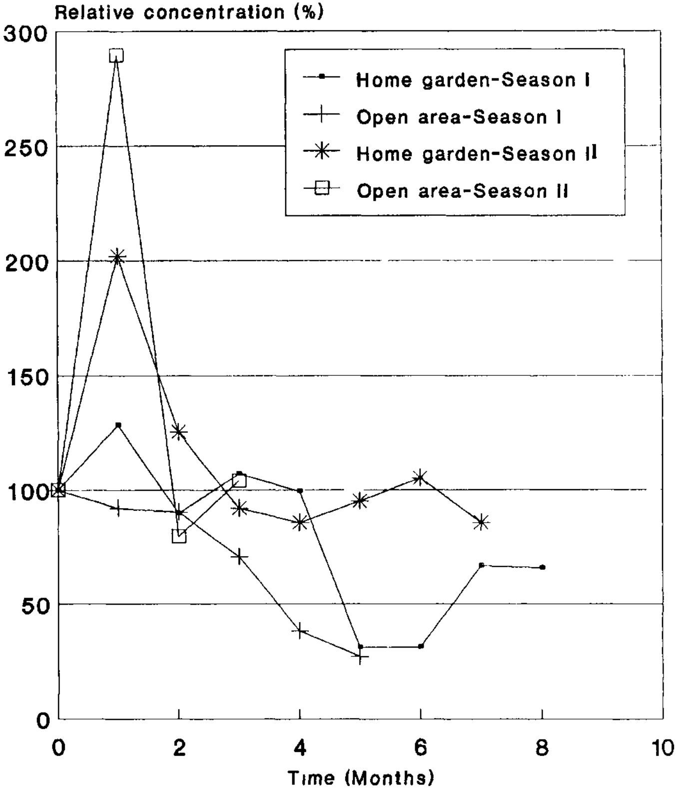

Fig.14 Changes in relative concentration of calcium in decaying litter mass

4 2.2 5 Magnesium

Unlike calcium, the relative content of magnesium reduced gradually in the litter residues retrieved after one month (Fig 15) In the second month, the relative Mg content in the residues from home garden increased to 60 66 per cent The relative content of Mg in the residues obtained from home garden recorded 58 49 per cent at the end of the study while in open area, it recorded 54 16 per cent In the former case, there was high degree of inconsistency in relative content

The residues of the litter applied during north east monsoon exhibited a gradual reduction in their relative magnesium content at the end of the first month The relative magnesium in the litter residues collected from home garden at the end of the study was 63 04 per cent

4.2.2.6 Sulphur

The changes in relative sulphur content with respect to various study situations are depicted in Fig 16 The residues of the litter applied in the south west monsoon season showed an abrupt increase in their relative sulphur concentration by the end of first month The residues from the open area showed further increase till the end and registered a maximum of 350 33 per cent The data also indicated that the residues from the home garden experienced a decrease during the second and third month (88 14%) and increased

4 2.2 5 Magnesium

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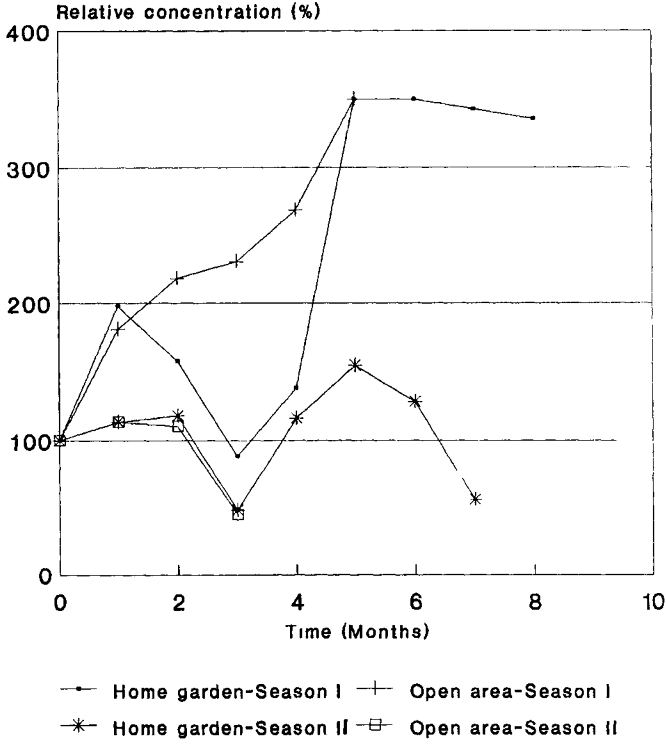

Fig.16 Changes in relative concentration of sulphur in decaying litter mass

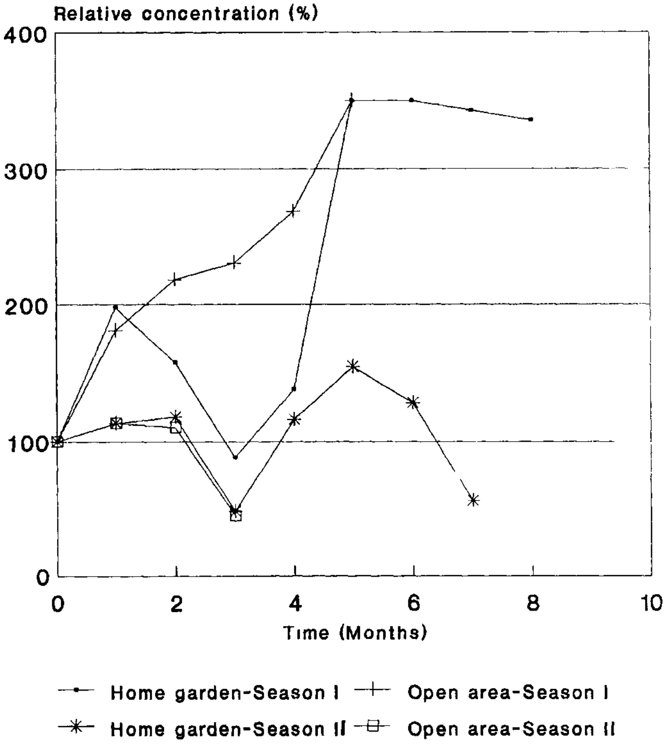

Fig.16 Changes in relative concentration of sulphur in decaying litter mass

ın the subsequent two months and recorded ıts peak (350 21%) durıng the fıfth month The relatıve content at the end of the samplıng was 335 59 per cent

The relatıve S content of the lıtter resıdues durıng the second season was ıncreased to 113 65 per cent durıng the fırst month of samplıng Durıng the thırd month, the relatıve S content was lowest ın both the sıtuatıons In the home garden the maxımum relatıve content of S (154 62%) was recorded ın the fıfth month of samplıng The relatıve content of the S ın the resıdues durıng the last samplıng was 55 30 per cent

4.2.3 Changes in absolute amount of nutrıents in the residual mass

The data related to the absolute amount of nutrıents ın the resıdual mass at varıous perıods of study are tabulated ın Tables 10 to 16 The dynamıcs ın absolute amount of nutrıents ın dıfferent sıtuatıons over perıods are graphıcally presented ın Fıgures 17 to 22 The mathematıcal models suggested to predıct the mıneralısatıon of dıfferent nutrıent elements at perıodıcal ıntervals under dıfferent sıtuatıons are presented ın Appendıx V

4 2 3 1 Nıtrogen

It could be seen from the table and fıgure that general mıneralısatıon of absolute nıtrogen content had showed bıphasıc

Table 10 Changes in the absolute amount of nutrients of the residual mass retrieved at monthly intervals

Situation		Time (month)	Residual mass (g)	Absolute amount of nutrients (%)					
				N*	P*	K*	Ca*	Mg	S
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Season I	Home garden	0	23 82	100 00	100 00	100 00	100 00	100 00	100 00
		1	16 74	76 19	31 85	8 81	85 92	39 70	144 08
		2	9 41	36 79	14 21	5 42	34 99	25 86	54 89
		3	3 11	13 62	7 04	1 21	14 24	6 67	11 59
		4	0 74	2 10	0 43	1 05	3 15	2 29	4 30
		5	2 64	7 55	0 01	0 03	3 48	6 89	38 85
		6	0 08	0 26	0 06	0 69	0 11	0 20	1 12
		7	1 77	6 35	1 24	0 21	4 74	4 59	25 51
		8	0 52	2 02	0 46	0 00	1 52	1 28	7 37
	Open area	0	23 82	100 00	100 00	100 00	100 00	100 00	100 00
		1	14 69	66 74	36 37	5 65	57 65	40 35	110 67
		2	3 94	15 24	4 66	1 67	14 92	8 96	36 09
		3	5 41	19 40	1 37	2 51	15 78	13 83	52 89
		4	2 59	7 13	0 00	1 28	4 55	6 82	30 41
		5	1 26	3 39	0 00	0 22	1 41	2 88	18 33
		6	0 01	0 01	NA	NA	NA	NA	NA
		7	0 04	0 02	NA	NA	NA	NA	NA
		8	0 85	0 68	NA	NA	NA	NA	NA

Contd

Table 10 contd

(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Season II	Home garden	0	16 97	100 00	100 00	100 00	100 00	100 00	100 00
		1	7 73	43 89	36 46	36 94	87 41	30 93	51 98
		2	4 05	22 27	20 61	9 53	32 63	16 55	26 56
		3	2 13	11 48	10 83	8 43	11 53	9 53	5 94
		4	0 48	2 35	2 36	5 23	2 41	1 90	3 27
		5	1 79	7 70	0 03	0 29	10 18	9 83	15 80
		6	1 24	4 18	6 71	0 37	7 68	4 76	9 82
		7	0 56	2 21	2 78	0 00	2 84	2 09	0 36
		8	0 03	0 09	NA	NA	NA	NA	NA
		9	0 05	0 13	NA	NA	NA	NA	NA
	Open area	0	16 97	100 00	100 00	100 00	100 00	100 00	100 00
		1	7 70	45 01	35 74	7 55	143 49	32 00	46 98
		2	0 96	5 23	4 76	0 52	4 52	3 70	6 28
		3	0 66	3 68	3 22	0 26	4 03	2 44	1 70
		4	0 12	0 47	NA	NA	NA	NA	NA
		5	0 06	0 22	NA	NA	NA	NA	NA
		6	0 29	1 21	NA	NA	NA	NA	NA
		7	0 11	0 43	NA	NA	NA	NA	NA
		8	0 10	0 33	NA	NA	NA	NA	NA

* CV (0 05) for comparison of interaction effect

	N	P	K	Ca
Month	9	6	1	6
CV	0 1	3 57	14 32	4 69
SEM(+)	0 03	1 05	4 22	1 38

Season I - South west monsoon season

Season II - North east monsoon season

NA Decomposition was almost completed sample was not sufficient for analysis pattern with an initial rapid phase and a latter slow phase Around 90 per cent of the nitrogen was mineralised in the initial rapid phase which lasted only for three months

4 2 3.1.1 Effect of season

Absolute nitrogen content was comparatively high in the litter residue mass applied in the south west monsoon season (71 46%) compared to north east monsoon season application (44 50%) after one month of incorporation of litter and the difference was found to be statistically significant(Table 11) The absolute nitrogen was more in the first season residues in almost all the months except sixth and ninth month where in the second season, litter residues were having more nitrogen In general, the absolute N content reduced gradually till the end in both the seasons with an exception in fifth month The absolute nitrogen at the end of the study in the first season was 3 19 per cent whereas in second season it was 0 06 per cent

4.2.3.1.2 Effect of field condition

Absolute N content in different field situations did not differ significantly throughout the study period However, in almost all the months the litter residues from the home garden retained more N compared to open area

4 2.3 1.3 Interaction effect of season and field conditions

Absolute N content in the residual litter mass obtained from various study situations during different months of sampling are

Table 11 Changes in the absolute amount of nitrogen in the residual mass as influenced by season and field conditions (pooled data)

Study situation	Months after incorporation of leaf litter								
	1	2	3	4	5	6	7	8	9
Season I	71 46	26 02	16.51	4 62	5.47	0 13	3 12	3.19	NA
Season II	44.50	13 77	7.58	1.41	3.96	2 69	1.32	1.32	0.06
CD (0 05)	22 66	NS	NS	NS	NS	1 92	NS	NS	-
SEM±	9 83	-	-	-	-	0 83	-	-	-
Home garden	60.04	29 53	12.55	2.22	7.63	2 22	0.23	4 28	0.06
Open area	55 92	10 26	11 54	3 80	1.80	0 61	4 23	0 23	NA
CD (0 05)	NS	NS	NS	NS	NS	NS	NS	NS	-
SEM±	-	-	-	-	-	-	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

NA - Decomposition was almost completed - sample was not sufficient for analysis

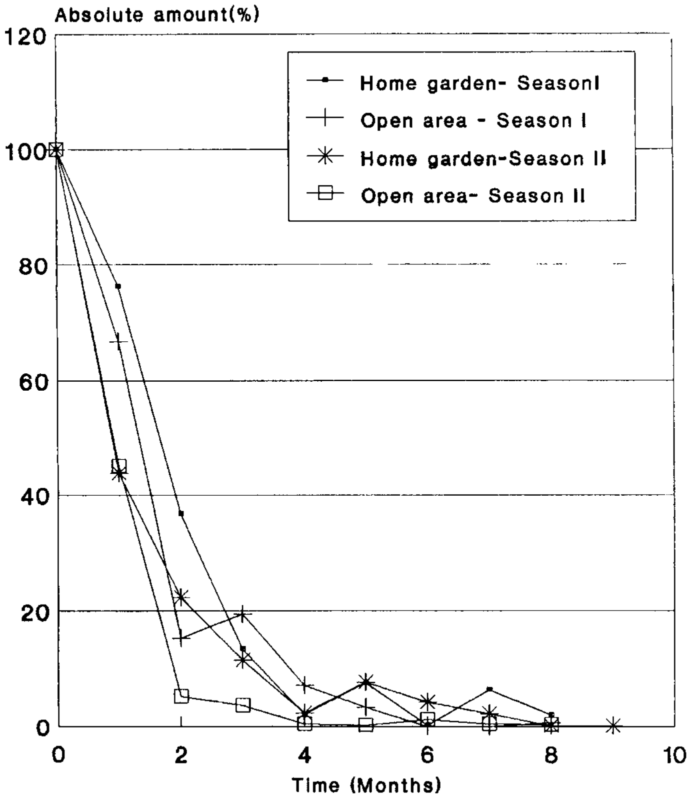

Fig.17 Changes in absolute amount of nitrogen in litter mass

tabulated in Table 10 At the end of the first month, the absolute N content was high in home garden during the first season (76 19%) while samples from the home garden of the second season registered lowest absolute content (43 89%) during the first month of sampling The absolute N content in the litter residues decreased gradually in all the situations till the end of fourth month In the fifth month, the absolute N content in the residues from the home garden during both the seasons registered a slight increase whereas in open areas, it decreased further Absolute N content in the residues collected during the first season from home garden was more (2 02%) at the end of eighth month whereas in other situations it was lower than 0 75 per cent

The nitrogen mineralisation pattern in all the study situations showed a best fit with the second order hyperbolic function with r^2 value of more than 0 976

4.2 3.2 Phosphorus

Absolute content of phosphorus in leaf litter mass during the process of mineralisation indicated a biphasic pattern with an initial rapid phase followed by slow latter phase (Fig 18) In general, nearly 90 per cent of the absolute phosphorus was mineralised during the first three months

4.2.3.2.1 Effect of season of application

The absolute P content during the second season was comparatively high (36 10%) in the residues collected in first month of sampling A gradual decrease with slight fluctuations were observed throughout the study period

4.2.3 2.2 Effect of field condition

The absolute content of phosphorus in the decaying mass kept for decomposition in different field situations did not differ significantly upto fifth month In the first month of study, the absolute P content was found to be more in residues from open area (36 06%) while in the subsequent months the content was more in residues from home garden

4.2 3.2.3 Interaction effect of season and field conditions

The absolute phosphorus content in the residual mass from home garden of the second season was slightly more (36 46%) during the first month of sampling The absolute P content declined gradually in the subsequent months in all the study situations This trend was noticed till the end of fifth month Absolute P content in the residues from the home garden in both the seasons increased considerably at the time of sixth month of sampling and during this time the residues from second season recorded significant amount of P compared to other situations After six months of incorporation of litters during the first season, the P content reduced gradually and reached 0 46 per cent in the residues retrieved from the home garden

Table 12 Changes in the absolute amount of phosphorus in the residual mass as influenced by season and field conditions (pooled data)

Study situation	Months after incorporation of leaf litter							
	1	2	3	4	5	6	7	8
Season I	34 11	9 39	4.21	0.22	0 01	0 03	0.62	0 23
Season II	36 10	12 68	7.04	1.18	0 02	3 36	1 39	NA
CD (0 05)	NS	NS	NS	NS	NS	2 43	NS	-
SEM±	-	-	-	-	-	1 05	-	-
Home garden	34 15	17 41	8.94	1.40	0 03	3 38	2 01	0 23
Open area	36 06	4 66	2.31	0 00	0 00	NA	NA	NA
CD (0 05)	NS	NS	NS	NS	NS	-	-	-
SEM±	-	-	-	-	-	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

NA - Decomposition was almost completed - sample was not sufficient for analysis

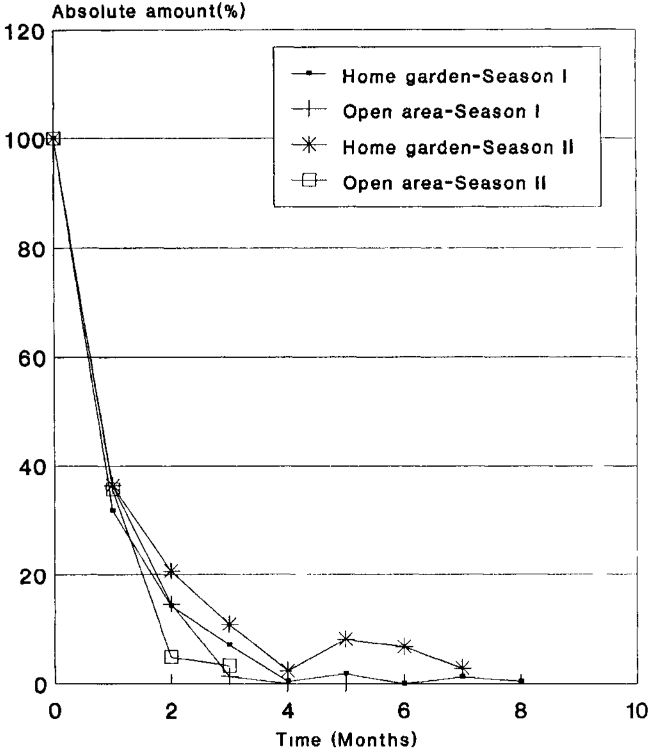

Fig.18 Changes in absolute amount of phosphorus in litter mass

Among the several models suggested for predicting mineralisation of P, the second order hyperbolic function was found to be a good fit for all situations except for the open area of the second season which showed a good fit with parabolic function (r^2 = 0 999)

4.2.3.3 Potassium

The absolute concentration of potassium in the litter residual mass retrieved at various months are presented in Tables 10 and 13 Like N and P, potassium mineralisation also followed a biphasic pattern (Fig 19) In the first month itself, the decaying mass losts nearly 80 per cent of the absolute K

4 2.3.3.1 Effect of season of application

Absolute content of potassium present in the first season litter mass was significantly low (7 23%) compared to second season (22 25%) during the first month of sampling The absolute potassium content experienced a gradual decrease till the end of fifth month in both the seasons In the sixth month of sampling, an increase in absolute content was observed in both the cases and this was followed by a reduction during the subsequent periods

4.2 3.3.2 Effect of field conditions

At the time of first month sampling the absolute K content was significantly higher in the residues collected from the home

Table 13 Changes in the absolute amount of potassium in the residual mass as influenced by season and field conditions (pooled data)

Study situation	Months after incorporation of leaf litter							
	1	2	3	4	5	6	7	8
Season I	7 23	3 54	1 86	1 17	0 12	0 35	0 11	0 00
Season II	22 25	5 03	4 35	2 61	0 14	0 19	0 00	NA
CD (0 05)	9 74	NS	NS	NS	NS	NS	NS	-
SEM±	4 22	-	-	-	-	-	-	-
Home garden	22 87	7 47	4 82	3 14	0 16	0 53	0 11	0 00
Open area	6.60	1 10	1 38	0.64	0 11	NA	NA	NA
CD (0 05)	9.74	NS	NS	NS	NS	-	-	-
SEM±	4.22	-	-	-	-	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

NA - Decomposition was almost completed - sample was not sufficient for analysis

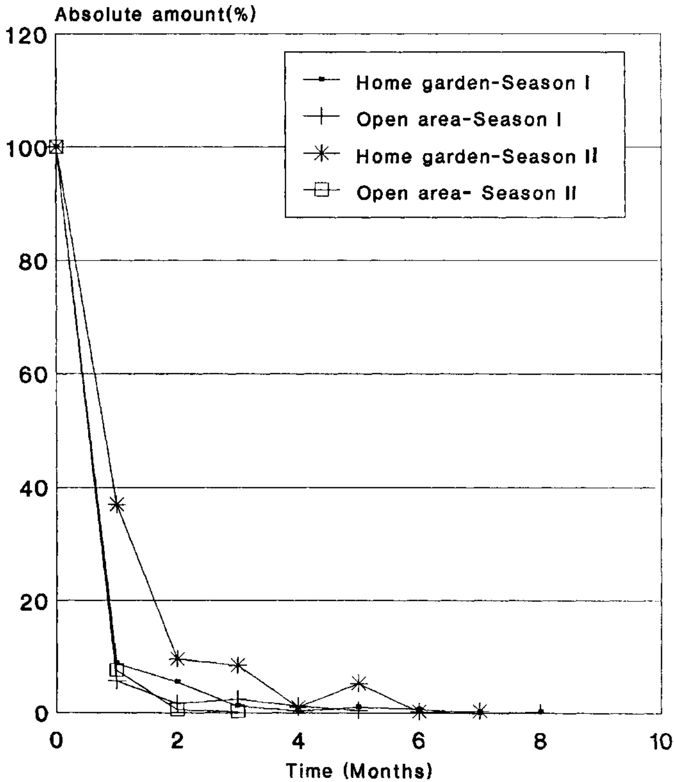

Fig. 19 Changes in absolute amount of potassium in litter mass

garden (22 87%) The absolute K content in the litter mass reduced gradually till the end of fifth month The K content of the residues from the home garden was considerably more compared to open area Like other elements, the K content was found to be increased in the sixth month and reduced further in subsequent months

4 2 3 3 3 Interaction effect of season and field conditions

The absolute potassium content was significantly more in the litter residues retrieved from home garden during the north east monsoon period (36 94%) As in the case of N and P, the absolute potassium was also decreased gradually till the end of fifth month At the time of sixth month of sampling, the absolute potassium was higher in the litter residues from home garden particularly during the first season (0 69%)

Among the several models suggested for predicting the mineralisation against time, the second order hyperbolic function was found to be best fit with r^2 value more than 0 778 in all the study situations

4.2.3.4 Calcium

The data presented in Tables 10 and 14 indicate the changes in absolute calcium content in decaying litter mass at monthly intervals as influenced by the season and field conditions The fluctuations in absolute amount Ca in decaying mass during different period of decomposition is depicted in Fig 20

Table 14 Changes in the absolute amount of calcium in the residual mass as influenced by season and field conditions (pooled data)

Study situation	Months after incorporation of leaf litter							
	1	2	3	4	5	6	7	8
Season I	71.78	24.96	15.01	3.85	2 45	0 05	2.37	0 76
Season II	115.45	18.58	7.78	1.21	5.09	3 84	1.42	NA
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	-
SEM±	-	-	-	-	-	-	-	-
Home garden	86 66	33.81	12.88	2.78	6.83	3 89	3.79	0.76
Open area	100.57	9 72	9.90	2.28	0.71	NA	NA	NA
CD (0 05)	NS	NS	NS	NS	5.99	-	-	-
SEM±	-	-	-	-	2.60	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

NA - Decomposition was almost completed - sample was not sufficient for analysis

4.2 3 4.1 Effect of season of application

The changes in the absolute amount of calcium in the decaying mass due to seasons are presented in Table 14 The calcium content in the detritus from the second season was high (115 45%) in the first month of sampling Absolute content of calcium was decreased gradually in south west monsoon season and drastically in north east monsoon season (18 58%) during the second month of sampling During the initial months of study, the absolute content of Ca was higher in the first season residues compared to second season litter residues except in the first month However, after five months of incorporation, the absolute Ca was found to be much higher in the litter residues retrieved during the second season

4.2.3.4.2 Effect of field conditions

The pooled analysis of data indicate that the residues obtained from the open area was having more amount of absolute calcium compared to residues from home garden in the first month (Table 14) In subsequent months, the absolute calcium content was much higher in the litter residues from the home garden This was reduced gradually from first month to the end except during the first month sampling from home garden which it showed a slight increase The absolute calcium content was significantly high in the litter residues collected from the home garden (6 83%) compared to open area after five months of decomposition During the eighth

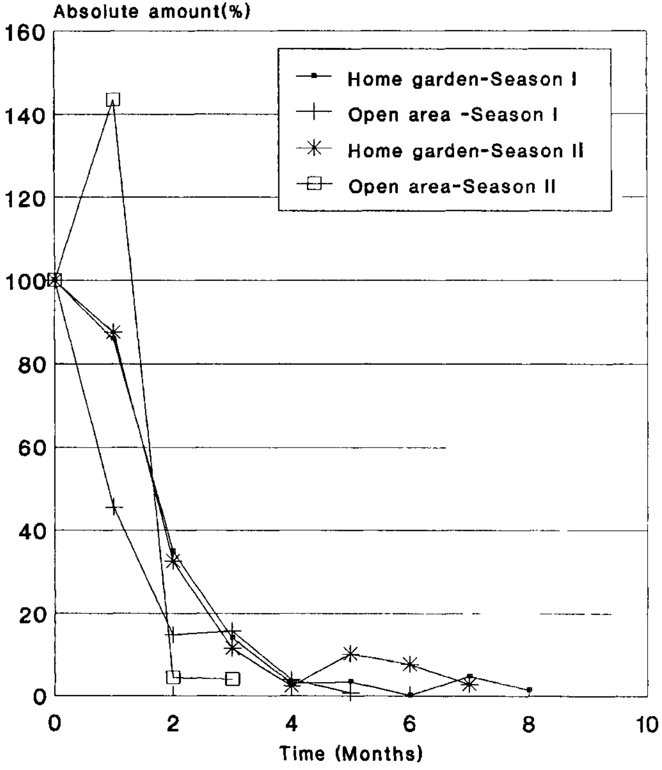

Fig.20 Changes in absolute amount of calcium in litter mass

month, the absolute calcium content of residues was 0 76 per cent in home garden

4 2.3 4.3 Interaction effect of season and field conditions

The data presented in Table 10 represent the changes in absolute amount of calcium in decaying mass at various periods The absolute calcium content of the residues decreased during the first month of sampling in all the situations except the open area of the second season which showed an abrupt increase in calcium content (143 49%) In subsequent months the calcium content decreased gradually The absolute Ca content in the litter residues from home garden during second season was found to be significant (7 68%) in the sixth month sample

Among the various models suggested for nutrient mineralisation pattern, the second order hyperbolic function was found to be the best fit with r^2 value more than 0 976 in all the cases except the open area of the second season (r^2 = 0 852)

4.2.3.5 Magnesium

Like other elements, the mineralisation of magnesium followed a biphasic pattern with an initial rapid phase (Fig 21) The data presented in the Tables 10 and 15 represent the changes in absolute amount of Mg at various stages of decomposition In general, about 90 per cent of initial magnesium was mineralised within three months of decomposition of leaf litter

Table 15 Changes in the absolute amount of magnesium in the residual mass as influenced by season and field conditions (pooled data)

Study situation	Months after incorporation of leaf litter							
	1	2	3	4	5	6	7	8
Season I	40 02	17.41	10 25	4 55	4.88	0 10	2.30	0 64
Season II	31 46	10.13	5.98	0.95	4.92	2.38	1.04	NA
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	-
SEM±	-	-	-	-	-	-	-	-
Home garden	35 31	21.21	8.10	2.09	8.36	2 48	3.34	0.64
Open area	36.17	6.33	8.13	3.41	1.44	NA	NA	NA
CD (0.05)	NS	NS	NS	NS	6 18	-	-	-
SEM±	-	-	-	-	2.68	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

NA - Decomposition was almost completed - sample was not sufficient for analysis

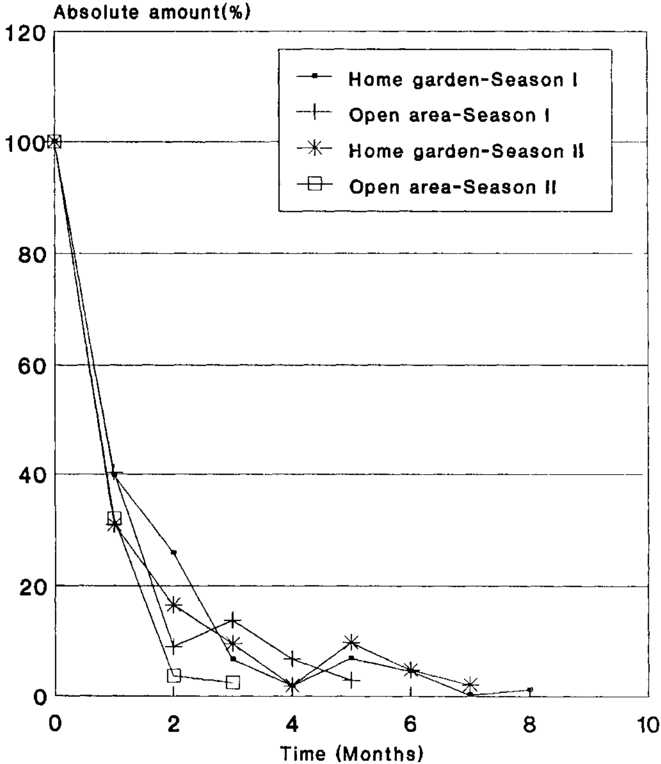

Fig. 21 Changes in absolute amount of magnesium in litter mass

4 2.3.5.1 Effect of season of application

The magnesium content in the residual mass decreased gradually from 40 02 per cent to 0 64 per cent (at the end of the study) during the south west monsoon season application However, the reduction during this period was from 31 46 per cent to 1 04 per cent in the north east monsoon season

4.2.3.5.2 Effect of field condition

Like other elements, the magnesium content in the litter residues from the open area was slightly higher (36 17%) compared to home garden (35 31%) In subsequent samplings, the residual mass from home garden had considerably more amount of absolute magnesium After six months of incorporation of litters, the absolute Mg content in the detritus from the home garden was 8 36 per cent and subsequently this showed a gradual decrease till the end of the study

4.2.3.5.3 Interaction effect of season and field conditions

Absolute magnesium content was higher in residues from the open area of the first season (40 35%) after one month of decomposition of leaf litter The absolute Mg in the residual litter mass reduced gradually in subsequent months with slight fluctuations No significant difference could be observed throughout the study period in the interaction effect of season and field conditions on absolute content of magnesium in the residual mass

Second order hyperbolic function was found to be a good fit for predicting magnesium release pattern from the decomposing litter mass for all the study situations except open area during the second season which showed a good fit with parabolic function (r^2 = 0 996)

4 2.3.6 Sulphur

Absolute concentration of sulphur exhibited high fluctuations in decaying litter mass (Fig 22) Data tabulated in Tables 10 and 16 clearly indicate the fluctuations in sulphur content of decomposing leaf litter mass

4.2 3.6.1 Effect of season of application

At the time of first month of sampling, the absolute sulphur content in the decaying litter mass of the first season was significantly high (127 37%) compared to second season (49 48%) The absolute sulphur content in the residual mass of the first season was comparatively high throughout the study period though the difference is not statistically significant In both the seasons, the absolute S content decreased gradually from second month onwards with slight fluctuations

4 2 3 6.2 Effect of field conditions

Absolute sulphur content in the home garden leaf residues was slightly higher during the initial two months In the first month of sampling, the home garden litter residues recorded 98 03 per cent

Table 16 Changes in the absolute amount of sulphur in the residual mass as influenced by season and field conditions (pooled data)

Study situation	Months after incorporation of leaf litter							
	1	2	3	4	5	6	7	8
Season I	127 37	45 49	32.24	17.36	28.59	0 56	12.76	3 68
Season II	49 48	16 42	3.82	1.64	7.98	4 91	0.18	NA
CD (0.05)	71 72	NS	NS	NS	NS	NS	NS	-
SEM±	31.10	-	-	-	-	-	-	-
Home garden	98.03	40 73	8.76	3.79	27.32	5 47	12.94	3 68
Open area	78.82	21.18	27.30	15.21	9 25	NA	NA	NA
CD (0 05)	NS	NS	NS	NS	NS	-	-	-
SEM±	-	-	-	-	-	-	-	-

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

NA - Decomposition was almost completed - sample was not sufficient for analysis

of absolute sulphur whereas residues in the open area had 78 82 per cent The absolute sulphur content decreased gradually in subsequent months The decaying litter mass from home gardens at the time of ninth month of sampling recorded 3 68 per cent of sulphur

4.2.3 6.3 Interaction effect of season and field conditions

The residues from both the home garden and open area during the south west monsoon period showed a considerable increase in their absolute sulphur content at the time of first month sampling The litter residues from home garden of the first season recorded 144 08 per cent of absolute sulphur where as litter from open area registered 110 67 per cent of initial absolute sulphur content In subsequent months, the sulphur content in the litter residues mineralised and reduced gradually with slight fluctuations Though the absolute sulphur content showed some amount of variations, the difference among the situations was not significant in any of the sampling periods

Log normal function was found to be the best fit (r^2 = 1 000) for modelling sulphur mineralisation in open area during north east monsoon season application whereas in all other situations second order hyperbolic function was found to be good fit with r^2 more than 0 860

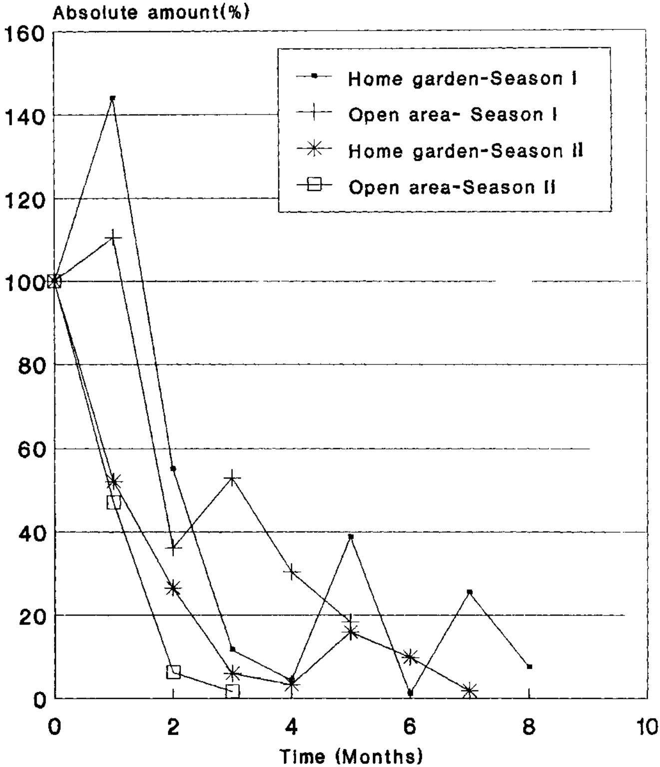

Fig.22 Changes in absolute amount of sulphur in litter mass

4.2.4 Relative mineralisation efficiency of nutrients under various study situations

The observations furnished in Table 17 indicate the absolute amount of nutrient present in the residual mass after a period of three months In all the situations rate of mineralisation of nutrients did not differ significantly However, in general, potassium appeared to be mineralised faster In home garden, during the first season, potassium in the litter mass mineralised faster with an absolute content of 1 21 per cent This was immediately followed by magnesium, phosphorus, sulphur, nitrogen and calcium But when the study was conducted in open area, during the same season, phosphorus showed quicker mineralisation (1 36%) followed by potassium (2 51), magnesium (13 83%) calcium (15,78%) nitrogen (19 40%) and sulphur (52 89%) In the home garden of the north east monsoon season, the sulphur was found to be mineralised faster (5 94%) followed by potassium, magnesium, phosphorus, nitrogen and calcium (11 53%) In the open area, during the north east monsoon season, the absolute content of K was found to be 0 26 per cent followed by S(1 70%), Mg(2 44%), P(3 24%), N(3 68%) and Ca (4 03%)

4.3 Changes in pH and nutrient status of soil due to leaf litter decomposition

The present study was also envisaged to find out the effect of leaf litter decomposition on changes in soil pH and nutrient

Table 17 Nutrients remaining in the residual mass after three months of decomposition

Study situation		Absolute amount of nutrient remaining (%)						Order of mineralisation
		N	P	K	Ca	Mg	S	
Season I	Home garden	13 29	7.04	1.21	14.23	6.67	11.59	K ≥ Mg ≥ P ≥ S ≥ N ≥ Ca (NS)
	Open area	19 40	1.36	2.51	15.78	13.83	52.89	P ≥ K ≥ Mg ≥ Ca ≥ N ≥ S (NS)
Season II	Home garden	11 48	10 83	8 43	11.53	9 53	5 94	S ≥ K ≥ Mg ≥ P ≥ N ≥ Ca (NS)
	Open area	3 68	3 24	0.26	4.03	2 44	1 70	K ≥ S ≥ Mg ≥ P ≥ N ≥ Ca (NS)

Season I - South west monsoon season

Season II - North east monsoon season

NS - Not significant

Table 18 Changes in the pH and major nutrients of soil as influenced by litter decomposition at monthly intervals

Situation (1)	Months (2)	pH (3)	Organic C (%) (4)	N (%) (5)	P (kg/ha) (6)	K (kg/ha) (7)	C N (8)
	0	5 8	0 79	0 20	28 67	774 67	3 95
	1	5 5	0 88	0 17	23 07	784 00	5 18
	2	5 6	0 67	0 21	22 84	784 00	3 19
	3	5 5	0 46	0 18	26 88	532 00	2 59
	4	5 6	0 91	0 18	21 50	476 00	5 06
Home garden	5	5 5	0 88	0 21	16 13	439 00	4 19
	6	5 6	1 37	0 21	14 78	448 00	6 52
	7	5 6	0 91	0 21	14 78	336 00	4 33
	8	5 8	1 45	0 21	14 78	504 00	6 91
	9	5 9	0 78	0 29	13 44	364 00	2 69
	10	5 9	0 99	0 21	9 41	616 00	4 71
Season I	0	5 8	0 41	0 17	28 22	420 00	2 41
	1	5 4	0 37	0 17	23 30	494 67	2 18
	2	5 8	0 34	0 21	21 50	364 00	1 62
	3	5 8	0 69	0 18	25 54	252 00	3 83
	4	6 2	0 80	0 21	17 47	252 00	3 81
Open area	5	5 4	0 91	0 29	22 85	392 00	3 14
	6	5 5	1 52	0 24	14 78	336 00	6 33
	7	5 4	1 75	0 27	16 13	224 00	6 48
	8	5 7	1 64	0 18	21 50	364 00	9 11
	9	5 8	1 15	0 21	12 10	252 00	5 48
	10	5 8	0 99	0 21	16 10	280 00	4 71

Contd

Table 18 contd

(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
Season II	Home garden	0	5 8	0 89	0 27	17 02	116 67	3 30
		1	5 6	0 99	0 16	18 07	149 33	6 19
		2	5 4	0 78	0 18	33 60	149 33	4 33
		3	5 5	0 71	0 17	37 63	214 67	4 18
		4	5 3	0 76	0 19	26 58	163 33	4 00
		5	5 3	0 73	0 20	33 01	154 00	3 65
		6	5 4	0 82	0 18	21 74	116 67	4 56
		7	5 6	0 80	0 19	28 22	168 00	4 21
		8	5 8	0 80	0 20	30 15	46 67	4 00
		9	5 8	0 69	0 16	33 60	42 00	4 31
		10	5 9	0 83	0 15	28 82	32 67	5 53
	Open area	0	5 8	0 77	0 12	23 89	172 67	3 67
		1	5 6	0 45	0 17	27 33	275 33	2 65
		2	5 5	0 60	0 18	36 11	168 00	3 33
		3	5 4	0 68	0 15	36 59	256 67	4 53
		4	5 5	0 49	0 20	19 12	107 33	2 45
		5	5 6	0 58	0 19	36 59	182 00	3 05
		6	5 7	0 90	0 19	24 79	354 67	4 74
		7	5 6	0 67	0 17	27 48	294 00	3 94
		8	5 7	0 54	0 19	38 53	37 33	2 84
		9	5 7	0 45	0 20	30 02	28 00	2 25
		10	5 8	0 72	0 15	28 52	28 00	4 80

Season I - South west monsoon season

Season II - North east monsoon season

carbon content The organic carbon content of the soil from open area increased to 0 69 per cent in the third month After four months of decomposition, the organic carbon content of the soil showed a significant increase in both the fields The trend was continued till the end of the study with slight fluctuations

Like the first season, during the second season also, the initial organic carbon content in home garden was more (0 89%) compared to open area (0 77%) The organic carbon content in soils from home garden was increased (0 99%) after one month of incorporation whereas it was slightly declined in open area (0 45%) It could be seen from the table that in subsequent months, the organic carbon content in the soils of home garden varied considerably and reached its lowest level during the eighth month (0 41%) In open area, the organic carbon content showed a slight increase during the third and fourth month compared to second month, experienced reduction in subsequent month and reached its peak in sixth month (0 90%) The organic carbon content in the soil at the end of the tenth month was 0 72 per cent

4 3.2.2 Nitrogen

The changes in soil nitrogen pool over a period after incorporation of leaf litter are tabulated in Table 18 and depicted in Fig 23

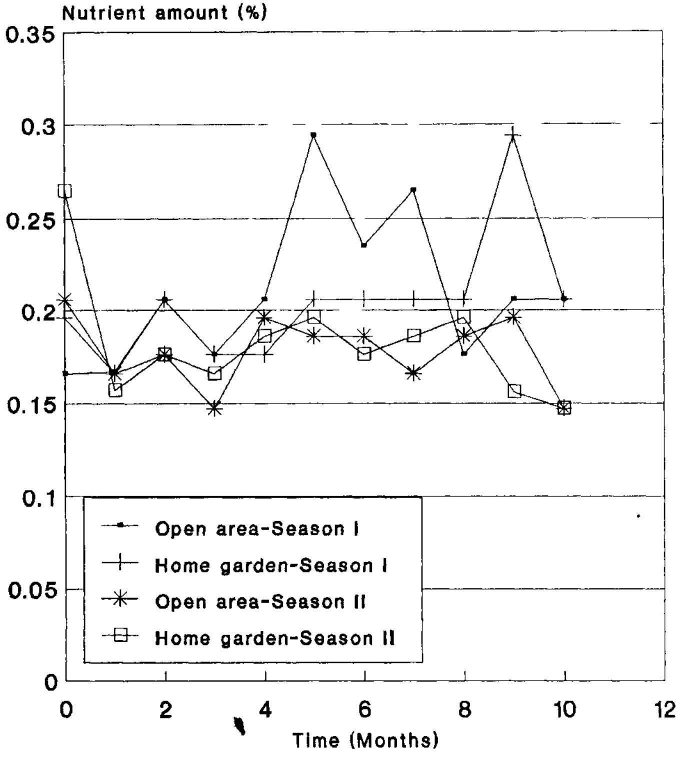

Fig. 23 Changes in nitrogen status of the soil as influenced by the decaying litter mass

During the first season, the initial soil nitrogen content was more in home garden (0 20%) compared to open area (0 17%) After one month of litter decomposition, the N content in the home garden was reduced to 0 17 per cent whereas in open area it did not change (0 17%) In the second and third month, the soil N content of both the fields followed almost a similar trend In the home garden, maximum soil N content was noticed after nine months of decomposition (0 29%) whereas in open area, the peak content was observed in the fifth month (0 29) The N content at the end of the study was found to be 0 21 per cent in both the study situations

During the second season, the initial nitrogen content was more in home garden (0 27%) After one month of incorporation of leaf litter, the N content in the soil was reduced to 0 16 per cent in home garden and 0 17 per cent in open area During subsequent months, the N content in the soil recorded a more or less similar fluctuations in both the fields till the end of the study It was interesting to note that the N content of the soils collected from both the field conditions never crossed above the initial content during the entire study period

4.3 2 3 Available phosphorus

The observation pertaining to the soil phosphorus over a period after incorporation of leaf litter is presented in Table 18 and the dynamics of P at different stages of decomposition is graphically represented in Fig 24

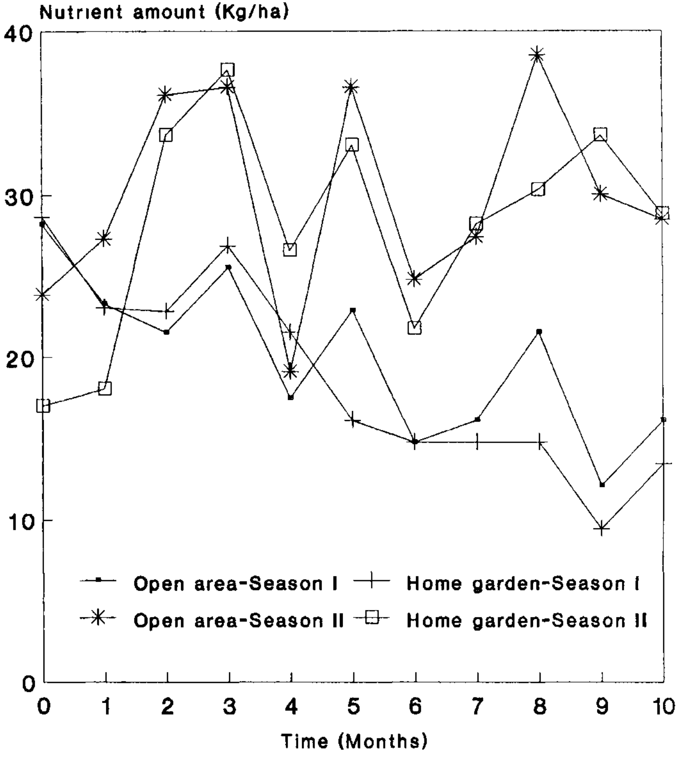

Fig. 24 Changes in phosphorus status of the soil as influenced by the decaying litter mass

During the first season, the available P content in the home garden was 28 67 kg/ha, whereas in open area it was 28 22 kg/ha The available P content reduced during the initial two months in soils collected from both the field conditions In the third month, the available P in the soil was increased slightly

In home garden, the available P content started declining from fourth month onwards and reached its lowest value after ten months of incorporation (9 41 kg/ha) In open area, the available P content experienced a series of fluctuations and reached its lowest value of 14 78 kg/ha after six months of leaf decomposition The available P at the end of the study was 16 13 kg/ha

During the second season, the initial phosphorus content was more in open area (23 89 kg/ha) which slightly increased upto third month The available P content did not change profoundly with regard to field conditions Unlike first season, the available P content in the soil had never reduced to initial content during the entire study period

4.3 2.4 Exchangeable potassium

The data furnished in Table 18 and illustrated in Fig 25 indicate that during the first season, the exchangeable potassium at the time of incorporation of leaf litter was highest in home garden (774 67 kg/ha) compared to open area (420 00 kg/ha) Exchangeable potassium content was increased after one month of

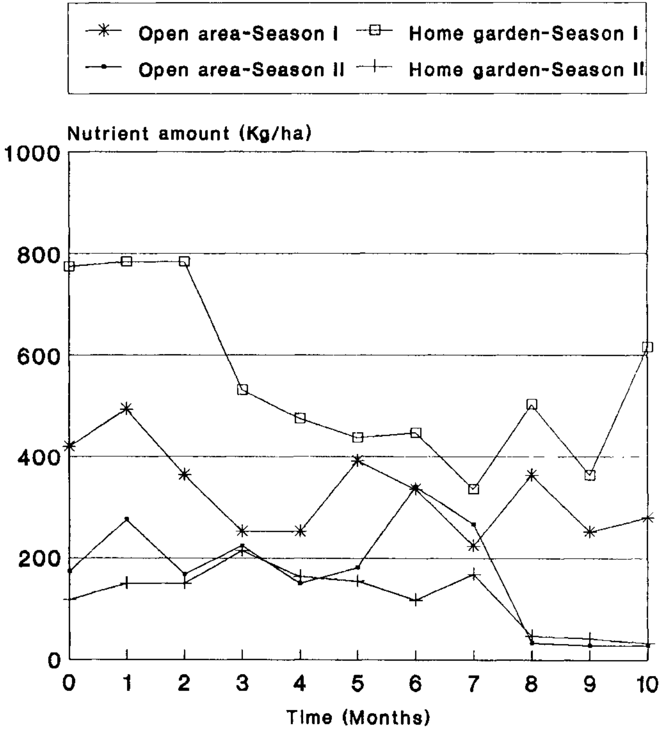

Fig. 25 Changes in potassium status of the soil as influenced the decaying litter mass

decomposition in both the cases However, in subsequent months the exchangeable K content showed a reduction The content of K in soil collected from the home garden at the end of the experiment was 616 00 kg/ha whereas in open area it was 280 00 kg/ha

In the second season, the initial exchangeable K content was found to be more in open area (172 67 kg/ha) In both the cases, the exchangeable K recorded an increase after one month of starting the experiment In home garden, the exchangeable K was maximum after three months whereas in open area, the maximum could be seen after six months In both the situations, the minimum exchangeable K content was noticed at the end of the study

4 3 4 5 C.N ratio

The data related to soil C N ratio of the study situations are presented in Table 18 The fluctuations in C N ratio over a period of time is also depicted in Fig 26 The initial C N ratio at the beginning of the study was low in all the situations

In the first season, the C N ratio of the soils of home garden and open area was found to be respectively 5 18 and 2 18 after one month of litter decomposition The C N ratio showed varied fluctuations in different months in both the experimental situations The C N ratio reached its peak after eighth month of incorporation in both the cases In subsequent months, it experienced slight fluctuations

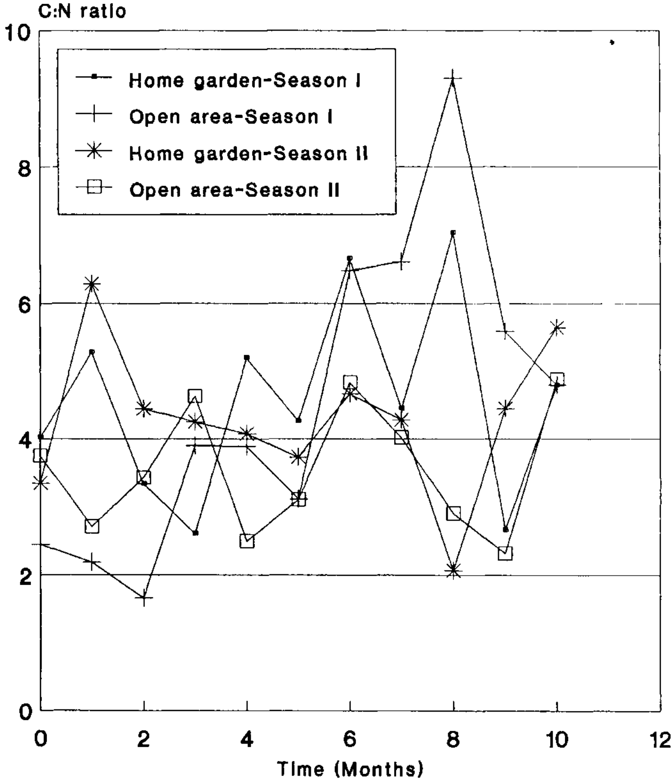

Fig. 26 C:N ratio of the soil as influenced by the decaying litter mass

During the second season, the C N ratio of soil in the home garden showed an increase (6 19) while open area experienced a reduction (2 65) In subsequent months, in home garden, the soil C N ratio showed a decrease upto fifth month, shot up in the sixth month and reached its lowest value of 0 21 in eighth month, whereas in open area, the C N ratio increased in second and third months, decreased in fourth month, shot up in fifth month (4 71) and reached its minimum (2 25) in ninth month

4 3.2.6 Secondary nutrients

Data pertaining to the changes in the secondary nutrient content of the soil due to the addition of leaf litter are given in Table 19 and depicted in Fig 27

4 3 2 6 1 Exchangeable calcium

The exchangeable Ca content of the soil before starting the decomposition study was comparatively high in home garden(188 91 kg/ha) and low in open area (138 39 kg/ha) of the first season However, in all the cases, the Ca content was found to be increased at the end of the study (Fig 27) Among the different study situations, soils from home gardens showed considerably lesser amount of gain

4 3.2.6.2 Exchangeable magnesium

Among the different study situations, the magnesium content in the open area during the second season was considerably more at

Table 19 Changes in the secondary nutrient status of the soil as influenced by litter decomposition

Nutrient element	Time (Month)	Season I		Season II	
		Home garden	Open area	Home garden	Open area
Ca (kg/ha)	0	188 91	138 39	156 05	164 27
	10	221 76	180 69	197 12	227 24
Mg (kg/ha)	0	236 54	216 83	177 41	256 26
	10	295 68	275 97	413 95	473 09
S (kg/ha)	0	196 00	2072 00	560 00	448 00
	10	140 00	1820 00	168 00	168 00

Season I - South west monsoon season

Season II - North east monsoon season

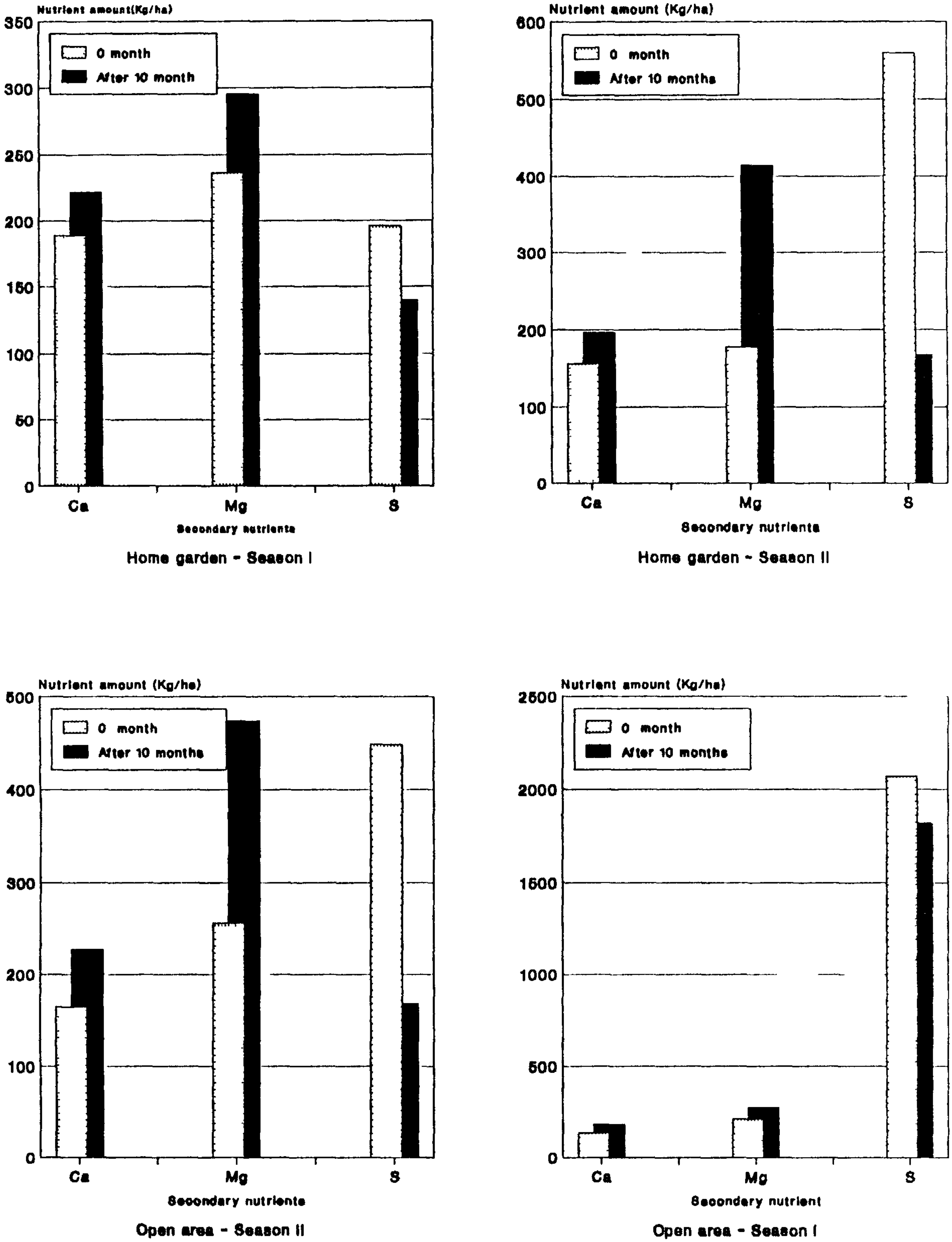

Fig. 27 Secondary nutrient staus of the soil as influenced by decaying litter mass

the end of the study (473 09 kg/ha) In other cases also, the available magnesium content was increased compared to its initial level

4 3 2 6 3 Available sulphur

The available sulphur content in the soils of open area collected during the first season at the beginning of the study was found to be maximum (2072 kg/ha) It could also be seen from the table that the available sulphur in all the study situations was reduced after ten months of decomposition

Discussion

DISCUSSION

Litter production and their decomposition are the primary mechanisms through which the nutrient pool in the natural ecosystem is maintained It is a well established fact that the leaf litters of tree species contain considerable amounts of nutrients When the leaf litters are incorporated into the soil, it is exposed to various physical and biological factors resulting the decomposition and this upon mineralisation serve as a potential source for most of the macro and micro nutrients to the plants As a result of decomposition litter mass reduces and finally disappears from the ecosystem

The addition of nutrients to the soil through litter is the paramount role of trees in agroforestry systems The nutrients are absorbed from the deeper layer and are deposited in the upper layer through the process of nutrient cycling

In modern agriculture and agroforestry systems, a sound knowledge of the rates of decomposition and nutrient release patterns from the decaying leaf litter is very essential for the proper nutrient budgeting of the crops

The present series of studies were carried out in College of Forestry, Vellanikkara to assess the rate of decomposition of leaf litters, the nutrient release pattern and also to study the improvement of soil nutrient status by the addition of litters of *Acacia mangium* Willd The experiment was conducted in two different field conditions during two seasons The salient findings are discussed hereunder

5.1 Leaf litter decomposition

5.1.1 Rate of decomposition

The decomposition of leaf litter was found to be faster particularly during the initial stages of decomposition during the north east monsoon season Presence of favourable soil temperature, soil moisture, soil fauna and other micro organisms coupled with physico-chemical qualities of the litter would have attributed for rapid rate of decomposition during north east monsoon season This result is in accordance with the findings of Pascal (1988) and Sankaran *et al* (1993) who also observed faster rate of decomposition during September to December In the latter part of the study, the rate of decomposition was found to be more rapid during south west monsoon period The onset of summer showers associated with high soil temperature could be the probable reason for faster rate during this time

The rates of decomposition in home garden and open area were more or less on par indicating the poor influence of field condition on the decomposition of leaf litter However, in almost all the months, the rate of decomposition was found to be slightly faster in open area compared to home garden The time required for complete decomposition of leaf mass in home garden was 20 fortnights, interestingly in open area also the process was completed within 20 fortnights More exposure of soil to rainfall, temperature and sunlight would have attributed for faster decomposition rate in open area compared to home garden where the floor is densely covered by canopies of trees and shrubs The studies on leaf biomass decomposition in selected homesteads of Vellanikkara (Kerala) revealed that 95 per cent of the biomass was decomposed within one year after incorporation (Kunhamu, 1994)

Through out the study period, the rates of decomposition under different study situations were almost similar However, in majority of the cases, it could be seen that the litter mass kept in open area during the second season registered lower residual mass indicating the higher rate of decomposition At the end of the third month, mass remaining in the litter bags from open area during the north east monsoon season was 3 87 per cent followed by home garden (12 52%) Bharadwaj *et al* (1992) also made similar observations based on the studies carried out under various agroecosystems

It is interesting to note that in the present study in all the situations, more than 90 per cent of the initial litter mass was decomposed within three months Gong (1982) reported that around 98 5 per cent of leaf litter mass decomposed within 4 to 5 weeks when the study was carried out in tropical ecosystem in Malaysia Munshi *et al* (1987) reported that the entire leaf litter mass was decomposed within 144 days of incorporation in a deciduous forest clearly indicating a high rate of decomposition initially George (1993) also observed a faster rate of decomposition of the litters of casuarina and leucaena in a silvipastoral system

5.1.2 Pattern of decomposition

Generally, a biphasic pattern of decomposition was noticed in all the study situations Nearly 90 per cent of the total litter mass kept for the study was decomposed in the initial rapid phase which lasted for three months and this rapid phase was followed by a prolonged slow phase Remaining ten per cent of the litter mass was decomposed by the end of tenth month The initial rapid decay could be due to the prevailing congenial environmental condition associated with the presence of readily digestible water soluble compounds in the litter This might have triggered the activity of soil fauna and soil microbes which are mainly responsible for the decomposition In addition, the high leaching losses of water soluble fractions from the decomposing material during the rainy periods might have resulted a heavy mass loss during the initial phase

Singh *et al* (1993) in their studies using sal, teak, eucalyptus and poplar observed similar decomposition pattern in two phases Kunhamu (1994) observed that the initial decomposition rate was much faster in leaf litters of tree species like *Schleichera oleosa, Macaranga peltata, Terminalia paniculata, Bridellia retusa* and *Pongamia pinnata* In all these species, the initial rapid phase was followed by a slow phase Jenney *et al* (1949) observed a biphasic pattern of decomposition and concluded that the initial faster rate of decomposition could be due to the higher rate of leaching at this time The latter slower phase of decomposition in the present study could be due to the increased content of biodecay resistant refractory fractions like lignin and phenols Berg and Staaf (1981) and Kunhamu (1994) also of the opinions that the significant reduction in the rate of decomposition during the latter phase is due to the accumulation of biodecay resistant material which are less vulnerable for microbial action

5.1.3 Factors affecting leaf litter decomposition

5.1 3 1 Effect of litter quality on the rate of decomposition

5.1 3 1.1 Initial nitrogen and C N ratio

The influence of nitrogen content and C N ratio on the rate of decomposition is evident from the data furnished earlier The initial nitrogen content was high (3 02%) in the litter kept for decomposition during the second season The C N ratio of the leaf litter collected during the second season was slightly low compared to first season

During the second season, a significantly faster rate of decomposition was observed particularly in the first month However, during the subsequent months, more litter decomposition was observed for the residues having lower C N ratio

The faster rate of decomposition during second season might be due to high amount of initial nitrogen and comparatively lower initial C N ratio Bahuguna *et al* (1990) reported that higher initial nitrogen content of eucalyptus litter lead to faster rate of decomposition compared to sal which had low initial nitrogen Kumar and Deepu (1992) attributed the faster rate of decomposition of leaf litter mass to the initial high nitrogen content The positive influence of initial nitrogen content on the rate of decomposition was also emphasised by Constantinides and Fownes (1994) and Jamaludheen (1994)

Crop plant litters and crop residues with high initial nitrogen content and low C N ratio are known to decompose rapidly (Singh and Gupta, 1977 and Meentemayer, 1978) Organic residues having a C N ratio of 10 1 exhibited highest degree of decomposition compared to residues with a ratio of 20 1 or 15 1 (Bondar, 1975) From the present study, it could be summarised that in general, the litters with low C N ratio decomposed much faster compared to litters with high C N ratio

5.1.3 1 2 Lignin and lignin · nitrogen ratio

The influence of lignin content on the rate of decomposition is also quite evident from the data presented earlier The litter having a lower initial lignin (15 90%) decomposed faster compared to the litter having high content (21 90%) Similar observations were also made by Melillo *et al* (1982), Berndse *et al* (1987), Tian *et al* (1992) and Kunhamu (1994) in litter decomposition studies conducted under various agroclimatic conditions

In the present study, lignin content was found to be increased as the time elapsed which clearly indicated its pronounced influence on the rate of decomposition during the latter stages Barry *et al* (1989) stated that slow rate of decomposition in the latter phase is lignin controlled while the initial rapid mass loss phase is controlled by nitrogen present in the soluble carbon compounds

It could be seen from the observations that the litter collected during the second season was having a lower lignin nitrogen ratio recording a relatively faster rate of decomposition during the initial phase This finding is in accordance with the observations made by Melillo *et al* (1982), Edmonds (1987) and Kumar and Deepu (1992) However, this relationship was not found to exist during the latter part of the study

5.1.3.2 Effect of environmental factors on the rate of decomposition

5.1 3.2.1 Weather parameters

An attempt was made to study the influence of weather parameters on the rate of decomposition No statistical relationship could be established between the atmospheric temperature, relative humidity and rain fall with the rate of decomposition But slightly higher rate of decomposition was evident during the rainy periods coupled with higher atmospheric temperature and humidity However, this aspect needs further investigations

5.1.3 2.2 Soil factors

It is noteworthy that in the present study soil temperature and moisture are influencing the rate of decomposition in a positive manner The influence of soil temperature and moisture on the rate of decomposition has also been observed by Jenney *et al* (1949), Alexander (1977), Gupta and Singh (1977), Singh *et al* (1980), Singh and Joshi (1982) and Madge (1965) High soil moisture and temperature definitely favour the microbial activity which are mainly responsible for the litter decomposition (Whitkamp and Van Der Dritt, 1961)

5.1.4 Decay rate co-efficients

The decay rate co-efficients for various study situations were found to be different in the present study The k value was more for open area of the first season (0 392) In general, the k values recorded in the present study were found to be higher in relation to k values reported by Kunhamu (1994) for some tropical species and Jamaludheen (1994) for *Acacia auriculiformis* Sankaran *et al* (1993) also found variation in k values for different study sites Interestingly, the k value observed by them was much lower when compared to the present study

Half life values of *Acacia mangium* leaf litter observed in the present study are also interesting to discuss The half life values were ranging from 1 78 to 2 29 fortnights

The predicted half life values were of shorter duration compared to values reported from elsewhere Sankaran *et al* (1993) observed a varied half life periods for *Acacia auriculiformis* leaf litters ranging from 5 9 to 11 6 months under different site conditions Kunhamu (1994) observed a significant difference in the half life periods of different species when the decomposition study was conducted in home gardens

5.2 Nutrient release pattern

Leaf litter decomposition is the primary mechanism by which the organically bound nutrients are mineralised to soil for subsequent absorptions by plants Tropical tree leaves are found to contain higher levels of plant nutrients and their incorporation into the soil enriches the labile soil nutrient pool Chemical composition is an intrinsic property of the leaf litter which determines the rate of turnover of organically bound nutrients (Meentemayer, 1978) Different species exhibit different nutrient release pattern during the process of decomposition (Kunhamu, 1994)

5.2.1 Nitrogen

Nitrogen concentration in the fresh litter sample was found to be much higher than that reported for the litters of many other tropical tree species Moreover, the nitrogen content of the leaf litter collected for the study in different seasons was different Similar differences in the nitrogen content during different months were observed by George (1993) and Jamaludheen (1994)

A close observation of the data shows that nitrogen concentration increased in all the study situations except in the home garden of the second season during the first month The conversion of carbon into CO_2 due to faster oxidation and leaching of soluble carbon compounds and the subsequent weight loss resulted in increased N concentration (George, 1993 and Kumar and Deepu, 1992) The accumulation of N could be from herbivore frass, precipitation and soil substrate as reported by Swift *et al* (1979) The decreased N in the home garden could be attributed to higher demand for nitrogen for the intense microbial activity during the initial stages of decomposition Moreover, the leaching of water soluble nitrogenous substances might have accounted for its decrease (Nykvist, 1963 and Kunhamu, 1994) A high degree of variation in nitrogen concentration was observed under different study situations Presence of various microbial types and their population and the prevailing soil conditions might have resulted an apparent fluctuations in the concentration of nitrogen under various study situations

Despite the variation in the nitrogen concentration, the absolute amount of nitrogen decreased gradually with the progress in decomposition in all the seasons and field conditions However, the absolute amount of nitrogen differed significantly in different seasons during few months Since the leaf decay rate was different for different seasons the corresponding absolute amount was also found to be different George (1993) observed an increase in nitrogen concentration but a decrease in absolute amount of nitrogen in leaf litters of casuarina, acacia, ailanthus and leucaena Similar findings were also reported by Coldwell and Delong (1950)

5.2.2 Phosphorus

Phosphorus content in the fresh leaf litter collected during the first season study period was low (0 058%) compared to second season (0 074%) It could be attributed to efficient retranslocation of nutrients from ageing foliage during dry season as reported by Das and Ramakrishnan (1985) and Sharma and

Pande (1989) compared to wet season where lower retranslocation efficiency was reported (Miller *et al* , 1979)

During the first season, the P content of the decomposing litter collected from home garden decreased gradually during the initial months followed by a slight increase towards the end of the study Similar trend was observed by Jamaludheen (1994) in *Emblica officinalis, Artocarpus heterophyllus* and *Casuarina equisetifolia* The initial decrease in P content could be due to the rapid loss of P bounded in easily leachable compounds and the subsequent increase could be attributed to the better retention of P due to its immobile nature (Upadhyah, 1987 and Kunhamu, 1994) In the present study, more or less similar trend in the mineralisation of P was noticed under varying situations

Absolute amount of P in the residues showed a biphasic pattern with an initial rapid decline phase followed by latter slow phase The concentration changes were not substantially enough to make greater changes in the absolute amounts owing to faster mass loss in all the study situations particularly during initial rapid decomposition phase

5.2.3 Potassium

Like N and P, the K content in the litter mass collected during the first season was comparatively low (0 79%) Potassium is found to be highly mobile both in plant and soil

The potassium content of the residual leaf litter reduced drastically during the initial two months In the latter part, it is found to be more or less steady in all the situations except in home garden during the north east monsoon season Potassium is not structurally bound in the organic compounds and also the quick leachability in water could be the major reasons for the initial rapid decline phase as stated by Bocock (1963), Gosz *et al* (1973), Kunhamu (1994) and Jamaludheen (1994)

Absolute amount of K in the residual mass exhibited a biphasic pattern The present study indicates that more than 90 per cent of the potassium in the leaf litter mineralised within first two months Rapid mass loss of K could be due to high rainfall coupled with high humidity, temperature and microbial activities This finding is in agreement with the reports made by Kunhamu (1994) and Lisanework and Michelsen (1994)

5.2.4 Calcium

Calcium is one of the major nutrients required for plant growth as it is indispensable for cell division and cell elongation Like other elements, the Ca content was observed to be high in the fresh leaf litters collected during the north east monsoon season (0 82%) The calcium content of the residual mass recorded an increase in almost all the study situations after one month of exposure to decomposition In subsequent months, it reduced gradually with slight fluctuations. A close perusal of the data shows that the increase in the relative concentration of Ca was more than 200 per cent during the second season at the time of first month of sampling The rapid leaching of other water soluble substances might have resulted an apparent increase in calcium content (Kunhamu, 1994) The faster decomposition process as suggested by Thomas (1970), Gosz *et al.* (1973) and Kunhamu (1994) might be the probable reason for most of the calcium loss

Studies on the absolute amount of calcium also revealed more or less similar results Absolute content of Ca in decaying mass showed an increase during the second season (115 45%) compared to first season. In succeeding months of sampling, a decrease in absolute Ca was evident from the study Among the two field conditions, the absolute amount of Ca was more in the residues collected from open area at the end of first month However, during the subsequent months, litter mass from home garden showed more amount of Ca It is also worth observing that during the initial stages, the residues from the home garden of the first season showed more absolute content of Ca while during latter part, the residues from home garden of the second season retained more calcium content The more amount of absolute Ca in the residues from the home garden could be attributed to slower rate of decomposition

5.2.5 Magnesium

Magnesium is one of the essential elements for plant growth as it is an indispensable part of chlorophyll and also plays a role in protein synthesis The magnesium content of the leaf litter collected for the study during both the seasons was found to be 1 15 per cent In general, during the initial stages of decomposition, a reduction in magnesium content was observed in all the study situations In subsequent months, it experienced varied fluctuations This is in agreement with the observations made by Kunhamu (1994) in his studies using litters of *Bridellia retusa* and *Terminalia paniculata* Absolute amount of Mg in residual mass is an indirect measure of the extent of release of this nutrient Release of magnesium from the litter mass followed a distinctive biphasic pattern In the initial stages, a rapid release was observed followed by slow latter phase Initial rapid release might have been due to the rapid mass loss which finally resulted a decrease in the concentration Initial decrease in magnesium content which is similar to mass loss pattern indicate the fact that magnesium constitutes a major part of more recalcitrant soluble portion of the leaf litter The faster release of Mg in accordance with the mass loss pattern was also reported in scotpine needles (Staaf and Berg, 1977), tropical woody species (Kunhamu, 1994) and Ethiopian forest species and plantations (Lisanework and Michelsen, 1994) However, Attiwill (1968) attributed faster rate of Mg release to its higher mobility and leachability

5.2.6 Sulphur

Sulphur is an essential element for the synthesis of amino acids and various metabolites in the plant system Like other elements, the S content of the litter collected during the second season study period was more (0 88%) It is quite evident from the data furnished earlier that the sulphur content in the residual mass at the time of first month of sampling was increased in all the study situations Interestingly, the sulphur content in the residues from the open area of the first season enjoyed an increase till the end, whereas in other study situations, it was inconsistent till the end Similar type of fluctuations in S content were also noticed by Kunhamu (1994) in tropical species and Bockheim *et al* (1991) in northern pine oak and trembling aspen leaves The fluctuations in the S concentration of the litter residues could be due to the deposition of sulphate ions on leaf litter either by precipitation or stem flow or through fall (Blair, 1988) The continued increase in S concentration in the residues from the open area during the first season could have been due to the diffusion of sulphate ions to leaf litter from the soil which initially had a very high amount of available sulphur (2072 kg/ha) at the time of leaf incorporation

Absolute amount of sulphur in the residues after one month of incorporation was increased during the first season, whereas during the second season, an initial rapid decrease was observed

In subsequent months, the absolute amount of S declined with varied phases Among the two field conditions, the absolute content was high in the residues collected from home garden particularly during the beginning and end of the study period The increase in absolute amount of S could be due to the increase in concentration of sulphur in residues despite the rapid mass loss due to decomposition However, the steep decline in sulphur content could be attributed to rapid mass loss during initial phase of decomposition

5.2.7 Relative mineralisation efficiency of nutrients

Relative mineralisation efficiency of different elements did not differ significantly with regard to the study situations However, among the six elements studied, potassium was found to be mineralised quickly in home garden during the first season and in open area during the second season The faster mineralisation of K is mainly due to the faster rate of leaching of water soluble fractions from the decomposing residues The faster K mineralisation was also observed by several workers (Staaf and Berg, 1982, Bergali *et al* , 1993 and Kunhamu, 1994)

Mineralisation of P was quicker in open area during south west monsoon season, while sulphur mineralised faster in home garden during north east monsoon season The faster mineralisation of P could be due to the soil and climatic conditions favouring the P mineralisation Alexander (1977) reported that the mineralisation of P was faster under soil and climatic conditions favouring the ammonification The rapid mineralisation of sulphur in the home garden during the second season could be due to rapid mass loss combined with reduction in sulphur content during that particular period Among the six elements studied, Ca mineralised slowly in almost all the study situations and this was followed by N In most of the situations, magnesium mineralised with a moderate rate The slow mineralisation of calcium might be due to the lower mobility and structural complexity of that element in plant tissues as reported by Kunhamu (1994), while the slow mineralisation of nitrogen could be attributed to wider C N ratio in decomposing leaf litter coupled with aerobic condition in the study situations which generally resulted slower rate of mineralisation (Singh *et al* , 1992)

5.3 Changes in pH and nutrient status of soil due to leaf litter decomposition

The incorporation of leaf litter and its further decomposition will enrich the soil by addition of various nutrient elements During the process of mineralisation, various organic compounds are formed and these compounds upon conversion bring changes in the soil pH and nutrient status

5.3.1 Soil pH

It is a well established fact that the incorporation of organic matter into the soil alters the pH Several workers have reported that the addition of organic residues to soil increases the pH in acidic soils (Debnath and Hajra, 1972 and Singh *et al* , 1992) while decreases pH in alkaline soils (Katyal, 1977 and Bajpai, *et al* , 1980) However, in the present study, in all the study situations pH showed a slight decrease during initial months and a slight increase during the latter part of the study Interestingly, at the end of the study, soil collected from all the situations registered more or less a pH very near to the initial value The formation of organic acids and release of CO_2 due to faster rate of decomposition might have caused a slight reduction in soil pH particularly in the initial stages of the study (Cang *et al* , 1985) The increase in pH during latter part could be due to the reduction of Fe present in the soil (Ponnamperuma, 1965)

5.3.2 Soil nutrient status

5.3.2.1 Organic carbon

Organic carbon content of the soil determines the mobilisation of nitrogen and there by influences its availability for the plant growth The addition of leaf litter enriches the organic matter content, which on decomposition accretes organic carbon portion of the soil It is believed that the maximum mobilisation and availability of nitrogen in the soil are governed by its organic carbon content

In the present study, in home garden, the organic carbon content of the soil exhibited an increase in the first month during the south west monsoon season whereas in open area, it reduced In succeeding months, this showed fluctuations and reached its peak during the latter half of the study and finally reached to 0 99 per cent During the north east monsoon season, in home garden, the organic C content in the soil increased in the first month while decreased in open area In subsequent months, the organic C content recorded varied level of fluctuations

The increase in soil organic carbon content could be due to the addition from decomposing leaf litter It could be stated that the decrease in organic carbon content might be due to faster degradation of soil organic carbon as a result of enhanced microbial activity (Flaig, 1984)

5.3.2.2 Nitrogen

During the initial stages of decomposition, the N content in home garden tended to be reduced while in open area it remained almost stable In general, the fluctuations in nitrogen content was observed in subsequent months till the end, when the nitrogen content was found to be 0 21 per cent in both the field conditions

During the second season, a decrease in nitrogen content of the soil was observed throughout the course of investigations with slight fluctuations

The addition of leaf litter in the soil increases the organic carbon content which might have resulted a rapid growth in microbial population The insistent demand for nitrogen by microbes to build their tissues could have immobilised this nutrient element (Bardy, 1984) This condition persists until the activities of the decomposers gradually subside owing to lack of easily oxidizable carbon This could be one of the probable reasons for increase in mineral N content in the latter part of the study During the second season, the continuous addition of organic carbon due to the decomposition could have resulted in nitrogen immobilisation by decomposers Apart from this, various denitrification process operating in the ecosystem might have resulted in loss of N from the soil nutrient pool

A lower C N ratio observed in the present study might have been due to the fact that addition of leaf litters acted as a source of carbon for decomposers that have increased their activity resulting rapid mass loss and reduction in carbon content

5 3.2.3 Available phosphorus

It has been already discussed that the incorporation of organic matter to soil increases the nutrient pool by adding nutrients through the process of mineralisation It could be stated that in the present series of studies during the south west monsoon season, the available P even after the incorporation of leaf litter did not cross the initial content in any of the field conditions The availability of P in the soil is primarily governed by soil pH and other related factors However, the addition of leaf litter brings the accretion in microbial population which results in immobilisation of P in microbial tissues (Brady, 1984)

During the north east monsoon season, the available phosphorus content of the soil increased gradually in both the situations Unlike, first season the available P never reduced to initial content Thomas (1995) reported that the addition of green manures increased the availability of P even up to three folds compared to control Prabhakar *et al* (1972) also noticed that the addition of green manures increased availability of native soil P by 25 to 37 per cent The organic acid synthesized during the process of decomposition could have been responsible for the increased availability of phosphorus (Brady, 1984)

5.3.2.4 Exchangeable potassium

The data furnished earlier clearly explains the fact that the exchangeable potassium content of the soil during the first season increased under both the field conditions after one month of incorporation of leaf litter However, in subsequent months, the K content reduced gradually with slight fluctuations

It is clear from the study that the potassium content of the soil increased due to leaf litter incorporation The rapid mass loss coupled with heavy leaching losses from the decomposing litter could be the possible reasons for the increased availability of K However, the K availability in the soil was found to be decreased in subsequent months during the first season which might be due to heavy leaching losses during the rainy days Similar results were observed in the second season also particularly during the months which received pre-monsoon showers The increased availability of K due to leaf litter incorporation was also observed by Sivakumar (1992)

5.3.2.5 Secondary nutrients

The decomposition of organic residues increased the exchangeable Ca and Mg content of the soil due to the mineralisation of these elements held up in the organic tissues In the present study, an increase in the content of exchangeable Ca and Mg was observed after ten months of exposure of leaf litter for decomposition Similar observations were also made by Sivakumar (1992) It could be seen from the data that the availability of sulphur after ten months of decomposition was reduced drastically in all the study situations The leaching loss during rainy days, conversion of available sulphur to unavailable form, or immobilisation due to microbial action could be some of the factors associated with decrease in S content (Brady, 1984)

Summary

SUMMARY

Incorporation of litter of trees and shrubs supply large quantities of organic matter which are mainly responsible for the addition of both macro and micro nutrients to the soil through the process of decomposition The decomposition of litter and the release of nutrients to the soil nutrient pool in various agro/farm forestry system has been well studied This is one of the most probable reasons in maintaining the aggregate stability and inherent fertility of the forest soil The rate of decomposition and nutrient release pattern are strongly dependent on the quality of leaf biomass, field conditions and other prevailing environmental factors

The present series of investigations were undertaken in the College of Forestry, Vellanikkara to find out the nutrient content and pattern of leaf litter decomposition of *Acacia mangium* Willd under two different field conditions during south west monsoon and north east monsoon periods The salient findings of the study are summarised hereunder

1 The rate of leaf litter decomposition was generally faster in both home garden and open area during the two seasons Entire leaf litter decomposed completely within ten months

2 Significant difference was noticed with regard to season of application The decomposition was faster in north east monsoon season particularly during the initial months But during the latter part of the study period, rate of decomposition was more rapid in south west monsoon season The field conditions did not influence the rate of decomposition significantly However, a slightly faster rate was observed in open area compared to home garden

3 A characteristic bimodal pattern of biomass decomposition was observed in all the study situations with a rapid initial phase for a period of three months followed by slow latter phase

4 The rate of decomposition was faster in the litter having high initial nitrogen content and low C N ratio

5 The lignin content of the leaf litter influenced the rate of decomposition The strong negative influence of lignin on the rate of decomposition was evident in all the study situations The low lignin nitrogen ratio of the litter during the second season favoured faster decay rate particularly in the initial months

6 Only a poor correlation between weather parameters and rate of decomposition was observed However, in most of the study situations, there exists a relationship between the combined effect of time elapsed soil temperature and moisture with decay rate

7 Generally, litter collected during the second season registered more content of most of the elements like, N, P, K, Ca and S at the time of incorporation

8 A higher degree of variation in nitrogen content was noticed during the course of investigation At the end of the study, the nitrogen was found to be lower in all the situations when compared to the initial content

9 The litter kept for decomposition in two field conditions during both the seasons showed a reduction in P content initially followed by slight fluctuations and finally registered a lower value

10 Potassium content of the leaf litter showed a drastic reduction during the initial three months followed by more or less a steady state in subsequent months However, in home garden, during the second season, the K content was found to be inconsistent

11 In all the study situations, calcium concentration of the residues increased in the first month except in the open area, during the first season where it showed a declining trend A high degree of variation in Ca content was noticed in the second half of the study The content of calcium recorded in the residues at the end of the study was much lower when compared to initial level

12 Magnesium content of the leaf litter also followed more or less similar trend Lowest content was observed at the end of the study

13 Present study did not reveal any systematic changes in sulphur content The sulphur content of the residues increased gradually after one month, declined drastically in the second month except in the open area during the first season Its content in the residues during the first season at the end of the experiment was higher than the initial value, whereas during the second season it was lower compared to initial content

14 Despite the fluctuations in the nutrient concentrations in general, absolute amount of most of the nutrients in both the seasons and field conditions gradually declined as decomposition advanced

15 In general potassium mineralised faster in most of the study situations However, P mineralised faster in open area during the first season, while sulphur mineralisation was rapid in home garden during the second season The mineralisation pattern of individual element was found to be influenced by field conditions, seasons and their interaction In general calcium and nitrogen mineralised slowly

16 Among the several mathematical models fitted to predict the absolute amount of nutrients in the residual mass the second order hyperbolic function was found to be the best fit for almost all elements in various study situations In most of the cases r^2 values were found to be more than 0 85

17 The influence of leaf litter decomposition on changes in soil pH was not significant The addition of leaf litter to soil brought fluctuations in total nitrogen content Availability of phosphorus was significantly improved during the second season, while the exchangeable potassium content in the soil was improved during both the seasons

18 Accretion in exchangeable calcium and magnesium in the soil was evidenced at the end of the study However the availability of sulphur declined slightly after ten months of incorporation of litters in the soil

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Appendices

Appendix I

Weather parameters during the study period (June 1994 to September 1995)

Months	Weather parameters				
	Mean monthly rainfall (mm)	Mean monthly maximum temperature (°C)	Mean monthly minimum temperature (°C)	Mean Relative humidity (%)	No of rainy days
June 94	955 1	28 9	22 9	90	27
July 94	1002 1	28 6	22 4	91	29
Aug 94	509 2	30 30	22 8	85	20
Sept 94	240 5	31 8	23 2	78	8
Oct 94	358 2	32 3	22 7	90	20
Nov 94	125 3	31 8	23 3	68	5
Dec 94	0	32 2	22 2	58	0
Jan 95	0	32 9	22 4	59	0
Feb 95	0 5	35 4	23 4	60	0
Mar 95	2 8	37 6	23 8	60	0
Apr 95	118 7	36 6	24 9	71	5
May 95	370 5	33 5	23 9	78	13
June 95	500 4	31 6	23 1	86	19
July 95	884 7	29 9	23 2	89	26
Aug 95	448 7	30 6	23 7	86	22
Sept 95	282 5	30 1	23 5	82	13

Mean annual rainfall

i) for south west monsoon application (June 94 to May 95) - 3682 4 mm

ii) for north east monsoon application (Oct 94 to Sept 95) - 3092 3 mm

Appendix II

Decay coefficients and half life of decomposing litter mass of *Acacia mangium* under various study situations

Study situation		K	r^2	S E E	Half life (Fortnight)
Season I	Home garden	0 347	0 846	0 019	2 00
	Open area	0 392	0 658	0 038	1 78
Season II	Home garden	0 303	0 841	0 015	2 29
	Opern area	0 388	0 264	0 032	1 79

Season I - South west monsoon season

Season II - North east monsoon season

Appendix III

Mathematical relationship between time elapsed and absolute nutrient content of the residual mass under different study situations

Study situation (1)	Nutrient (2)	Equation (3)	Coeff of A (4)	Coeff of B (5)	Coeff of C (6)	r^2 (7)
	N	Y = A+B/X+C/X*X	-11.8200	87.9800	-0.0088	0.981
		Y = A+B*X+C*X*X	100.2000	-35.0800	2.9670	0.954
	P	Y = A+B/X+C/X*X	-5.5910	37.4600	-0.0037	0.997
		Y = A+B*ln(X)	1 7170	0.0004	0.0000	0 969
		Y = A+B*X+C/X	23 4300	-3.6210	0.0077	0 951
	K	Y = A+B/X+C/X*X	-1 3370	10.4600	-0.0011	0 999
Season I Home garden		Y = A+B*X+C/X	6.8470	-1.0300	-0.0094	0 996
		Y = A+B/X	2.2211	0.0098	0.0000	0 991
		Y = A+B*ln(X)	14.4900	-9.1080	0.0000	0 987
	Ca	Y = A+B/X+C/X*X	-15.3600	99 6600	-0 0100	0 987
		Y = A+B*X+C*X*X	104.0000	-36 5000	3.0680	0.941
	Mg	Y = A+B/X+C/X*X	-4 8330	46 3000	-0 0046	0 981
		Y = A+B*ln(X)	22 1600	-8.8020	0 0000	0.925
		Y = A+B*X+C/X	31 7700	-4 6390	0 0068	0 919
	S	Y = A+B/X+C/X*X	-3 9950	55 2200	-0 0055	0 961

Contd

Appendex III contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	N	Y = A+B/X+C/X*X	-11 2900	74.6600	-0 0075	0.978
		Y = A+B*X+C*X*X	93 1500	33 5400	2 8510	0 909
	P	Y = A+B/X+C/X*X	-13.0200	47.0300	-0 0047	0.988
		Y = A+B*X+C*X*X	93 6400	-56.7800	7 8570	0 935
		Y = A+B*ln(X)	16.9000	-9 2460	0.0000	0.927
		Y = A+B*X+C/X	31.6400	-7.7290	0 0068	0.918
	K	Y = A+B/X+C/X*X	-0.3659	5.8470	-0 0006	0.999
		Y = A+B*X+C/X	5.5320	-1.0770	0.0095	0.999
		Y = A+B/X	2.3000	0.0098	0.0000	0.998
		Y = A+B*ln(X)	11.6000	-9.4850	0 0000	0.988
Season I Open area		Y = A+B^X*X^C	7.6370	0.6618	-0.2791	0.948
	Ca	Y = A+B/X+C/X*X	-10.6200	55.4400	-0 0055	0 999
		Y = A*e^[(X-B)/2]	736.4000	6.2740	-18.9700	0.972
		Y = A*B^X	110.2000	0.3965	0 0000	0.970
		Y = A*e^(B*X)	110.2000	-0.9252	0 0000	0 970
		Y = A*B^X*X^C	124.1000	0.3807	0 0242	0.963
	Mg	Y = A+B/X+C/X*X	-5 4620	43.8600	-0 0044	0 980
		Y = A+B*X+C/X	37.6800	-7.7070	-0 0062	0.929
		Y = A+B*ln(X)	22 4400	-8.6380	0 0000	0 924
	S	Y = A+B/X+C/X*X	1 7350	105.0000	-0 1050	0 856

Contd

Appendix III contd ..

(1)		(2)	(3)	(4)	(5)	(6)	(7)
		N	Y = A+B/X+C/X*X	-5.1670	49.7700	-0 0050	0 994
			Y = A+B*ln(X)	22.6000	-8 8290	0.0000	0 922
			Y = A+B*X+C/X	32.0000	-4.3040	0 0068	0 922
		P	Y = A+B/X+C/X*X	-1.9560	39.1300	-0.0039	0.991
			Y = A+B*ln(X)	22.7300	-8.6270	0.0000	0 955
			Y = A+B*X+C/X	31.3400	-4 7010	0.0069	0.949
Season II	Home garden	K	Y = A+B/X+C/X*X	-101900.0	415600.00	-41 5600	0.779
		Ca	Y = A+B/X+C/X*X	-14 580	99.0200	-0.0099	0.976
			Y = A+B*X+C*X*X	105.7000	-39.4600	3.6720	0 910
		Mg	Y = A+B/X+C/X*X	-1.2380	32.5000	-0 0032	0 991
			Y = A+B*ln(X)	21.2000	-8.7070	0 0000	0 974
			Y = A+B*X+C/X	26.4800	-3 9210	0 0074	0 963
			Y = A+B/X	10.7900	0.0089	0 0000	0 903
		S	Y = A+B/X+C/X*X	-3 9950	55 2200	-0.0055	0 961

Contd

Appendix III contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	N	Y = A+B/X+C/X*X	-9 8780	49 9400	-0 0049	0 976
	P	Y = A+B*X+C*X*X	99 8200	-79 1900	15 6900	0.999
		Y = A+B/X+C/X*X	-17 0800	51.8100	-0 0052	0 987
		Y = A*B^(1/X)*X^C	31.7300	0.9980	-2 2640	0.939
		Y = A+B*X+C/X	47.0700	-16.2500	-0 0053	0.929
	K	Y = A+B/X+C/X*X	-4 3300	11.6500	-0 0012	0 999
		Y = A+B*ln(X)	8.7530	-9.8870	0 0000	0.998
Season II Open area		Y = A+B*X+C/X	10 0700	-3.6430	0 0090	0.997
		Y = A+B/X	2.7820	0.0097	0 0000	0.993
	Ca	Y = A+B/X+C/X*X	-86.8700	225.1000	-0 0225	0.852
	Mg	Y = A+B*X+C*X*X	99 3700	-82.1600	16 6900	0 996
		Y = A+B/X+C/X*X	-16 1100	47.1800	-0 0047	0 989
		Y = A+B*X+C/X	42 2700	-14.7800	0 0058	0.942
		Y = A*B^(1/X)*X^C	28 2100	0.9979	-2 4270	0 941
	S	Y = A*e^[(ln(X)-B)^2/C]	29040 00	-4 7490	-3 5100	1.000
		Y = A*B^(1/X)*X^C	48.0300	0 9973	-3 0090	0.999
		Y = A+B/X+C/X*X	-25 0900	71 0300	-0 0071	0 987
		Y = A+B*Y+C*X*X	101 2000	-69 9000	12 1100	0 986
		Y = 1/[A*(X+B)^2+C]	0 1042	-0 6028	-0 0197	0 982

Season I - South west monsoon season

Season II - North east monsoon season

Appendix IV

Details of the mathematical models used to represent the absolute content of nutrients in the residual mass under different study situations

Sl No	Equation	Explanation
1	Y = A+B*X	Straight line model
2	Y = B*X	Line through origin
3	Y = 1/(A+B*X)	Reciprocal straight line model
4	Y = A+B*X+C/X	Line and reciprocal model
5	Y = A+B/X	Hyperbolic function
6	Y = X/(A*X+B)	Reciprocal hyperbolic function
7	Y = A+B/X+C/X*X	Second order hyperbolic function
8	Y = A+B*X+C*X*X	Parabolic function
9	Y = A*X+B*X*X	Par at origin function
10	Y = A*X^B	Power function
11	Y = A*B^X	Modified power function
12	Y = B^(1/X)	Root function
13	Y = A*X^(B*X)	Super geometric function
14	Y = A*X^(B/X)	Modified geometric function
15	Y = A*e^(B*X)	Exponential model
16	Y = A*e^(B/X)	Modified exponential model
17	Y = A+B*ln(X)	Logarithmic model
18	Y = 1/[+B*ln(X)]	Reciprocal log function
19	Y = A*B^X*X^C	Hoerl function
20	Y = A*B^(1/X)*X^C	Modified hoerl function
21	Y = A*e^[(X-B)/2]	Normal function
22	Y = A*e^[(ln(X)-B)^2/C]	Log normal function
23	Y = A*X^B*(1-X)^C	Beta function
24	Y = A*(X/B)^C*e^(X/B)	Gamma function
25	Y = 1/[A*(X+B)^2+C]	Cauchy function

APPENDIX V

Details of the methods used for chemical analysis of the soil

Characteristic	Soil solution ratio	Extraction period (min)	Extractant used	Method of estimation	Instrument used	References
pH (H_2O)	1 2 5	-	-	Direct reading	pH meter	Jackson (1958)
Organic carbon	-	-	-	Walkley-Black	Titrimetric	Jackson (1958)
Total N	-	-	-	Microkjeldhal	Titrimetric	Jackson (1958)
Available P	1 · 10	30	Bray-I	Chlorostannus reduced molybdo phosphoric blue colour in sulphuric acid system	UV Spectrophotometer	Jackson (1958)
Exchangeable K	1 5	30	N Ammonium acetate (pH 7)	Direct reading after dilution	Flame photometer	Jackson (1958)
Exchangeable Ca	1 5	30	N Ammonium acetate (pH 7)	EDTA method	Titrimetric	Jackson (1958)
Exchangeable Mg	1 5	30	N Ammonium acetate (pH 7)	EDTA method	Titrimetric	Jackson (1958)
Available S	1 10	30	Sodium acetate	Turbidimetric	UV Spectrophotometer	Jackson (1958)

NUTRIENT CONTENT AND DECOMPOSITION OF LEAF LITTER OF *Acacia mangium* WILLD. AS AFFECTED BY SEASON AND FIELD CONDITIONS

By

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ABSTRACT OF A THESIS

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ABSTRACT

A detailed experiment was conducted at the College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, during the period from 1993 to 1995 to study the nutrient content and pattern of leaf litter decomposition of *Acacia mangium* Willd during south west monsoon and north east monsoon seasons The experiment was conducted both in home garden and open area

The rate of decomposition was faster in all the study situations The initial nitrogen, lignin, C N ratio and lignin nitrogen ratio of leaf litter were found to exert profound influence on the rate of decomposition The decomposition rate was found to be a function of time, soil moisture and soil temperature

The nutrient release pattern in almost all cases followed a characteristic biphasic model with an initial rapid phase followed by a slower latter phase Among the different nutrients, potassium showed a faster rate of mineralisation in most of the situations while calcium and nitrogen mineralised slowly Among the several mathematical models tried to predict the absolute amount of nutrients in the residual mass, the second order hyperbolic function was found to be good fit in most of the cases Though the pH was not altered significantly by the decomposing litter mass, the content of most of the nutrient elements is found to be drastically influenced