LITTER PRODUCTION AND DECOMPOSITION STUDIES IN SELECTED SPECIES OF ACACIA

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled **"Litter production and decomposition studies in selected species of acacia"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or any other similar title, of any other University or Society.

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Dedicated to my
Mother Nature

Introduction

INTRODUCTION

Litter production and decomposition are the two primary mechanisms through which the nutrient pool in the forest ecosystem is maintained. Large quantities of leaf litter 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. The leaf deposits on the ground get incorporated in to the soil and decompose releasing most of the nutrients. This will act as a potential source for both macro and micronutrients to other plants.

A substantial portion of the accumulated nutrients in the plant biomass is returned to the soil through litter fall and the study of quantitative aspects of litter production is important, as it remains a major pathway for both energy and nutrient transfer in forest ecosystems.

The litter on the soil surface acts as input-output systems and has a substantial role in the nutrition of wood lands, particularly of those soils of low nutrient status where the trees rely to a great extent upon the recycling of litter nutrients (Scott, 1955).

Litter on the forest floor, made up of various plant components (leaves, branches, twigs and husk) affects the moisture status of the top layers of soil and the water run off pattern as well as nutritional aspects and site quality. When litter decomposes, it releases nutrients into the soil, directly affecting the status of available nutrients (Bazilewich and Rodin, 1966).

In terrestrial ecosystems, leaf litter decay is regulated by an array of factors, of which the two most important are probably climate and the chemical nature of the litter termed "substrate quality" (Swift *et al*., 1979). In many studies, N content or more usually the C:N ratio has been seen to be of critical importance (Melin 1930).

The expansion of plantations of exotic tree species and the increased use of fertilizers to establish them have prompted interest in how nutrient cycle in these plantations relative to native ecosystems. In the case of fast growing species, it becomes more essential to study the geochemical cycle of the essential elements in support of their survival in future.

The present study attempts to provide the amount of litter production, nutrient return, rate of decomposition and the nutrient release pattern of three species of acacia viz., *Acacia mangium* Wild., *Acacia aulacocarpa* A. Cunn. ex Benth and *Acacia crassicarpa* A. Cunn. ex Benth.

Review of Literature

REVIEW OF LITERATURE

2.1 LITTER PRODUCTION

A substantial portion of the accumulated nutrients in the plant biomass is returned to the soil through litter fall and thus the study of quantitative aspects of litter production is important as it remain a major pathway for both energy and nutrient transfer in forest trees.

2.1.1 Pattern of litter fall

The pattern of litter fall varies greatly throughout different climatic zones. The total litter production in the major climatic zones from alpine to equatorial forest showed an increasing trend (Bray and Gorham, 1964).

Monthly litter fall in acacia plantations in Kerala showed a unimodal pattern with its peak during December-January. The litter fall ranged between 280-2600 kg ha^{-1} and highest litter fall was recorded in January (Sankaran *et al*., 1993).

A study conducted by Venkataraman *et al*. (1983) on the extent of litter fall in *Eucalyptus globulus* and *Acacia mearnsii* plantations in Nilgiris showed a total litter production of 960 kg ha^{-1} for black wattle. Litter fall characteristics in *A.auriculiformis* stand were observed by Assif (1990) for a period of nine months and reported that annual litter production was 7804.5 kg ha^{-1} with an average monthly mean value of 650.3 kg ha^{-1}. He noticed an increase in the monthly litter production during the dry season and lower production in the wet season. In *A. auriculiformis* litter production followed a monomodal distribution pattern with distinct peak in December (28.5 per cent of the total annual litter production).

Pokhriyal *et al*. (1989) made a detailed analysis of the leaf emergence and shedding behaviour on *Populus deltoides* at Dehradun and found that almost 90 per cent of the leaves were shed in October-December. Lonsdale (1988) analysed the total litter fall and leaf litter fall from 389 forest sites throughout the world using multiple regression analysis considering latitude, altitude and precipitation as the predictor variables.

Madge (1965) working in a mixed deciduous forest of Nigeria found that maximum leaf fall occurred during the dry season months of November-March. He also stated that the leaf fall fluctuated a little during the wet season and progressively measured at the start of the dry season, culminating during the driest month. Kumar and Deepu (1992) conducted studies on the litter dynamics in a moist deciduous forest ecosystem in the peninsular India. The phenology of litter fall followed a characteristic monomodal distribution pattern with a distinct peak during the dry period from November-December to March-April.

A striking variability has been observed with regard to the annual amounts of litter produced by different tree species in different parts of the world. Ramprasad and Mishra (1985) displayed the litter productivity statistics in a dry deciduous teak forest in Madya Pradesh considering locality factors and species.

2.1.2 Factors affecting litter fall

The extent of litter production in different species as well as within the species depends on the interplay of several factors. Species composition, climate, soil fertility status, altitude, slope, exposure, stand density, age of the trees etc. are some of the factors which are capable in bringing variations in litter fall (Jensen, 1974).

2.1.2.1 Species composition

The effect of species variations on litter fall has been clearly demonstrated by Pande and Sharma (1986). They conducted litter fall studies on *Shorea robusta*, *Pinus roxburghii*, *Tectona grandis* and *Eucalyptus tereticornis* plantations raised under identical edaphic and climatic conditions. Annual litter fall was 8286.21 kg ha^{-1} in sal and 5908.12, 5004.44 and 4780.81 kg ha^{-1} for eucalyptus, teak and chirpine respectively. Maximum litter fall was in March-April for sal, April-May for chirpine and teak. Eucalyptus had two peaks, one in October-November (22%) and other in

April-May. They concluded that the first peak may be genetically determined (corresponding to litter fall in Australia) and the second peak caused by environmental stress. Gill *et al*. (1987) reported that litter fall in *Acacia nilotica* stands were significantly higher (2537-5746 kg ha^{-1}) than *Eucalyptus tereticornis*.

2.1.2.2 Age of the trees

It is reported that there are considerable differences in leaf emergence and litter fall within a species depending on the stage of growth. The amount of litter fall increased with increasing age until the canopy become closed and then the litter fall maintained constant over a long period of time (Zavitkovski and Newton, 1971). Monthly litter collections were made for 12 months in 5, 12 and 28 years old *Triplochiton scleroxylon* plantations in Nigeria using tray traps. Annual total amounts of litter fall were 7942, 4993 and 6330 kg ha^{-1} respectively (Okimoyegun, 1985).

2.1.2.3 Stand density

An exponential relationship between litter accumulation and stand density was observed by Boyer and Fahnestock (1966) in an even aged second growth *Pinus palustris* plantation at south-east Alabama. Sachavrovskii (1973) described the litter fall studies made in *Picetam myortillosum* stands of age 85-100 years where 60 per cent were Norway spruce and 40 per cent hard woods. It was observed that the amount of litter decreased with decreasing stand density. Litter production studies on chirpine, teak and sal, were made with varying stand density (Subbarao and Debral, 1972) and found that stand density and age were the major factors determining litter production while precipitation and wind velocity also significantly affected litter fall. Comparative studies of litter production in a teak plantation and adjoining natural forest revealed that litter production was greater in plantation than natural stand (Chaubey *et al*., 1988).

2.1.2.4 Altitude

Altitudinal variations also affect the litter fall characteristics. Litter fall and through fall materials were measured for one year in 79 year old *Northofagus solandri* forest. Total fall was 5688 kg ha^{-1} $year^{-1}$ for lower slope and 4970 kg ha^{-1} for adjacent upper slopes (Bagnull, 1972). Above ground litter fall was measured in 25 stands along a 700 m gradient in altitude in White Mountain, U.S.A. Climatic features correlated linearly with altitude along this gradient. Pattern of litter fall for part of the gradient, changed with mean July temperature, degree days and evapotraspiration in an inverse manner with altitude (Reiners and Lang, 1987).

2.1.3 Nutrient return through litter fall

In natural forests and man made plantations, litter plays a fundamental role in the cycling of nutrients as considerable amounts of nutrients are returned to the soil through litter fall and make available them for re-absorption. Hence the amount of nutrients in the fallen litter is of considerable significance (Venkataraman *et al*., 1983). Even though leaf litter constitute only a smaller portion of the total biomass, they account for the major share of nutrients stored in the organic matter (Enright, 1979).

Studies by Adam *et al*. (1984) on the nutrient dynamics in acacia species revealed that large amounts of N, Ca, Mg and K are immobilized in the acacia biomass, much of which is returned to the soil after canopy closure. They also noted a relative abundance of N_2 in acacia species due to N_2 fixation. Mean concentrations of N, P and K in the litter of *Dillenia pentagyna*, *Grewia tiliaefolia*, *Xylia xylocarpa*, *Lagerstroemia lanceolata*, *Terminalia sp*. and *Bridelia retusa* were studied in moist deciduous forests of western Ghats. Concentrations of N, P and K in the litter were profoundly variable amongst the species. Initial nitrogen content of leaf litter varied from 0.65 to 1.6 per cent, phosphorus from 0.034 to 0.077 per cent and potassium from 0.25 to 0.62 per cent (Kumar and Deepu, 1992).

Patterns of litter nutrient concentration were studied in plantation of *Shorea robusta, Tectona grandis, Pinus roxburghii* and *Eucalyptus tereticornis* at Dehradun. Nutrient concentration changes in leaf tissues were negatively correlated with magnitude of leaf fall in the case of sal for all nutrients, in teak and pine for nitrogen and phosphorus. These changes were due to the back translocation of nutrients from leaves prior to leaf fall (Sharma and Pande, 1989). Venkataraman *et al*. (1983) conducted litter fall and nutrient release studies in *Eucalyptus globulus* and *Acacia mearnsii* plantations in Nilgiris. In blue gum annual addition of litter amounted to 1935 kg ha^{-1}, resulting in an annual rate of 31 kg N ha^{-1}, 0.8 kg P ha^{-1}, 4.3 kg K ha^{-1}, 18.8 kg Ca ha^{-1} and 21 kg Mg ha^{-1}, in addition to 1548 kg ha^{-1} of organic matter. Black wattle added annually 960 kg ha^{-1} of litter which by way of nutrients worked out to annual additions of 22.1 kg N ha^{-1}, 0.5 kg P ha^{-1}, 3.4 kg K ha^{-1}, 3.3 kg Ca ha^{-1} and 0.9 kg Mg ha^{-1} in addition to 662 kg organic matter per hectare. Okimoyegun (1985) studied the nutrient release in a *Triplochiton seleroxylon* plantation at Nigeria and found that N_2 return was directly related to litter mass.

Substantial information is available on nutrient dynamics in Eucalyptus plantations round the world. But very little is known on acacias (Pande *et al*., 1986). They suggested that comparatively much higher amounts of nutrients are retained in the leaf and twig components of *Acacia auriculiformis* as against Eucalyptus. Chakraborty and Chakraborty (1989) conducted studies on the changes in soil properties under *Acacia auriculiformis* plantations in Tripura and concluded that soil N, K and organic carbon status improved to a great extent.

2.2 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 and Anderson and Swift, 1983).

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 on tropical forest ecosystems where vegetation depends on the recycling of the nutrients contained in the plant detritus (Singh, 1968; Cole and Johnson, 1978 and Prichet and Fisher, 1987). 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).

2.2.1 Rate of decomposition

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

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), where as 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 1 to 3 per cent per annum (Olson, 1963). 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. It is taking only 0.1 to 0.6 years for complete decomposition in moist deciduous conditions and moist semi evergreen forests in tropical environment, while it takes more or less one year in temperate forests (Ovington, 1962), 1.6 years in subtropical forests, 3 to 5 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 litter of Q*uercus langinosa* and P*inus 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 curtissi* and *Pinus caribae*a under evergreen dipterocarp forests and pine forests in Malaysia. After 16 weeks of observation, weight loss was 39 and 19.5 per cent for Shorea in dipterocarp and pine forests respectively, where as the respective figures for pine was 13.6 and 19.5 per cent. 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 5 to 8 months (Kumar and Deepu, 1992).

2.2.2 Influence of environmental factors on rate of decomposition

Rate of decomposition of leaf litter is influenced by many environmental factors such as rainfall, temperature, physical and chemical properties of the soil, relative abundance of macro and microorganisms. Sankaran *et al*. (1993) reported that the maximum weight loss in acacia leaf litter occurred in September to November during northeast monsoon period in Kerala, India. He concluded that rainy season provides congenial conditions for rapid breakdown of leaf litter.

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

Madge (1965) found a positive influence of soil moisture in controlling the activities of soil organism, particularly arthropod. 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). 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 the 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°C. A high rate of litter decay during rainy season in tropical condition had also been observed by Singh *et al*. (1980). 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 (>100%) and low moisture content (<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.

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°C to 25 per cent at 10°C and 12 per cent at 5°C.

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).

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).

Soil microbes play a paramount role in decomposition, of litter applied to the soil. In the early stages of decomposition, heterotrophic bacteria are highly active. 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).

Bocock (1964) found that litter decomposition by earthworms and millipedes was rapid during the initial five months of decomposition. These animals accounted 40 per cent of the decomposition of *Fraxinus excelsa* 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).

2.2.3 Effects of species on the rate decomposition

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.

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.

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 the mean annual temperature, altitude and lignin content were the main factors regulating the weight loss and nutrient mineralisation. 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 southeast Missoori.

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. Litter 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 Wester Nigeria by Egunjobi (1974).

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. 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 caribaea*. 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 caribaea* where asymptotic model was found to be more appropriate (Spain and Feuvae, 1987).

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 difference in the rates of decomposition among the species and included that the concentration of lignin, nitrogen and C:N ratio had significant effect on decomposition.

2.2.4 Effects of stand age on the rate of decomposition

Bargali *et al*. (1993) studied 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 significantly correlated with initial nutrient concentration. Similar studies in Douglas fir at different ages indicated that maximum rate of decomposition was in the stand of twenty four years old (Edmonds, 1979).

2.2.5 Effect of litter quality and water soluble substances 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, Meentemeyer, 1978 and Kretzshman and Ladd, 1993). Water soluble materials present in the leaf biomass provide readily available energy source for decomposers and therefore said to be highly influenced 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 solubilisation 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 excelsa* was 32 per cent while in *Caucus petraea* it was only 18 per cent (Gilbert and Bocock, 1960).

Leaf litter of yellow birch, sugar maple and beach showed marked differences in the weight losses by the end of first month due to intense leaching of soluble organic materials (Gosz *et al*., 1973). Studies conducted by Berg and Landmark (1987) on the decomposition of scots pine and lodgepole pine revealed that mass loss rates were positively correlated with concentration of water soluble substances and nitrogen and relatively with those of lignin.

2.2.5.1 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, 1996; Aber and Melillo, 1980). Generally there will be a positive relationship between the rate of decomposition and initial nitrogen content of the leaf litter (Jamaluddeen, 1994).

Fresh plant material varies considerably in their nitrogen content. Tropical tree leaf biomass has a higher nitrogen 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.

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.

2.2.5.2 Carbon : Nitrogen ratio

Decomposition of biomass is highly influenced by the C:N ratio of plant residue. Plant litter with high initial nitrogen content and low C:N ratios are known to decompose rapidly (Singh and Gupta, 1977; Meentemeyer, 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 and N content were the best predictors of mass loss rate. Alexander (1977) reported that C:N ratio of 20:1 or narrower will be sufficient to supply nitrogen for the decomposing microorganisms and also to release nitrogen for plant use.

2.2.5.3 Lignin and Lignin : Nitrogen ratio

Effect of lignin and N on the decomposition of litter in nutrient poor ecosystems was studied by Berndese *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. Tian *et al*. (1992) found negative correlation between decomposition rate constants and percentage of lignin content of the plant residues. Kumar and Deepu (1992) found that high Lignin:Nitrogen ratio was associated with lower rate of mineralisation.

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). It revealed that the low mineralisation of lignin was due to high mineral N 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 N 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:N ratio.

2.2.6 Patterns of biomass decomposition

The decomposition dynamics involve a rapid initial rate of disappearance followed by a subsequent lower rate. The rapid phase involves the metabolization of readily digestible water soluble compounds such as simple sugars, proteins, amino acids and polysaccharides (Rangaswamy and Bagyaraj, 1993). During the later slower phase, the compounds resistant to biodegradation was found to be metabolised (Brady, 1984).

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 up to 16 months.

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.

2.3 NUTRIENT RELEASE PATTERN

Mwiinga *et al*. (1994) studied the N mineralisation pattern in decomposition of leaf litter 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}.

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 litter of Dauglas 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 tropical 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.

Sharma and Ambasht (1987) studied the decomposition of *Alnus nepalensis* in eastern Himalaya and found that the initial labial 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.

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 three months, about 20 per cent of the P were mineralised and after which there was only a little change. Pottassium 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.

Bargali *et al*. (1993) investigated the nutrient release patterns in decomposing leaf litter 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. Attempts were made to monitor the nutrient flux in the decomposing leaf biomass of sal, teak, pine and eucalyptus (Pandey and Sharma, 1993). In, general, all the species exhibited maximum release of Ca followed by K, N, Mg and P.

The amount composition and subsequent decomposition of litter is of major importance in matters concerning energy flow, nutrient cycling and primary productivity (Ovington, 1962). Litter on the soil surface acts as an input - oil system and is important in the nutrition of woodlands particularly of those on soils of low nutrient status where the trees rely to a great extent up on the recycling of litter nutrients (Das and Ramakrishnan, 1985). The literature so far reviewed shows an information gap with regards to comparitive account of litter production, litter nutrient concentration and leaf litter decay of different species of acacia.

Materials and Methods

MATERIALS AND METHODS

3.1 STUDY SITE

Location

The present study was conducted in five year old plantations of *Acacia aulacacarpa* A. Cunn. ex Benth, *A. crassicarpa* A. Cunn. ex Benth and *A. mangium* Wild. (Plates 2, 3 and 4) at College of Forestry, Kerala Agricultural University, Vellanikkara, Trichur, Kerala (10°31' N latitude and 76°10' E longitude, elevation 22 m above MSL). The study was conducted for a period of one year (2000 June to 2001 May). The details of climatic and soil conditions are furnished below.

Climate

The area constituting the experimental plantations enjoys a warm humid tropical climate and had received a total annual rainfall of 2514.1 mm during the study period. Figure 1 shows mean maximum temperature, mean minimum temperature and monthly rainfall for the study period. The mean maximum temperature recorded at Vellanikkara varied from 28.4°C (June) to 34.9°C (March). The mean minimum temperature varied from 21.9°C (July) to 24.7°C (April). The mean relative humidity varied from 56 per cent (January) to 87 per cent (June).

Soil

The soil at the experimental location is oxisols. The predominant parent material is metamorphic rock of gneiss series. The average soil pH is 6.5. The topsoils and subsoil are porous and well-drained.

3.2 FIELD EXPERIMENT

The study involves assessment of annual amounts of litter fall, litter nutrient concentrations, leaf litter decay and nutrient release pattern of three species of acacia namely, *Acacia aulacocarpa*, *Acacia crassicarpa* and *Acacia mangium*. The Description of these species are furnished below.

***Acacia mangium* Wild.**

Mangium grows with relatively good form in plantations. The main bole is usually straight and clear. The tree nodulates profusely, coppices, and responds to silvicultural manipulation. Natural seed production is prolific. A noteworthy features is mangium's ability to grow on soils with pH as low as 4.2. Mangium's wood is a dense, all purpose hardwood with an attractive, medium-brown color. It is of high quality and has been likened to black walnut in properties. It has potential for sawn timber, molding, furniture, veneer, firewood and charcoal. The wood is also promising for pulp, paper and particle board. The trees are useful for shade, ornamental purposes, screening, boundaries and windbreaks, as well as for use in agroforestry and erosion control. The leaves can serve as forage for livestock.

Acacia aulacocarpa A. Cunn. ex Benth

It has a wide geographic range, from coastal districts of central New South Wales through eastern Queensland to the northern part of the Northern Territory and southern New Guinea. It also commonly occurs on poor soils in eucalyptus woodlands. The leaves are much shorter than those of mangium and has pale-yellow flowers occurring in spikes. The pods are oblong, transversely veined, about 2 cm wide, and have undulate margins. The trees grow in widely varying soils, including deep sands, ultisols, spodosols, and hard and gravelly clays, as well as in humus loams of good quality. In Australia *Acacia aulacocarpa* wood is marketed with that of mangium and three other acacias under the trade names black wattle or brown salwood. The narrow sapwood is pale yellow. The heartwood is dark brown, hard, strong, moderately durable to durable, and moderately heavy (specific gravity about 0.6). It is used for framing, weather boards, and joinery, and is an attractive timber for furniture and cabinetmaking. It is also a good fuelwood.

Acacia crassicarpa A. Cunn. ex Benth

A small tree or large shrub, *Acacia crassicarpa* usually grows to heights of 6-15 m, although trees taller than 30 m have been reported in Papua New Guinea. It is found mainly in the coastal lowlands of northern Queensland and on the Oriomo Plateau of Papua New Guinea at elevations ranging from near sea level to about 700 m. *Acacia crassicarpa* differs from *Acacia aulacocarpa* in that it has oblong pods, more than 2.5 cm wide, and with margins that are not undulate. Its phyllodes tend to be larger, with long pulvinuses that have a yellowish tinge, particularly when dry. The wood is having a more or less similar quality and durability as that of *Acacia aulacocarpa.*

3.3 LITTER PRODUCTION

Litter production studies were conducted in five year old plantations of *Acacia mangium, A. crassicarpa* and *A. aulacocarpa* for a period of one year. Litter collections were done in specially designed circular traps (collection area: 0.24 m^2) described by Hughes *et al.* (1987) (Plate 1). These traps were fixed on the ground at a height of about 0.5 m using bamboo poles. In plantations of each species, ten such traps were placed randomly after laying out 10 m x 10 m permanent sample plot. Litter collection was made from each trap at monthly intervals during the period of one year. The litter was separated into leaves (phyllodes), twigs and fruits and weighed separately. The samples were taken to the laboratory for dry weight estimation and chemical analysis.

3.3.1 Nutrient return

The nutrient return was calculated by multiplying the weight (oven dry) of different components of litter with the nutrient concentration.

3.4 LEAF LITTER DECOMPOSITION

Decomposition of leaf litter of *Acacia mangium, A. crassicarpa* and *A. aulacocarpa* was studied in two situations i.e. plantations and open area by standard litter bag technique (Olson, 1963) (Plates 5 and 6). Freshly fallen leaves (phyllodes) were collected from the above plantations and dried under shade for approximately 48 hours. Thirty gram samples were placed in litter bags of 20 cm x 20 cm size made of four mm nylon wire mesh. Representative litter samples were collected in triplicate to estimate the fresh to dry matter ratio at the time of transferring the sample into the

Plate 1. Litter trap kept inside the plantation

Plate 2. View of *Acacia aulacocarpa* stand

Plate 3. View of *Acacia crassicarpa* stand

Plate 4. *Acacia mangium* stand

Plate 5. Litter bag kept for decomposition inside the plantation

Plate 6. Litter bag kept for decomposition in the open area

litter bags. The bags were then spread on the surface of soil (altogether 36 litter bags, 12 months x 3 replicates for each species). The samples were drawn from the plot at monthly intervals for a period of one year. Three litter bags were recovered at each sampling, cleaned free of extraneous materials and oven dried for 48 hours. The contents of the bags were analyzed for oven dry weight, carbon, nitrogen, phosphorus, potassium and lignin (Allen *et al.*, 1978).

3.5 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 and K. The lignin content was also estimated in fresh samples and residues. The standard procedures adopted for the chemical analysis are furnished below.

3.5.1 Total carbon

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

3.5.2 Nitrogen

Nitrogen content in fresh leaf litter and residues retrieved at monthly intervals were 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).

3.5.3 Phosphorus

A known quantity (one gram) of the powdered leaf sample was digested in triacid mixture (nitric acid : perchloric acid : sulphuric acid in 1:1:3 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.

3.5.4 Potassium

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

3.5.5 Lignin

One gram of powdered sample was refluxed with acid detergent solution and the content was filtered and washed with hot water and acetone. The leftover 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 sulphuric acid and added with one gram of asbestos powder and allowed to remain for three hours with intermittent 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 five hours. The contents were cooled in a desiccator. The ash was weighed and lignin content was calculated.

3.6 STATISTICAL ANALYSIS

The observations recorded on litter production, leaf litter decomposition and changes in nutrient content of residual mass at various periods were analyzed statistically by using the methods suggested by Panse and Sukhatme (1978). The rate of decomposition was statistically correlated with weather parameters.

The decay rate coefficient was 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).

$$t_{(0.05)} = \ln (0.5)/-k$$
$$= - 0.693/-k$$

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 amount of litter fall, the rate of leaf litter decomposition and the nutrient release pattern from the decomposing leaf litter were studied in five year old plantations of three different species of acacia (*Acacia mangium* Wild., *A. crassicarpa* A. Cunn. ex Benth and *A. aulacocarpa* A. Cunn. ex Benth) during a period of one year (2000 June to 2001 May). The salient findings of the studies are described hereunder.

4.1 LITTER PRODUCTION

In litter production studies, the major three components of litter viz., leaves (phyllode), twig + bark and fruits were considered. The monthly litter fall for each of the three species, percentage contribution of the components to the total litter production and corresponding monthly percentage contribution to the total annual production are presented in Tables 1, 2 and 3 and Fig. 2, 3 and 4, respectively. From the tables it is evident that the total annual litter production for *A. aulacocarpa*, *A. crassicarpa* and *A. mangium* are 1418.31 gm^{-2} (14.18 ton/ha), 1276.99 gm^{-2} (12.76 ton/ha) and 2064.01 gm^{-2} (20.64 ton/ha) respectively. Mean monthly values are 118.19 gm^{-2}, 106.42 gm^{-2} and 141.15 gm^{-2}, respectively. As evident from the Fig. 2, 3 and 4 seasonal litter fall patterns of the three species exhibited a tremendous degree of variability. In general, it followed a monomodal distribution pattern with a distinct peak in December for the three species. A comparative study of the production of different components of litter (leaf, twig + bark and fruit) for the three species of acacia at monthly intervals is depicted in Table 4 and 5. The three species showed significant difference in litter fall during different months. In June *Acacia aulacocarpa* (35.86 g m^{-2}) and *A. crassicarpa* (28.85 g m^{-2}) showed no significant differences in litter production. But *A. mangium* produced 70.84 gm^{-2}, which significantly differed from other species. A similar trend was observed in August, March and May. In the month of July all the three species showed significant differences among them with regard to litter production. Monthly variation in the total litter production of the three species of acacia is as shown in Fig. 5. From the figure it can be seen that the three species showed more or less similar trend in litter production except for *Acacia*

Table 1. Monthly variation in litter fall of *A. aulacocarpa* (g/m^2)

Sl. No.	Months	Leaf	Twig + bark	Fruits	Total litter oven dry weight g/m^2	Percentage contribution to the annual litter production
1	June	35.86 (100.0)	-	-	35.86	2.52
2	July	49.54 (100.0)	-	-	49.54	3.48
3	August	64.85 (100.0)	-	-	64.85	4.57
4	September	104.83 (100.0)	-	-	104.83	7.38
5	October	99.64 (71.9)	15.22 (10.9)	23.53 (17.0)	138.39	9.75
6	November	112.80 (74.9)	15.04 (9.9)	22.57 (15.0)	150.41	10.59
7	December	257.31 (66.6)	53.00 (13.7)	76.00 (19.7)	386.31	27.24
8	January	109.46 (68.5)	19.97 (12.5)	30.36 (18.9)	159.81	11.25
9	February	123.07 (72.9)	23.66 (14.0)	21.92 (12.9)	168.65	11.87
10	March	63.02 (77.6)	8.89 (10.9)	9.29 (11.4)	81.20	5.73
11	April	47.25 (100.0)	-	-	45.25	3.19
12	May	33.23 (100.0)	-	-	33.23	2.34
Total		1100.86	135.72	183.67	1418.31	100

*Figures in parentheses are the percentage contribution of respective components

Table 2. Monthly variation in litter fall of *A. crassicarpa* (g/m^2)

Sl. No.	Months	Leaf	Twig + bark	Fruits	Total litter oven dry weight g/m^2	Percentage contribution to the annual litter production
1	June	28.85 (100.0)	-	-	28.85	2.26
2	July	27.24 (100.0)	-		27.24	2.13
3	August	54.91 (100.0)	-		54.91	4.30
4	September	68.91 (100.0)	-		68.91	5.39
5	October	93.26 (75.0)	12.43 (9.9)	18.65 (14.9)	124.34	9.74
6	November	102.48 (71.9)	15.66 (11.0)	24.19 (16.9)	142.34	11.15
7	December	248.98 (68.0)	47.59 (12.9)	69.57 (19.0)	366.14	28.67
8	January	104.90 (69.7)	17.98 (11.8)	26.97 (17.9)	149.86	11.74
9	February	116.04 (77.8)	13.39 (8.9)	26.78 (17.8)	148.79	11.65
10	March	63.88 (90.0)	-	7.02 (9.9)	70.90	5.60
11	April	57.27 (100.0)	-	-	57.27	4.49
12	May	30.04 (100.0)	-	-	30.04	2.35
Total		996.76	107.05	173.11	1276.92	100

*Figures in parentheses are the percentage contribution of respective components

Table 3. Monthly variation in litter fall of *A. mangium* (g/m^2)

Sl. No.	Months	Leaf	Twig + bark	Fruits	Total litter oven dry weight g/m^2	Percentage contribution to the annual litter production
1	June	98.89 (100.0)	-	-	98.84	4.75
2	July	90.54 (100.0)	-	-	90.54	2.59
3	August	108.61 (100.0)	-	-	108.61	5.22
4	September	131.53 (91.2)	13.00 (8.8)	-	144.54	6.95
5	October	129.45 (67.4)	21.88 (16.6)	30.99 (16.0)	162.33	8.70
6	November	139.60 (76.5)	26.30 (6.4)	36.41 (17.0)	202.33	9.72
7	December	295.98 (67.7)	62.78 (12.2)	89.69 (20.14)	448.46	21.55
8	January	153.90 (76.6)	26.38 (8.4)	40.67 (15.0)	219.87	10.57
9	February	179.09 (69.8)	20.66 (18.8)	29.84 (11.4)	229.61	11.03
10	March	115.08 (77.0)	13.04 (10.2)	18.05 (12.7)	150.44	7.23
11	April	98.49 (87.1)	-	9.74 (12.9)	108.23	5.20
12	May	100.21 (100.0)	-	-	100.21	4.82
Total		1641.32	184.04	255.39	2064.01	100

*Figures in parentheses are the percentage contribution of respective components

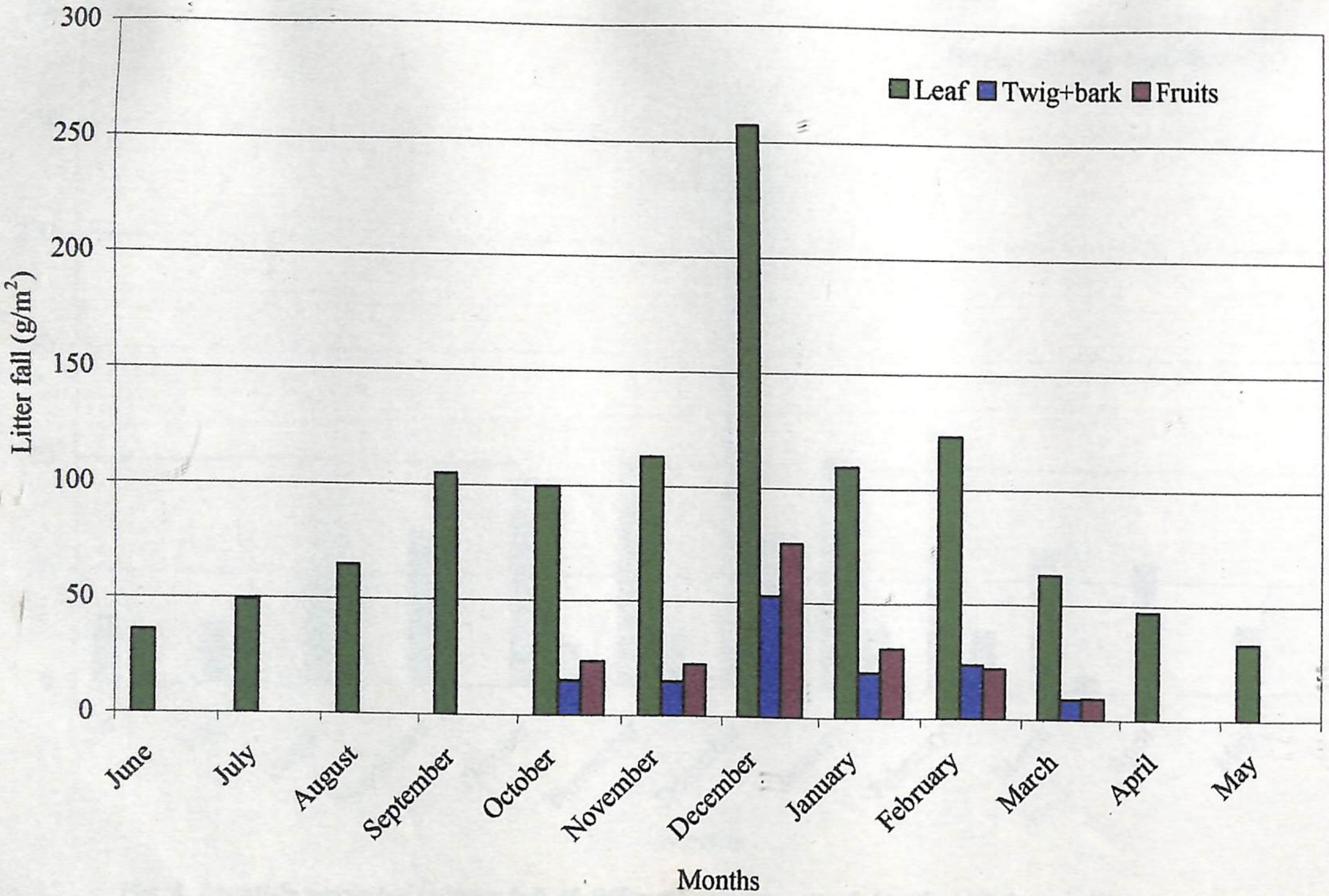


Fig. 2. Monthly variation in litter fall of different components of *Acacia aulococarpa*

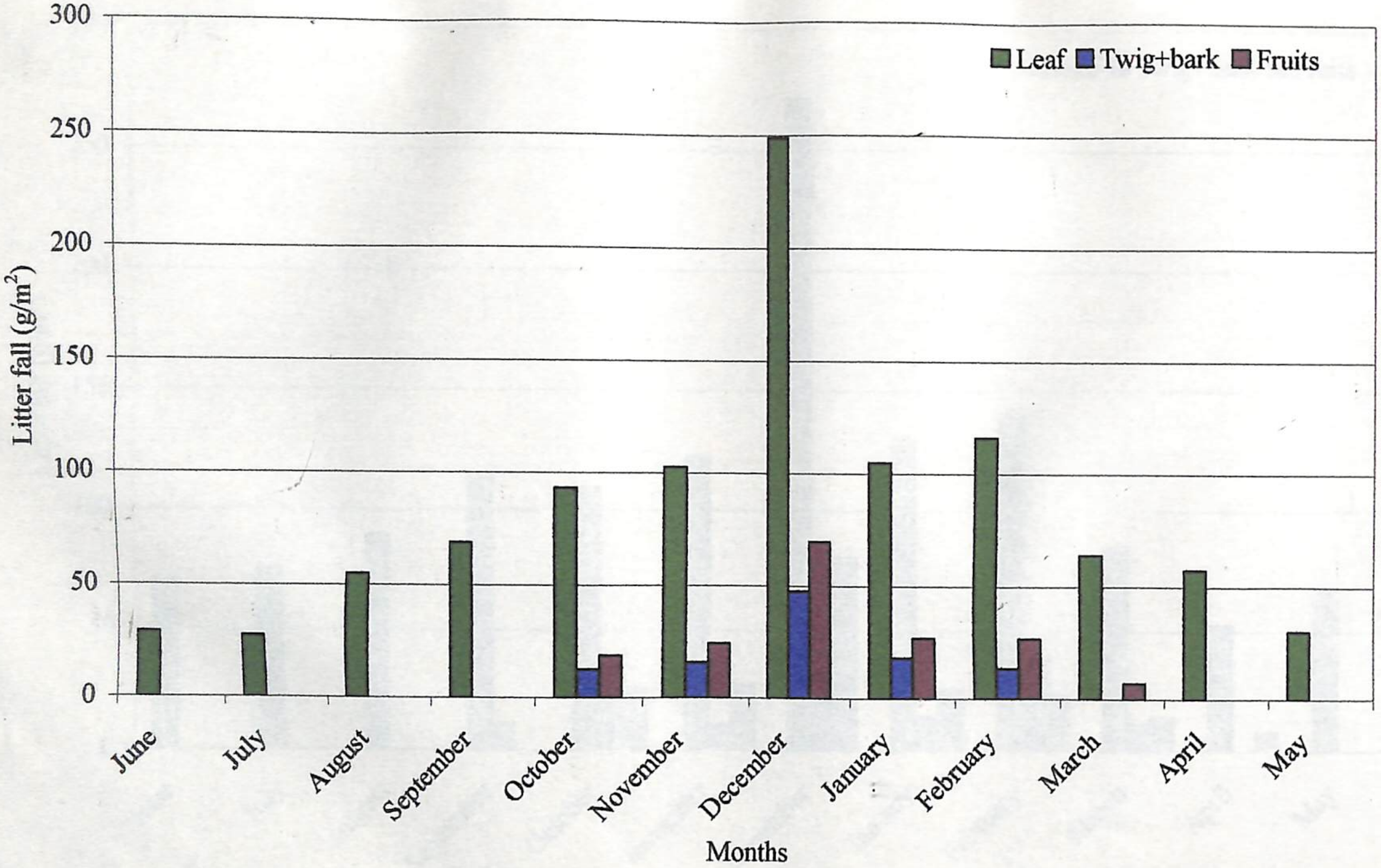


Fig. 3. Monthly variation in litter fall of different components of *Acacia crassicarpa* litter

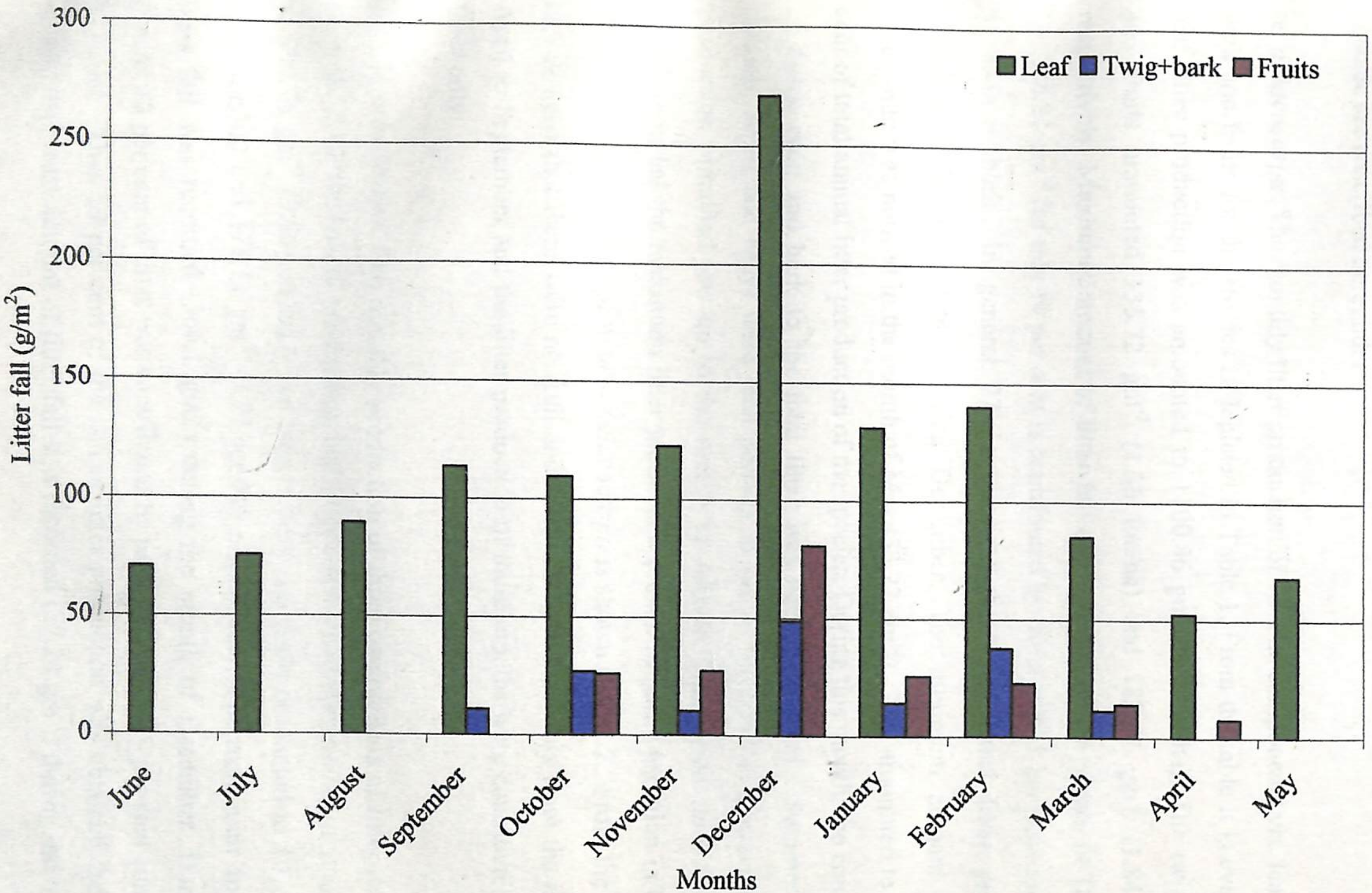


Fig. 4. Monthy variation in litter fall of different components of *Acacia mangium*

mangium, which produced almost same amount of litter during the months of March, April and May whereas the other two species showed a gradual decline in litter production during these months. The results of litter production studies for each of the species are described hereunder.

A. aulacocarpa: The monthly litter production of various components viz. leaf, twig + bark and fruits for the species is depicted in Table 1. From the table it is evident that leaf litter production was amounted to 1100.86 gm^{-2} (11 ton/ha). The twig + bark and fruits amounted 135.72 gm^{-2} (1.36 ton/ha) and 183.67 gm^{-2} (1.84 ton/ha) respectively. Maximum amount of litter fall occurred during the month of December i.e. 386.31 gm^{-2} (of this 19 per cent is contributed by fruits and 13 per cent contributed by twig + bark). In general 27 per cent of the total annual litter production (386.3 g m^{-2}) was obtained during December. The minimum amount of litter production was noticed in the month of May (33.23 gm^{-2}). This amounted to 2.34 per cent of total annual litter production of the species. During this month, the contribution of fruits, twig and bark to the total litter was negligibly small. Summer months (March, April and May) were lean periods as far as litter fall is concerned. Litter production remained low up to the month of August. The period from October to March recorded the maximum litter production (76%). Monthly variation in litter fall of different components of *Acacia aulacocarpa* is shown in Fig. 2. From the figure it can be seen that there were no fruit and twig + bark components from the month of April to September and the litter production of these months were contributed by leaf litter only.

Acacia crassicarpa: The monthly production of three components of litter are shown in Table 2. Of the annual production, leaf litter contributed maximum and it amounted to 996.76 gm^{-2} (9.96 ton/ha). The twig + bark and fruits amounted to 107.05 gm^{-2} (1.07 ton/ha) and 173.11 gm^{-2} (1.73 ton/ha) respectively. The maximum amount of litter fall was recorded (366.1 gm^{-2}) during the month of December. During this month, 13 per cent of litter was contributed by twig + bark and 19 per cent contributed by fruits. Thus 29 per cent of the annual litter production was obtained during this month. The least amount of litter fall was recorded (27.24 gm^{-2}) during the month of

Table 4. Monthly variation in litter fall of the three species of acacia (g/m^2)

Months	Leaf litter			Twig + Bark			Fruit			Total		
	A. A	A.C	A. M	A. A	A.C	A. M	A. A	A.C	A. M	A. A	A.C	A. M
June	35.86	28.85	70.84	-	-	-	-	-	-	35.86	28.85	70.84
July	49.54	27.24	75.24	-	-	-	-	-	-	49.54	27.24	75.24
August	64.850	54.91	89.61	-	-	-	-	-	-	64.85	54.91	89.61
September	104.83	68.91	113.53	0.00	0.00	11.01	-	-	-	104.83	68.91	124.54
October	99.64	93.26	109.45	15.22	12.43	26.89	23.53	18.65	25.99	138.39	124.34	162.33
November	112.80	102.48	122.60	15.04	15.66	10.32	22.57	24.19	27.41	150.41	142.33	160.33
December	257.31	248.98	270.98	53.13	47.59	48.83	76.00	69.57	80.69	386.44	366.14	400.50
January	109.46	104.90	130.90	19.97	17.98	14.30	30.36	26.97	25.67	159.79	149.85	170.87
February	123.07	116.04	140.09	23.66	13.39	37.68	21.92	26.78	22.84	168.65	156.21	200.61
March	63.02	63.88	85.08	8.89	0.00	11.31	9.29	7.02	14.05	81.20	70.90	110.44
April	47.25	57.27	52.49	-	-	-	0.00	0.00	7.74	45.25	57.27	60.23
May	33.23	30.04	68.21	-	-	-	-	-	-	33.23	30.04	68.21

A.A - *A. aulacocarpa*; A.C - *A. crassicarpa*; A.M - *A. mangium*

Table 5. Monthly variation in total litterfall of three species of acacia (g m^{-2}

Species	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
A.A.	35.85[a]	49.54[a]	64.85[a]	104.83[a]	138.39[a]	150.41[a]	386.44[a]	159.79[a]	168.65[a]	81.20[a]	45.25[a]	33.23[a]
A.C.	28.85[a]	27.24[b]	54.91[a]	68.91[a]	124.34[a]	142.33[a]	366.14[a]	149.85[a]	156.21[a]	20.90[a]	57.27[a]	30.04[a]
A.M.	70.84[b]	75.24[c]	89.61[b]	124.59[a]	162.33[a]	160.33[a]	400.50[a]	170.87[a]	200.61[a]	110.44[b]	60.23[a]	68.21[b]

* Significant at 5% level
A.A. - *Acacia aulacocarpa*
A.C. - *Acacia crassicarpa*
A.M. - *Acacia mangium*
Figures with similar superscripts do not differ significantly

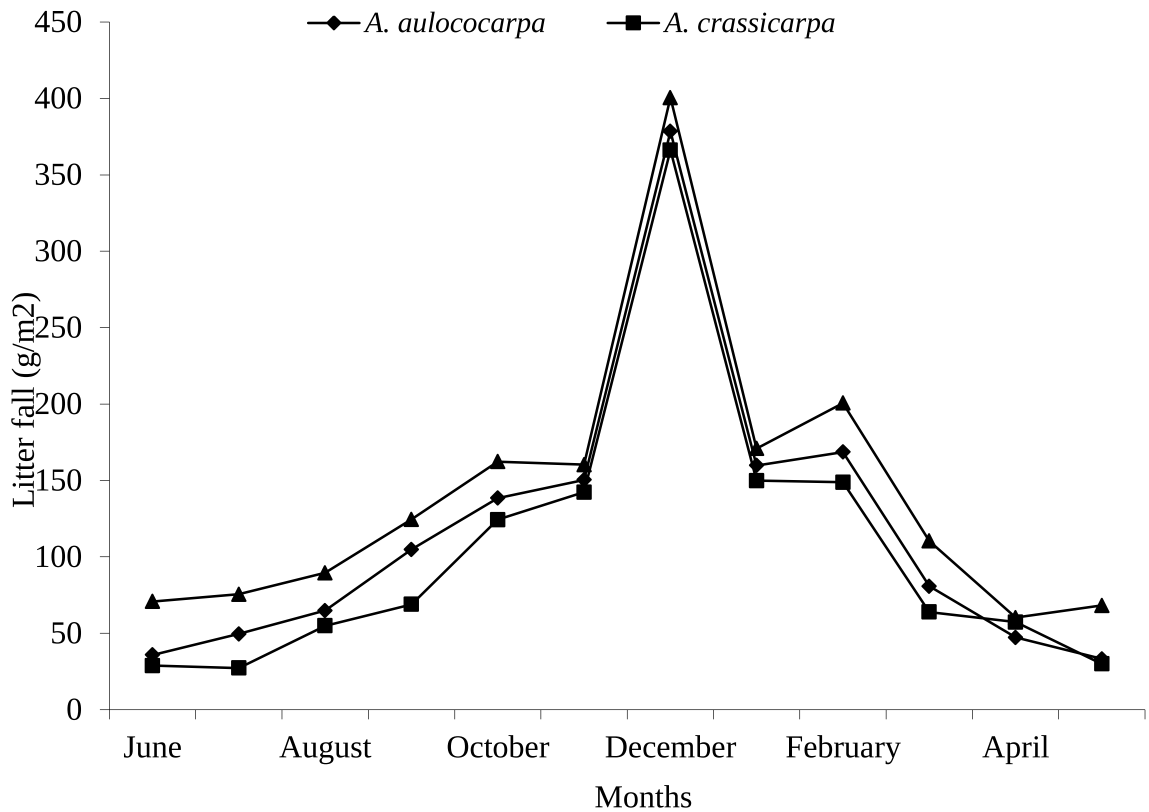


Fig. 5. Monthly variation in litter fall of three species of acacias

July. This amounted to 2.13 per cent of the total annual litter production of the species. During the month of July, the contribution of twigs, bark and fruits were negligibly small. The species produced very low quantities of litter during the periods from March to September. Maximum contribution to annual litter production occurred (74%) from October to February. Monthly variation in litter fall of different components of *A. crassicarpa* is shown in Fig.3. From the figure it can be seen that from the month of April to September there were no fruit and twig + bark components and the litter production of these months were contributed by leaf litter only.

***A. mangium*:** Monthly litter fall, contribution of three components viz., leaf (phyllode), twig + bark and fruits and the total annual production for *A. mangium* are presented in Table 3. The total annual litter production was estimated to be 2064.01 gm^{-2} (20.64 ton/ha) and the mean monthly value was 141.15 gm^{-2}. From the Table it is evident that *A. mangium* exhibited a tremendous variability with respect to seasonal litter fall pattern. The species produced maximum litter during December (22%). During this month 14 per cent of the litter was contributed by twig + bark and 20 per cent contributed by fruits. The lowest amount of litter fall occurred during the month of April and it amounted to 60.23 gm^{-2}. Thus the lowest contribution of 6.56 per cent of the total litter production occurred during this month. During this month, fruits contributed 12.9 per cent of the total litter and the contribution from twigs and bark were negligibly small. As in the case of other species, mangium also produced minimum amount of litter during the summer months. Litter production was found to be increasing substantially during the months of October-November and reaching its peak during December and declined there after. These periods i.e. from October to March amounted to 60 per cent of the total annual litter production. Monthly variation in litter fall of different components of *A. mangium* is shown in Fig.4. It can be seen from the above figure that there were no twig + bark components from the month of April to September. Similar the case with fruits also. However fruit fall is recorded in the month of April.

4.1.1 Litter nutrient concentration and nutrient return

Monthly variation in nitrogen, phosphorus and potassium contents of the litter of different species are depicted in Tables 6 to 8 and Figs. 6 to 14. For *Acacia*

Table 6. Monthly variation in the nutrient concentrations of *Acacia aulacocarpa* litter

Months	Nutrients (% dry weight)								
	N			P			K		
	Leaf	Twig + bark	Fruits	Leaf	Twig + bark	Fruits	Leaf	Twig + bark	Fruits
June	1.42	-	-	0.014	-	-	0.195	-	-
July	1.39	-	-	0.113	-	-	0.220	-	-
August	1.30	-	-	0.018	-	-	0.280	-	-
September	1.19	-	-	0.010	-	-	0.370	-	-
October	1.29	0.57	0.29	0.018	0.02	0.01	0.240	0.22	0.17
November	1.19	0.39	0.31	0.011	0.03	0.03	0.190	0.19	0.21
December	1.49	0.70	0.21	0.025	0.02	0.03	0.300	0.24	0.23
January	1.31	0.49	0.19	0.019	0.03	0.01	0.290	0.28	0.18
February	1.12	0.40	0.24	0.017	0.01	0.02	0.192	0.20	0.19
March	1.22	0.41	0.17	0.007	0.02	0.02	0.210	0.19	0.17
April	1.33	-	-	0.017	-	-	0.260	-	-
May	1.28	-	-	0.013	-	-	0.211	-	-
Mean	1.30	0.49	0.24	0.024	0.02	0.02	0.247	0.22	0.19

Table 7. Monthly variation in the nutrient concentrations of *Acacia crassicarpa* litter

Months	Nutrients (% dry weight)								
	N			P			K		
	Leaf	Twig + bark	Fruits	Leaf	Twig + bark	Fruits	Leaf	Twig + bark	Fruits
June	1.41	-	-	0.113	-	-	0.221	-	-
July	1.40	-	-	0.014	-	-	0.197	-	-
August	1.37	-	-	0.010	-	-	0.370	-	-
September	1.11	-	-	0.018	-	-	0.280	-	-
October	1.27	0.38	0.31	0.018	0.03	0.02	0.190	0.19	0.16
November	1.19	0.51	0.28	0.011	0.02	0.02	0.270	0.21	0.23
December	1.50	0.69	0.22	0.022	0.04	0.03	0.260	0.27	0.21
January	1.31	0.41	0.21	0.017	0.02	0.01	0.310	0.23	0.19
February	1.10	0.40	0.19	0.008	0.01	0.02	0.220	0.18	0.18
March	1.22	-	0.16	0.017	0.01	0.01	0.191	0.20	0.17
April	1.31	-	-	0.013	-	-	0.212	-	-
May	1.27	-	-	0.014	-	-	0.240	-	-
Mean	1.28	0.48	0.23	0.023	0.02	0.02	0.247	0.21	0.19

Table 8. Monthly variation in the nutrient concentrations of *Acacia mangium* litter

Months	Nutrients (% dry weight)								
	N			P			K		
	Leaf	Twig + bark	Fruits	Leaf	Twig + bark	Fruits	Leaf	Twig + bark	Fruits
June	1.46	-	-	0.013	-	-	0.241	-	-
July	1.37	-	-	0.112	-	-	0.240	-	-
August	1.24	-	-	0.016	-	-	0.250	-	-
September	1.20	0.60	0.30	0.008	0.03	0.01	0.340	0.31	0.29
October	1.35	0.66	0.31	0.012	0.02	0.03	0.230	0.21	0.19
November	1.19	0.37	0.29	0.010	0.03	0.02	0.170	0.19	0.17
December	1.54	0.80	0.32	0.024	0.04	0.03	0.290	0.27	0.29
January	1.25	0.53	0.22	0.015	0.02	0.01	0.310	0.29	0.18
February	1.10	0.39	0.30	0.007	0.03	0.02	0.195	0.19	0.21
March	1.11	0.43	0.19	0.006	0.01	0.03	0.240	0.31	0.20
April	1.22	-	0.20	0.013	-	0.01	0.220	-	0.17
May	1.23	-	-	0.017	-	-	0.213	-	-
Mean	1.27	0.54	0.27	0.021	0.03	0.02	0.245	0.25	0.21

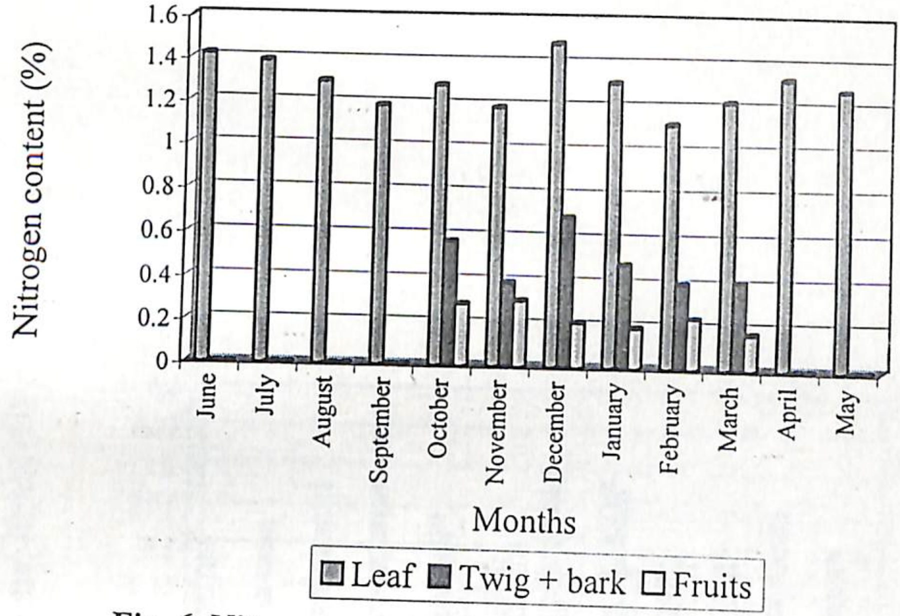


Fig. 6. Nitrogen content in different components of *Acacia aulococarpa* litter

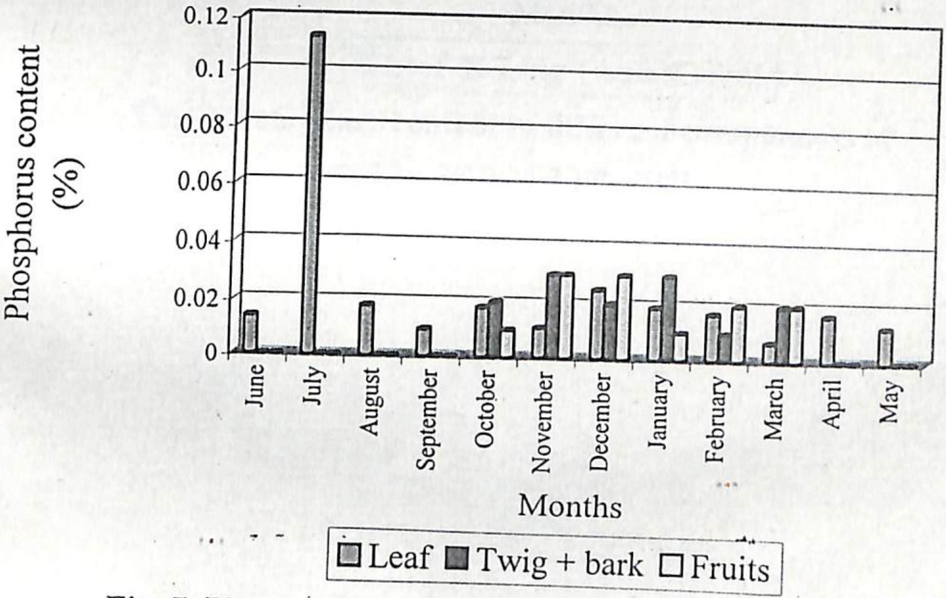


Fig. 7. Phosphorus content in different components of *Acacia aulococarpa* litter

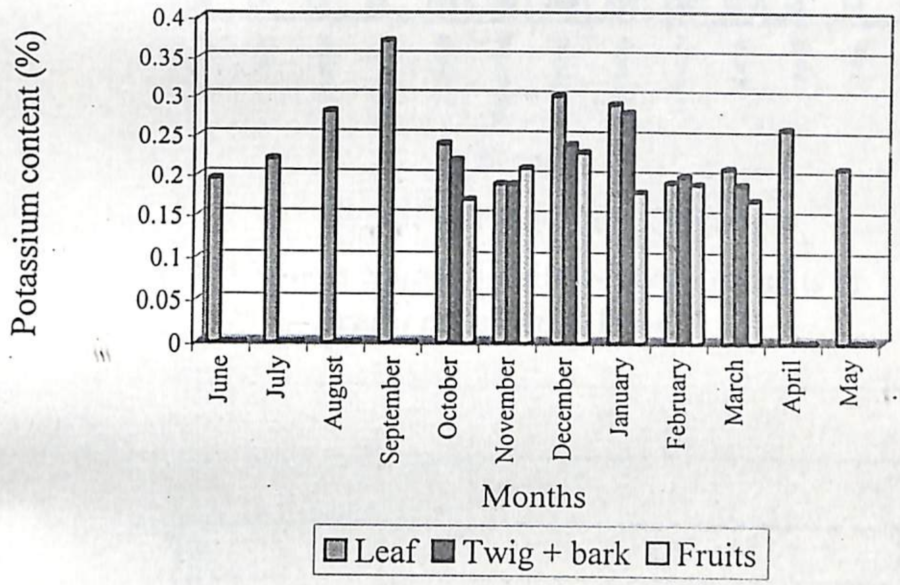


Fig. 8. Potassium content in different components of *Acacia aulococarpa* litter

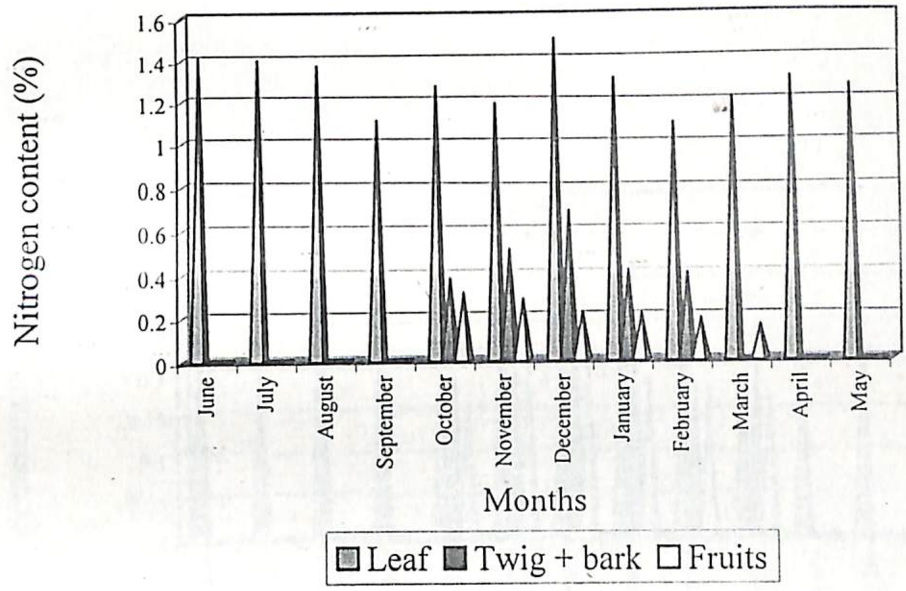


Fig. 9. Nitrogen content in different components of *Acacia crassicarpa* litter

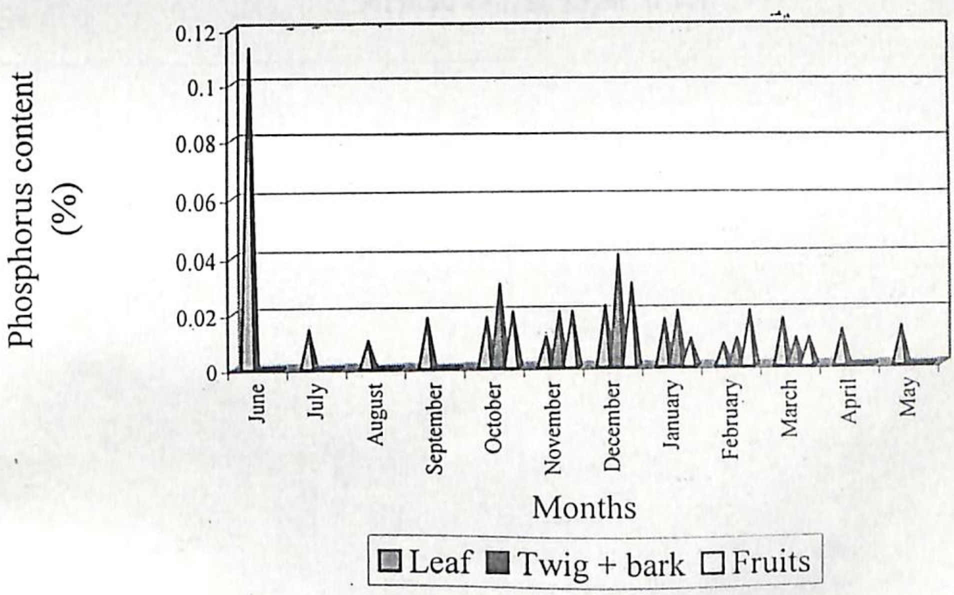


Fig. 10. Phosphorus content in different components of *Acacia crassicarpa* litter

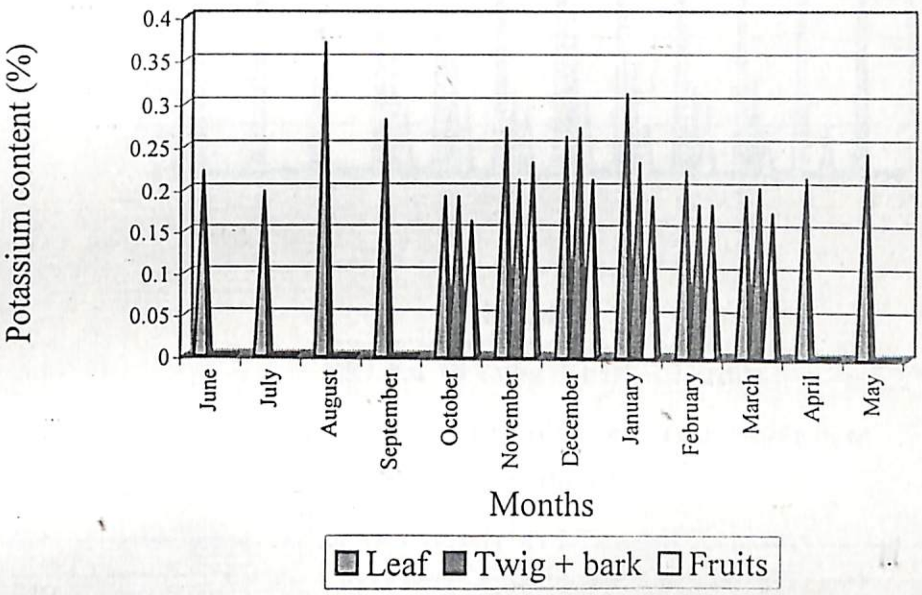


Fig. 11. Potassium content in different components of *Acacia crassicarpa* litter

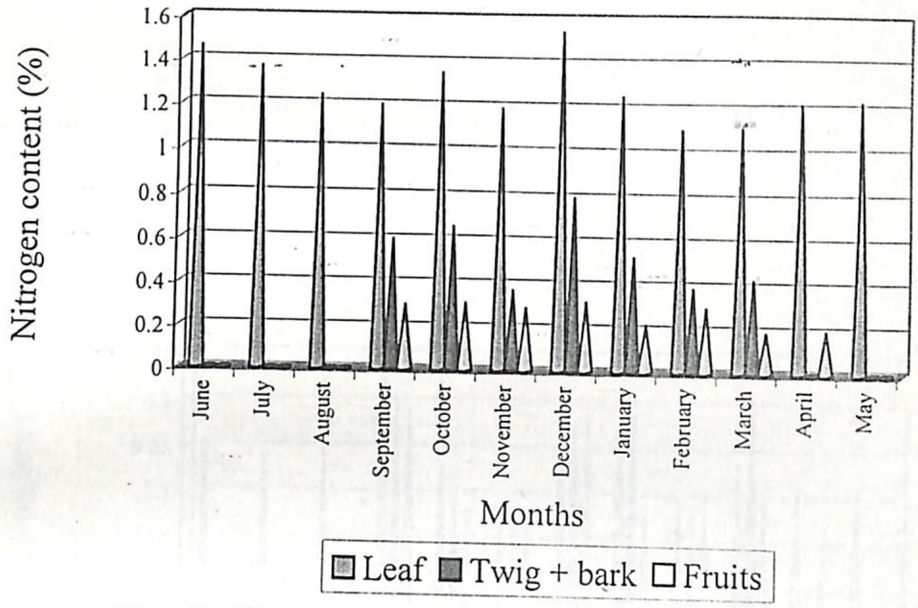


Fig. 12. Nitrogen content in different components of *Acacia mangium* litter

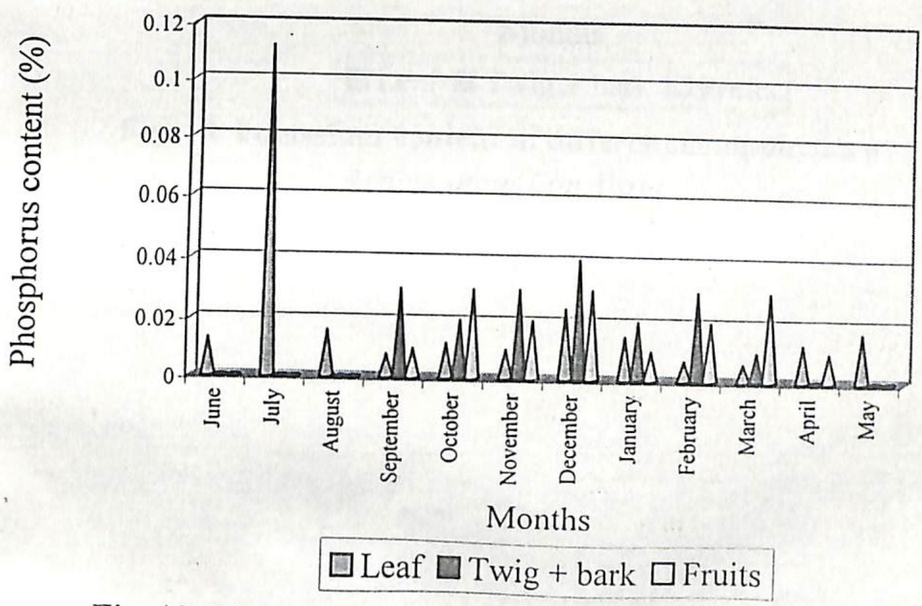


Fig. 13. Phosphorus content in different components of *Acacia mangium* litter

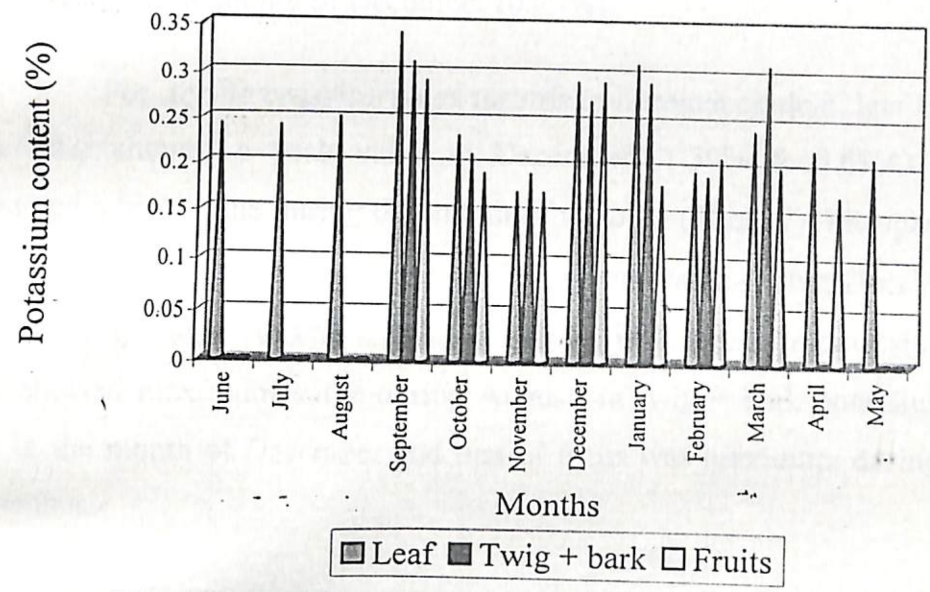


Fig. 14. Potassium content in different components of *Acacia mangium* litter

aulacocarpa as regards to nitrogen, the peak value was recorded in leaf (1.49%) followed by twig + bark (0.7%) and fruits (0.24%). Concentration of nitrogen was highest in the month of December whereas in fruits it was in the month of February (Table 6). Phosphorus content of leaf litter was high (0.025%) during December while twig + bark and fruits did not show significant difference during different months. Regarding the potassium content of leaf litter the peak value was obtained during January (0.29%), for twig + bark component, it was 0.28 per cent and fruits registered a peak value in the month of December (0.23%).

For *Acacia crassicarpa* as regards to nitrogen content, leaf litter and twig + bark litter showed a peak value in December (1.50% & 0.69%) whereas fruits registered a high value during the month of October (Table 7). Phosphorus content of different components of the litter recorded a peak value during December (leaf litter 0.022%, twig + bark - 0.04% and fruits 0.03%). With regard to potassium content, leaf litter showed maximum value during August. In twig + bark potassium content was high in the month of December and that of fruits was maximum during the month of November.

In *Acacia mangium* different components of litter exhibited high value of nitrogen content during the month of December (leaf litter 1.54%, twig + bark 0.8% and fruits 0.32%) (Table 8). A similar trend was also observed for phosphorus content. In this case, leaf litter registered a value of 0.024 per cent, twig + bark showed a value of 0.40 per cent and that for fruit litter, it was 0.03 per cent. Regarding the potassium content, maximum value for leaf litter was obtained during January (0.31%), whereas twig + bark and fruits registered a high value in the month of March (0.31%) and December (0.29%), respectively. Nutrient return through various components of litter is illustrated in Table 9. It is observed that return of N was found to be highest for *A. mangium* (225.31 kg ha yr^{-1}) followed by *Acacia aulacocarpa* (154.17 kg ha yr^{-1}) and *A. crassicarpa* (136.70 kg ha yr^{-1}). The phosphorus return showed a similar order with a value of 4.50 kg ha yr^{-1} for *A. mangium* followed by *A. aulacocarpa* (3.28 kg ha yr^{-1}) and *A. crassicarpa* (2.85 kg ha yr^{-1}). The potassium return also showed a similar trend with values (50.17 kg ha yr^{-1}) for *A. mangium*, 33.66 kg ha yr^{-1}

Table 9. Nutrient return from different species of acacia (kg/ha/yr)

Species	Nutrients											
	N				P				K			
	Leaf	Twig + bark	Fruit	Total	Leaf	Twig + bark	Fruit	Total	Leaf	Twig + bark	Fruit	Total
A. aulacocarpa	143.11	6.65	4.40	154.16	2.64	0.27	0.36	3.27	27.19	2.98	3.48	33.65
A. crassicarpa	127.58	5.13	3.98	136.69	2.29	0.21	0.34	2.84	24.61	2.24	3.28	30.13
A. mangium	208.44	9.93	6.89	225.26	3.44	0.55	0.51	4.50	40.21	4.60	5.36	50.17

for *A. aulacocarpa* and 30.15 kg ha yr^{-1} for *A. crassicarpa*. In all the three species leaf component returned maximum amount of nutrients. The component wise nutrient return of different species is shown in Table 9.

4.2 LEAF LITTER DECOMPOSITION

Leaf litter decomposition and nutrient release patterns were studied for three species of acacia namely *Acacia aulacocarpa*, *A. crassicarpa* and *A. mangium* for two different study situations i.e., in open area and plantation. The results are outlined below.

4.2.1 Rates of leaf litter decomposition

The data related to the decomposition of leaf litter of three species of Acacias at monthly intervals for two study situations are presented in Table 10 and 11. All the three species generally showed a faster rate of decomposition. Statistical analysis of the decomposition data corresponding to the end of first five months did not exhibit any significant difference with respect to the species or study situations. At the end of first month the percentage of initial weight remaining in the litter bags inside the plantation was maximum for *Acacia crassicarpa* (72.42%) followed by *Acacia mangium* (70.28%) and *Acacia aulacocarpa* (70.08%). At the end of second month the percentage of initial mass remaining in the litter bags was maximum for *Acacia crassicarpa* (40.52%) followed by *Acacia mangium* (39.63%) and *Acacia aulacocarpa* (37.46%). Decomposition data corresponding to the third month also showed no difference among the three species. However *Acacia crassicarpa* retained a higher percentage of initial mass (15.04%) followed by *Acacia aulacocarpa* (14.11%) and *Acacia mangium* (13.02%). A rapid reduction in the mass remaining in the litter bags was noticed among all the species at the end of fourth month of exposure for decomposition and more than 90 per cent of the initial mass was lost for all the species. Maximum decomposition was noticed for *Acacia mangium* followed by *Acacia aulacocarpa* and *Acacia crassicarpa*.

From sixth month onwards the three species showed relatively very slow decomposition rate. However, during the sixth month *Acacia aulacocarpa* revealed a difference when compared to the other two species. The percentage of initial weight remaining in the litter bags was maximum for *Acacia crassicarpa* (8.3%) followed by *Acacia mangium* (7.33%) and *Acacia aulacocarpa* (0.58%).

During seventh month of decomposition, *Acacia mangium* showed a significant difference in decomposition compared to the other two species (Table 11). The percentage of initial weight remaining in the litter bags was maximum for *Acacia crassicarpa* (8.1%) followed by *Acacia aulacocarpa* (7.61%) and *Acacia mangium* (3.32%).

. Decomposition data corresponding to the eighth month showed a significant difference among the species. *Acacia crassicarpa* retained maximum percentage of initial mass (3.9%) followed by *Acacia aulacocarpa* (2.31%) and *Acacia mangium* (0.16%).

During the ninth month, *Acacia crassicarpa* showed significant difference in decomposition when compared to the other two species (Table 11). The percentage of initial weight remaining in the litter bags was maximum for *Acacia crassicarpa* (2.74%) followed by *Acacia mangium* (0.34%) and *Acacia aulacocarpa* (0.11%).

By the end of tenth month, no residual mass was present in the litter bags for further decomposition in *Acacia aulacocarpa* and *Acacia mangium*. However, *Acacia crassicarpa* retained 0.58 per cent of initial mass during tenth month and 0.33 per cent of initial mass at eleventh month. No residual mass was present in the litter bags of *Acacia crassicarpa* at the end of twelveth month.

4.2.2 Rate of decomposition as affected by field conditions

The data furnished in Table 10 indicate the effect of field conditions on the rate of decomposition. In general, the rate of decomposition was found to be faster in open conditions. However, there was no significant difference in decomposition between the open area and plantation for the three species of acacia during the first five months (Table 12).

Table 10. Monthly variation in litter mass remaining in three species of acacia

Months	*Acacia aulacocarpa*				*Acacia crassicarpa*				*Acacia mangium*			
	Residual mass (g)		Relative mass (%)		Residual mass (g)		Relative mass (%)		Residual mass (g)		Relative mass (%)	
	Plantation	Open Area	Plantation	Open Area	Plantation	Open Area	Plantation	Open Area	Plantation	Open Area	Plantation	Open Area
Initial	17.83	17.83	100	100	17.20	17.20	100	100	18.76	18.76	100	100
June	12.50	11.17	70.08	62.76	12.50	12.29	72.42	71.50	13.18	8.70	70.28	46.40
July	6.68	3.15	37.46	17.64	6.97	6.75	40.52	39.25	7.43	1.63	39.63	8.68
August	2.51	3.87	14.11	21.70	2.59	2.50	15.04	14.54	2.44	0.93	13.02	4.97
September	0.74	1.96	4.20	10.98	1.08	1.22	6.32	7.10	0.57	0.16	3.02	0.84
October	2.15	1.13	12.08	6.37	2.33	2.22	13.54	12.9	1.98	0.08	10.56	0.43
November	0.1	-	0.58	0	1.42	1.22	8.30	7.10	1.38	0.51	7.33	2.73
December	1.36	0.02	7.61	0.11	1.39	1.10	8.10	6.42	0.62	0.14	3.32	0.74
January	0.41	0.14	2.31	0.79	0.67	0.68	3.90	3.97	0.03	0.12	0.16	0.63
February	0.02	0.12	0.11	0.04	0.47	0.33	2.74	1.90	0.06	0.08	0.34	0.42
March	-	-	0	0	0.1	0.04	0.58	0.24	-	-	0	0
April	-	-	0	0	0.06	0.02	0.33	0.09	-	-	0	0
May	-	-	0	0	-	-	0	0	-	-	0	0

Table 11. Changes in residual mass (%) of three species of acacia

Species	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
A.A.	70.08^{a}	37.46^{a}	14.11^{a}	4.20^{a}	12.08^{a}	0.58^{b}	7.61^{a}	2.31^{a}	0.11^{a}	0	0	0
A.C.	72.42^{a}	40.52^{a}	15.04^{a}	6.32^{a}	13.54^{a}	8.30^{a}	8.10^{a}	3.90^{b}	2.74^{b}	0.59	0.33	0
A.M.	70.28^{a}	39.63^{a}	13.02^{a}	3.02^{a}	10.56^{a}	7.33^{a}	3.32^{b}	0.16^{c}	0.34^{a}	0	0	0

* Significant at 5% level
A.A. - *Acacia aulacocarpa*
A.C. - *Acacia crassicarpa*
A.M. - *Acacia mangium*
Figures with similar superscripts do not differ significantly

Table 12. Changes in residual mass (%) of three species of acacia under different study situations

Species	Study situation	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May
A.A.	Plantation	70.08^{a}	37.46^{a}	14.40^{a}	4.20^{a}	12.08^{a}	0.58^{a}	7.61^{a}	2.31^{a}	0.11^{a}	0	0	0
	Open area	62.76^{a}	17.64^{a}	21.70^{a}	10.98^{a}	6.37^{a}	0	0.11^{b}	0.79^{b}	0.04^{a}	0	0	0
A.C.	Plantation	72.42^{a}	40.32^{a}	15.04^{a}	6.32^{a}	13.54^{a}	8.30^{a}	8.10^{a}	3.90^{a}	2.74^{a}	0.38^{a}	0.33^{a}	0
	Open area	71.50^{a}	39.25^{a}	14.54^{a}	7.10^{a}	12.90^{a}	7.10^{a}	6.42^{a}	3.97^{a}	1.90^{a}	0.24^{b}	0.09^{b}	0
A.M.	Plantation	70.28^{a}	39.63^{a}	13.02^{a}	3.02^{a}	10.56^{a}	7.33^{a}	3.32^{a}	0.16^{a}	0.39^{a}	0	0	0
	Open area	46.40^{a}	8.68^{a}	4.97^{a}	0.84^{a}	0.43^{a}	2.73^{a}	0.74^{b}	0.63^{a}	0.42^{a}	0	0	0

* Significant at 5% level
A.A. - *Acacia aulacocarpa*
A.C. - *Acacia crassicarpa*
A.M. - *Acacia mangium*
Figures with similar superscripts do not differ significantly

During the fourth month, for *Acacia aulacocarpa* the residual mass remaining in open area was very low (4.25%) when compared to the plantation

(10.98%). *Acacia aulacocarpa* showed significant difference between the two study situations from sixth month to eighth month while *Acacia mangium* showed significant difference in decomposition during seventh month only and *Acacia crassicarpa* exhibited no significant difference in decomposition between plantation and open area. At the end of ninth month, the residual mass remaining in the litter bags collected from the open area was found to be relatively high (0.42%) compared to the open area (0.34%) for *Acacia mangium*.

During tenth, eleventh and twelveth months, no residual mass was present for *Acacia aulacocarpa* and *Acacia mangium* in two study situations. However, *Acacia crassicarpa* retained residual mass during tenth and eleventh months. It also showed significant difference in decomposition between the open area and the plantation during the above months. During twelveth month, no residual mass was present in the litter bags for *Acacia crassicarpa*.

4.2.3 Pattern of leaf litter decomposition

The general pattern of leaf litter decomposition for the three species of acacia is illustrated in Fig.15 to 19. It followed a biphasic pattern with an initial rapid decomposition period followed by a slower decomposition phase. For all the three species, seventy five per cent of litter decomposed within the period of three months.

4.2.4 Factors affecting leaf litter decomposition

4.2.4.1 Effect of litter quality on the rate of decomposition

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

4.2.4.1.1 Nitrogen content and C:N ratio

The periodic data corresponding to total carbon content, nitrogen content and C:N ratio of various species at different study situations are furnished in Table 13

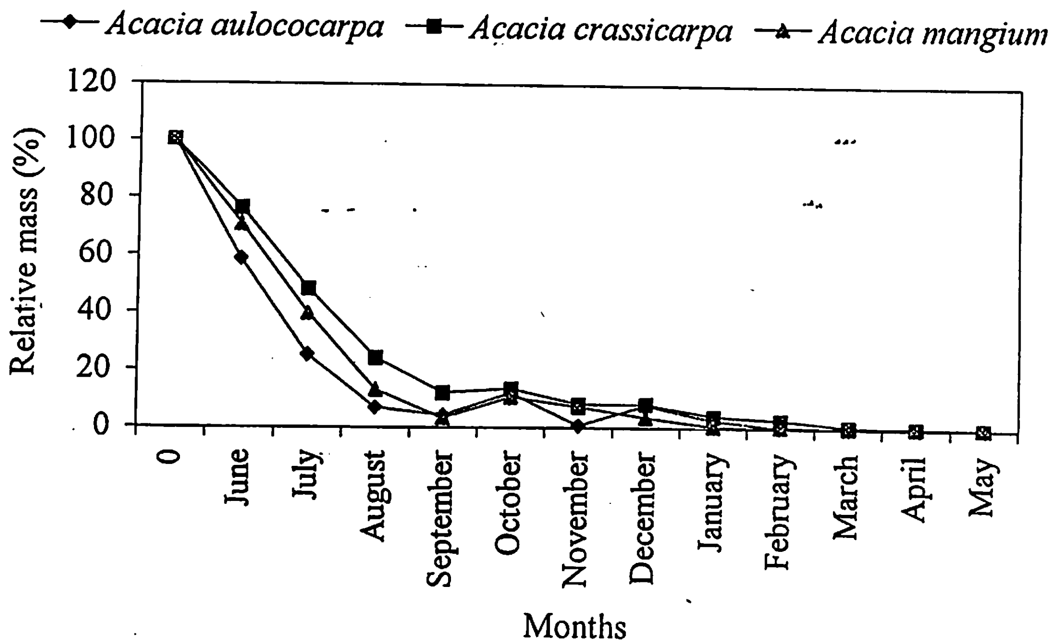


Fig. 15. Monthly variation in the rate of decomposition of leaf litter of three species in the plantation

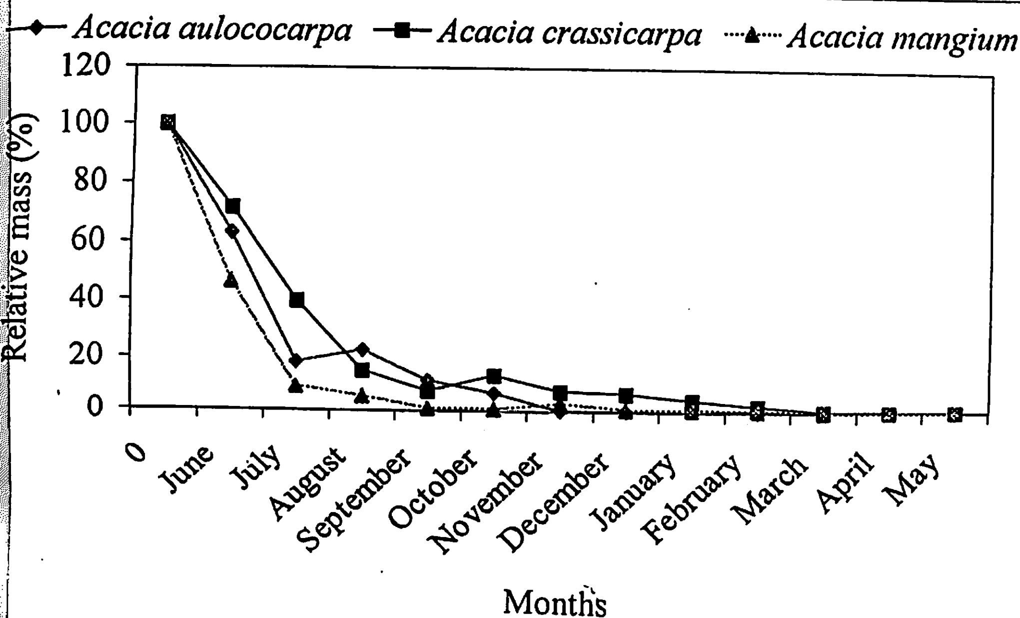


Fig. 16. Monthly variation in the rate of decomposition of leaf litter of three species in open area

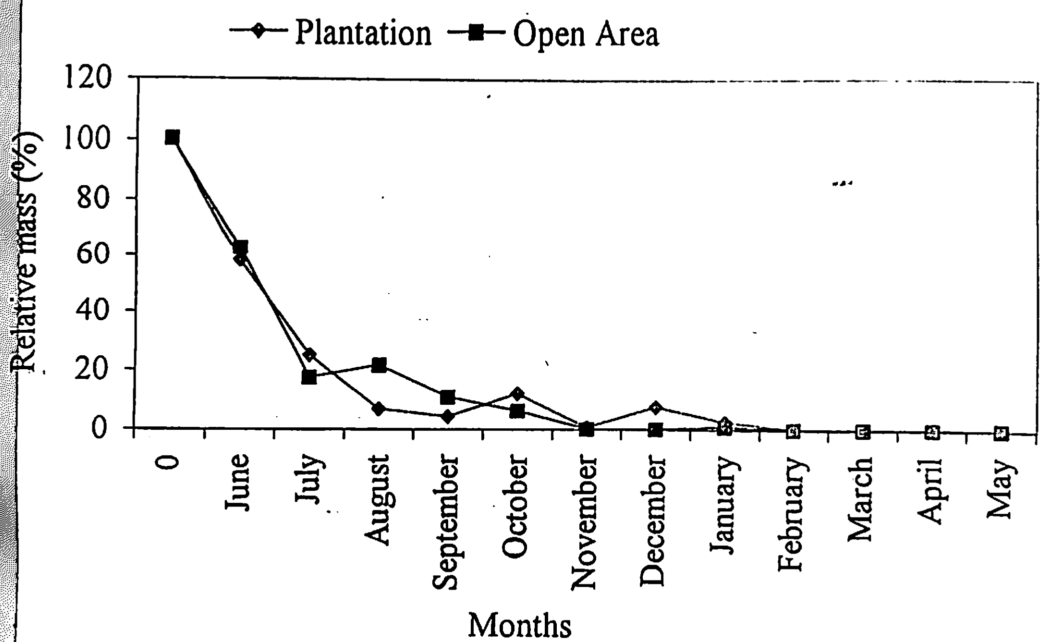


Fig. 17. Monthly variation in the rate of decomposition of leaf litter of *Acacia aulococarpa* under two study situations

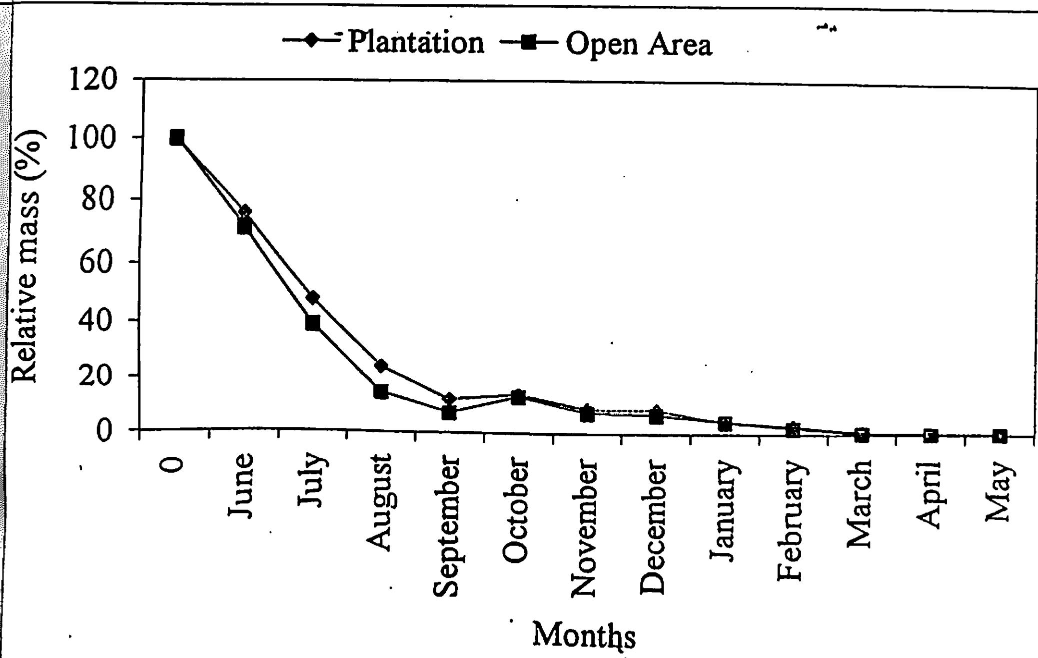


Fig. 18. Monthly variation in the rate of decomposition of leaf litter of *Acacia crassicarpa* under two study situations

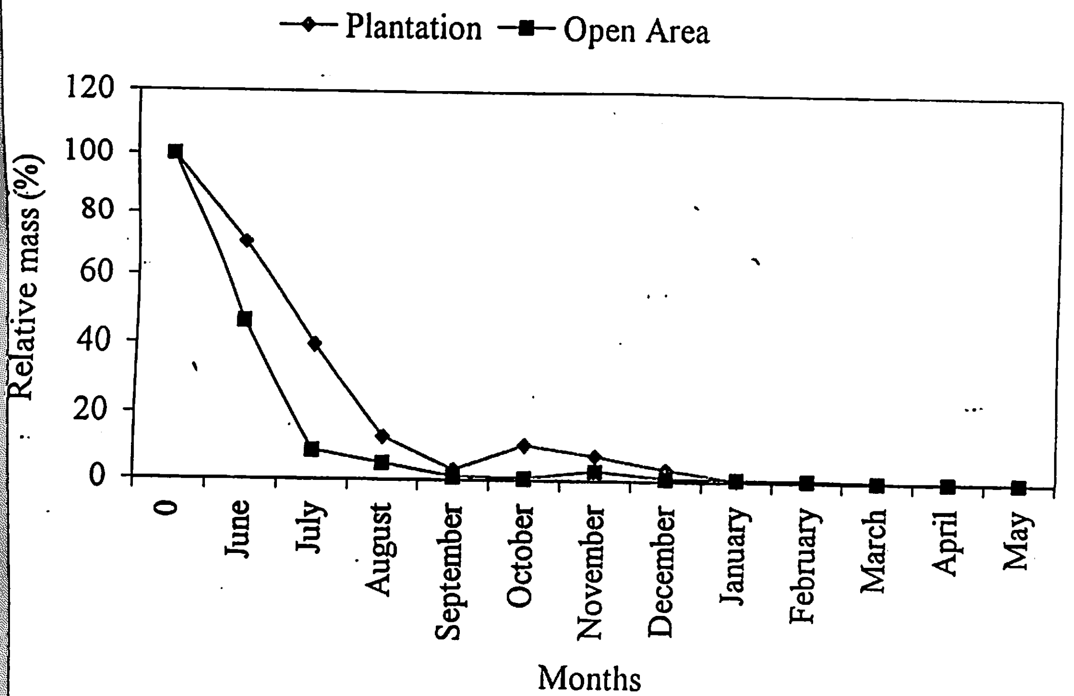


Fig. 19. Monthly variation in rate of decomposition of leaf litter of *Acacia mangium* under two study situations

Table 13. Total carbon, nitrogen content and C:N ratio of decomposing leaf litter at various sampling intervals

Species	Initial						1st month						5th month						9th month					
	Plantation			Open area			Plantation			Open area			Plantation			Open area			Plantation			Open area		
	C	N	C:N	C	N	C:N	C	N	C:N	C	N	C:N	C	N	C:N	C	N	C:N	C	N	C:N	C	N	C:N
A. mangium	92.9	2.53	36.71	92.9	2.53	36.71	84.23	2.51	33.56	81.25	2.49	32.63	74.52	2.24	33.27	75.54	2.1	35.97	41.82	1.59	26.30	43.62	1.68	25.96
A. aulacocarpa	90.34	2.32	38.93	90.34	2.32	38.93	82.31	2.4	34.29	81.0	2.37	34.18	75.31	2.21	34.08	73.41	2.2	33.36	40.82	1.48	27.58	42.26	1.31	32.25
A. crassicarpa	91.92	2.1	43.43	91.92	2.1	43.43	93.41	2.00	41.71	84.34	1.80	46.85	78.21	1.9	41.16	74.14	1.86	39.86	42.28	1.51	28.00	41.24	1.40	29.46

and the trend is depicted in Fig. 20. The initial nitrogen content of litter kept inside the plantation and open area was found to be maximum for *A. mangium* (2.53%) followed by *A. aulacocarpa* (2.32%) and *A. crassicarpa* (2.1%). In the case of litter placed inside the plantation, initial N content of different species declined gradually during different sampling intervals and at the end of 9th month, the initial nitrogen content was found to be minimum for *A. aulacocarpa* (1.48%) followed by *A. crassicarpa* (1.51%) and *A. mangium* (1.59%). N content of the residues retrieved from the open area also exhibited a declining trend at the end of 9th month and showed difference among the species with a minimum concentration of 1.31 per cent for *A. aulacocarpa* followed by *A. crassicarpa* (1.4%) and *A. mangium* (1.68%). The C:N ratio of litter of different species kept in the open area and plantation exhibited a declining trend during the various sampling intervals and reached a lowest value of 26.30 for *A. mangium* followed by *A. aulacocarpa* (27.58) and *A. crassicarpa* (28.0) for litter kept inside the plantation. In the open area also C:N ratio was lowest for *A. mangium* 25.96 followed by *A. crassicarpa* (29.46) and *A. aulacocarpa* (32.25).

4.2.4.1.2 Lignin content and lignin:nitrogen ratio

The result of the chemical analysis for lignin content and lignin:nitrogen ratio of all the species in two study situations with regard to various sampling intervals are presented in Table 14 and the trend is depicted in Fig. 21. *Acacia crassicarpa* registered a very high lignin content in initial samples (24.73%) followed by *A. aulacocarpa* (23.17%) and *A. mangium* (22.91%). All the three species exhibited difference in lignin content between them and between the study situations during the various sampling intervals. In the case of litter placed inside the plantation, lignin content of different species exhibited an increasing trend during different sampling periods and at the end of ninth month it was found to be maximum for *A. crassicarpa* (47.38%) followed by *A. aulacocarpa* (46.31%) and *A. mangium* (45.5%). Lignin content of the residues retrieved from the open area also registered an increasing trend and at the end of ninth month as it was maximum for *A. mangium* (46.5%) followed by *A. crassicarpa* (46.37%) and *A. aulacocarpa* (46.0%). The L:N ratio of litter of different species kept in the open area and plantation exhibited an increasing trend

Table 14. Changes in lignin content and lignin : nitrogen ratio of residues sampled at monthly intervals

Species	Initial						1st month						5th month						9th month					
	Plantation			Open area			Plantation			Open area			Plantation			Open area			Plantation			Open area		
	L	N	L:N	L	N	L:N	L	N	L:N	L	N	L:N	L	N	L:N	L	N	L:N	L	N	L:N	L	N	L:N
A. mangium	22.91	2.53	9.05	22.91	2.53	9.05	29.57	2.51	11.78	28.22	2.49	11.33	43.75	2.24	19.53	42.51	2.1	20.27	45.5	1.59	28.62	46.50	1.68	27.68
A. aulacocarpa	23.17	2.32	9.98	23.17	2.32	9.98	28.72	2.4	12.50	28.12	2.37	11.86	44.52	2.21	20.11	43.16	2.2	19.64	46.31	1.48	31.28	46.00	1.31	35.10
A. crassicarpa	24.73	2.1	11.77	24.73	2.1	11.77	29.21	2.00	14.62	29.10	1.80	16.19	44.89	1.9	23.66	43.86	1.86	23.57	47.38	1.51	31.37	46.37	1.40	33.23

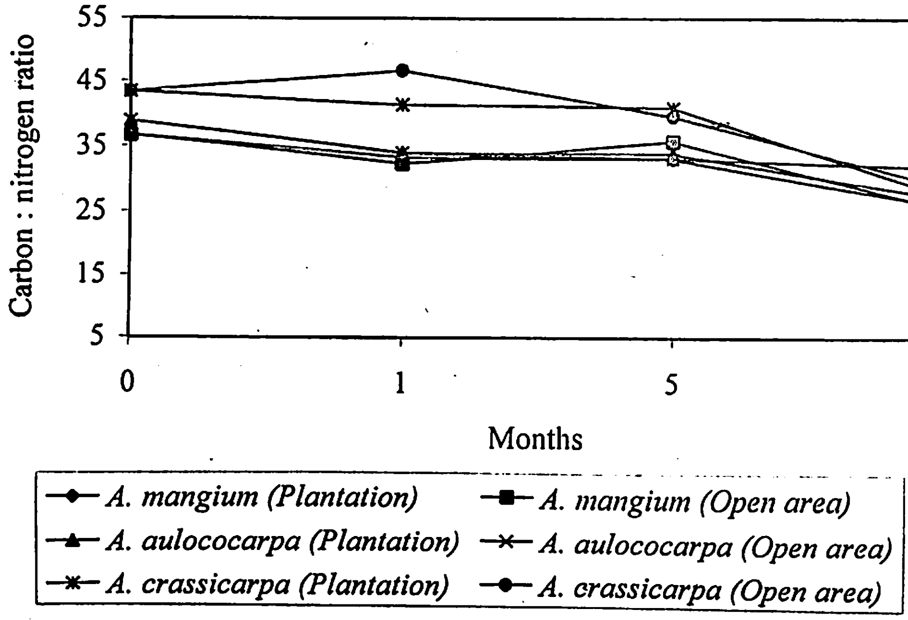


Fig. 20. Changes in carbon:nitrogen ratio in the decaying litter mass

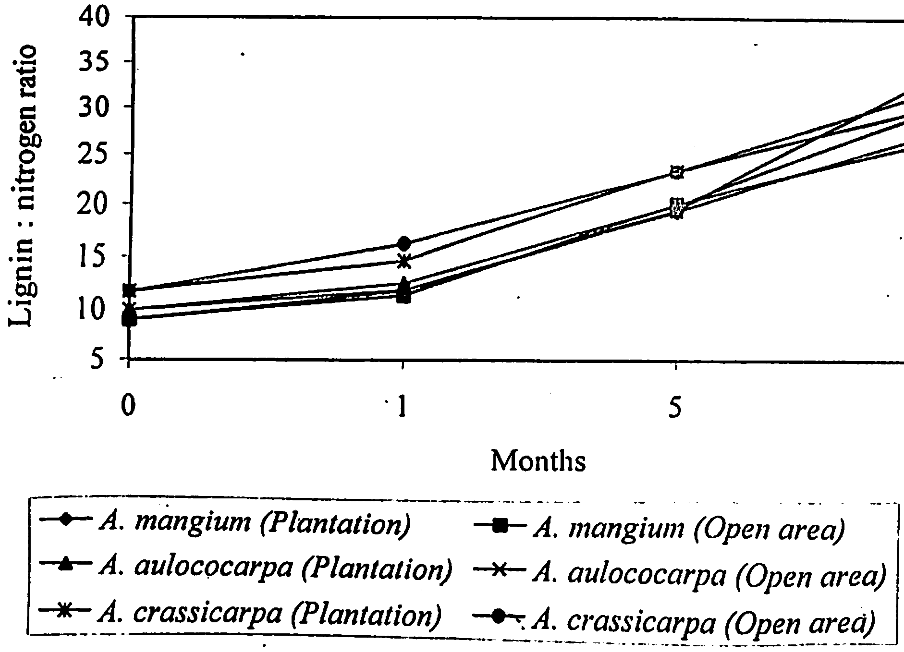


Fig. 21. Changes in lignin:nitrogen ratio in the decaying litter mass

during the various sampling intervals and reached a peak value of 31.37 for *A. crassicarpa* followed by *A. aulacocarpa* (31.28) and *A. mangium* (28.62) in the plantation. In the open area L:N ratio was found to maximum for *A. aulacocarpa* (35.1) followed by *A. crassicarpa* (33.23) and *A. mangium* (27.68).

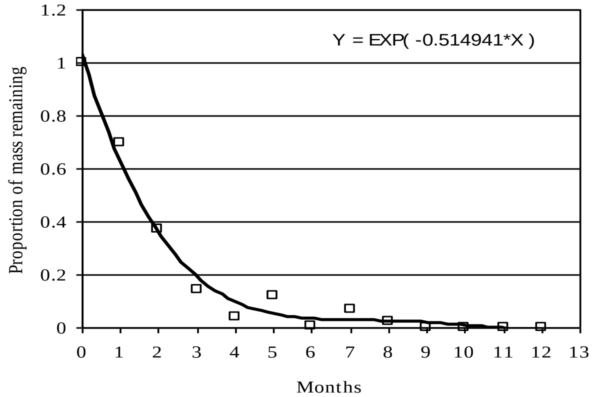
4.2.4.2 Effect of weather parameters on the rates of decomposition

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 statistically feeble.

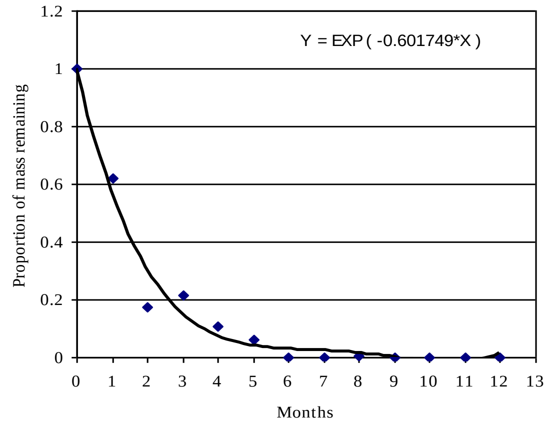
4.2.5 Decay rate coefficients

The statistically analysed data for the decay rate coefficient (k) for different species in two study situations are furnished in Appendix II. The decay coefficient was high for *Acacia aulacocarpa* in open area (0.601749) and lowest for *Acacia mangium* in open area (0.385362). Inside the plantation the decay coefficient was high (0.514941) for *A. aulacocarpa* and lowest for *A. crassicarpa*. To determine the pattern of decomposition over a period of time during various situations for different species, regression equations were fitted by relating the proportion of mass remaining in the litter bags with the time elapsed (Fig. 22). The exponential equation $X/X^0 = e^{-kt}$ was fitted for the three species in two study situations.

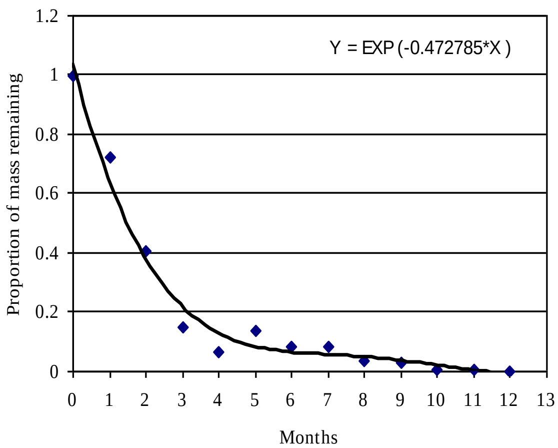
The data furnished in Appendix II also provide the predicted half life (time taken to decompose fifty per cent of the initial mass) values for various species in open area and plantations. Inside the plantation the half life values were maximum for *A. crassicarpa* (1.47 months) and half life values of *A. mangium* and *A. aulacocarpa* were found to be the same (1.35 months). In the open area half life values were maximum for *A. crassicarpa* (1.43 months) followed by *A. mangium* (1.18 months) and *A. aulacocarpa* (1.15 months).



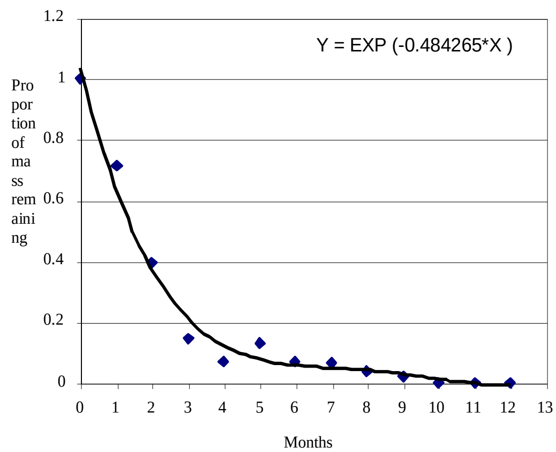
Leaf litter decay model for *Acacia aulococarpa* in plantation



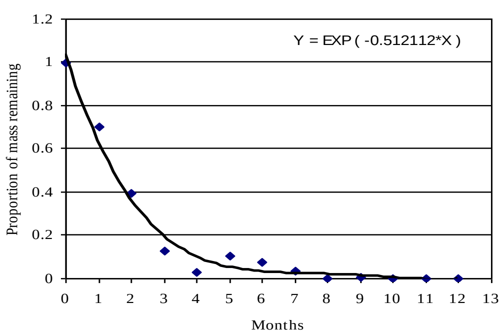
Leaf litter decay model for *Acacia aulococarpa* in open area



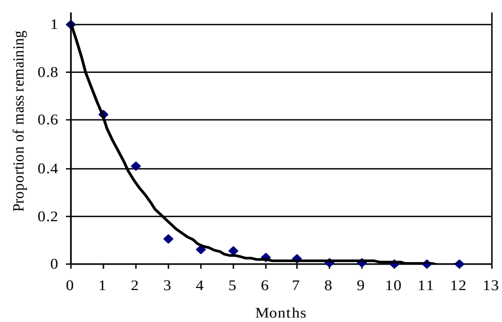
Leaf litter decay model for *Acacia crassicarpa* in plantation



Leaf litter decay model for *Acacia crassicarpa* in open area



Leaf litter decay model for *Acacia mangium* in plantation



Leaf litter decay model for *Acacia mangium* in open area

Fig.22. Decay models of litter mass of the three spesies of acacia in different study situations

4.2.6 Nutrient release pattern

The observations on the nutrient concentrations in the initial and residual litter mass retrieved at monthly intervals under various study situations for different species are tabulated in Tables 15 to 17 and illustrated in Fig. 23 to 28.

4.2.6.1 Nitrogen

The content of nitrogen present in leaf litter of different species and the two study situations (Fig. 23 and 26) were found to be different. Nitrogen concentration in the initial samples was maximum for *A. mangium* (2.53%) followed by *A. aulacocarpa* (2.32%) and *A. crassicarpa* (2.1%). The litter retrieved from the plantations registered a decline in concentration for *A. mangium* and *A. crassicarpa* but *A. aulacocarpa* showed a slight increase from fourth month to sixth month.

A similar trend was also observed for the residues collected from open area. From second month onwards a gradual decline in N concentration was noticed for all the three species in two study situations. However, in the fifth month all the species in two study situations registered an increase in nitrogen content and then declined. At the end of ninth month *A. crassicarpa* leaf litter inside the plantation and *A. mangium* in the open area exhibited an increase in N concentration. After ninth month, N content of *A. crassicarpa* leaf litter declined gradually till the end of the study.

4.2.6.2 Phosphorus

Acacia crassicarpa leaf litter recorded the maximum content of initial P (0.059%) followed by *A. mangium* (0.058%) and *A. aulacocarpa* (0.052%). The residual mass obtained from the three species under two study situations exhibited a gradual decline in the concentration of P, up to the fourth month (Fig. 24 and 27). The P content in the residues of *A. aulacocarpa* from open area showed a slight increase during the fifth month of sampling (0.03%). In *Acacia mangium* inside the plantation the concentration increased to (0.031%) in the sixth month and then reached 0.01 per

Table 15. Monthly variation in the nutrient content of the residual mass (g) of *Acacia mangium* at different study situations

Time (Month)	Plantation				Open area			
	Residual mass	N	P	K	Residual mass	N	P	K
0	18.76	2.53	0.058	0.79	18.76	2.53	0.058	0.79
1	13.18	2.51	0.042	0.68	6.70	2.49	0.048	0.51
2	7.43	2.34	0.038	0.54	1.63	2.31	0.042	0.10
3	2.44	2.30	0.029	0.10	0.93	2.12	0.29	0.10
4	0.57	2.21	0.027	0.10	0.16	2.00	0.027	0.07
5	1.98	2.24	0.021	0.08	0.08	2.10	0.021	0.07
6	1.38	2.21	0.031	0.07	0.51	1.90	0.008	0.08
7	0.62	2.10	0.008	0.08	0.14	1.81	0.010	0.07
8	0.03	1.60	0.010	0.07	0.12	1.61	0.010	0.06
9	0.06	1.59	0.010	0.07	0.08	1.68	0.010	0.05
10	NM	NA	NA	NA	NM	NA	NA	NA
11	NM	NA	NA	NA	NM	NA	NA	NA
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 16. Monthly variation in the nutrient content of the residual mass (g) of *Acacia aulacocarpa* at different study situations

Time (Month)	Plantation				Open area			
	Residual mass	N	P	K	Residual mass	N	P	K
0	17.83	2.32	0.052	0.74	17.83	2.32	0.052	0.74
1	12.50	2.40	0.048	0.51	11.17	2.37	0.042	0.50
2	6.08	2.34	0.039	0.30	3.15	2.24	0.033	0.10
3	2.51	2.30	0.026	0.10	3.87	2.20	0.020	0.08
4	0.74	2.20	0.025	0.07	1.96	2.18	0.010	0.07
5	2.15	2.21	0.021	0.08	1.13	2.21	0.030	0.08
6	0.10	2.00	0.008	0.06	1.10	1.70	0.020	0.07
7	1.36	1.70	0.008	0.06	0.02	1.62	0.012	0.07
8	0.41	1.50	0.012	0.07	0.14	1.50	0.012	0.07
9	0.02	1.48	0.012	0.06	0.12	1.31	0.010	0.07
10	NM	NA	NA	NA	NM	NA	NA	NA
11	NM	NA	NA	NA	NM	NA	NA	NA
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 17. Monthly variation in the nutrient content of the residual mass (g) of *Acacia crassicarpa* at different study situations

Time (Month)	Plantation				Open area			
	Residual mass	N	P	K	Residual mass	N	P	K
0	17.20	2.10	0.059	0.67	17.20	2.10	0.059	0.67
1	12.50	2.00	0.047	0.27	12.29	1.80	0.042	0.65
2	6.97	1.89	0.030	0.18	6.75	1.86	0.040	0.030
3	2.59	1.85	0.020	0.09	2.50	1.85	0.034	0.10
4	1.08	1.80	0.010	0.08	1.22	1.81	0.032	0.09
5	2.33	1.90	0.012	0.07	2.22	1.86	0.030	0.08
6	1.42	1.71	0.012	0.06	1.22	1.71	0.025	0.08
7	1.39	1.62	0.010	0.05	1.10	1.60	0.010	0.07
8	0.67	1.49	0.010	0.05	0.68	1.45	0.010	0.07
9	0.47	1.51	0.010	0.05	0.33	1.40	0.010	0.07
10	0.10	1.43	0.010	0.05	0.04	1.31	0.010	0.07
11	0.06	1.23	0.010	0.05	0.02	1.25	0.010	0.07
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

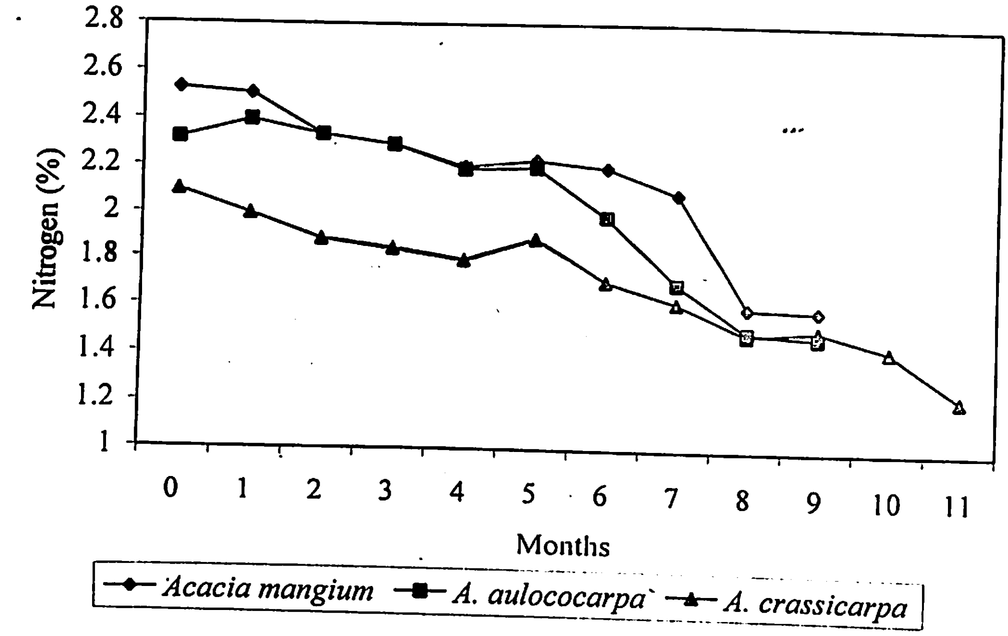


Fig. 23. Changes in the nitrogen concentration of leaf litter inside the plantation

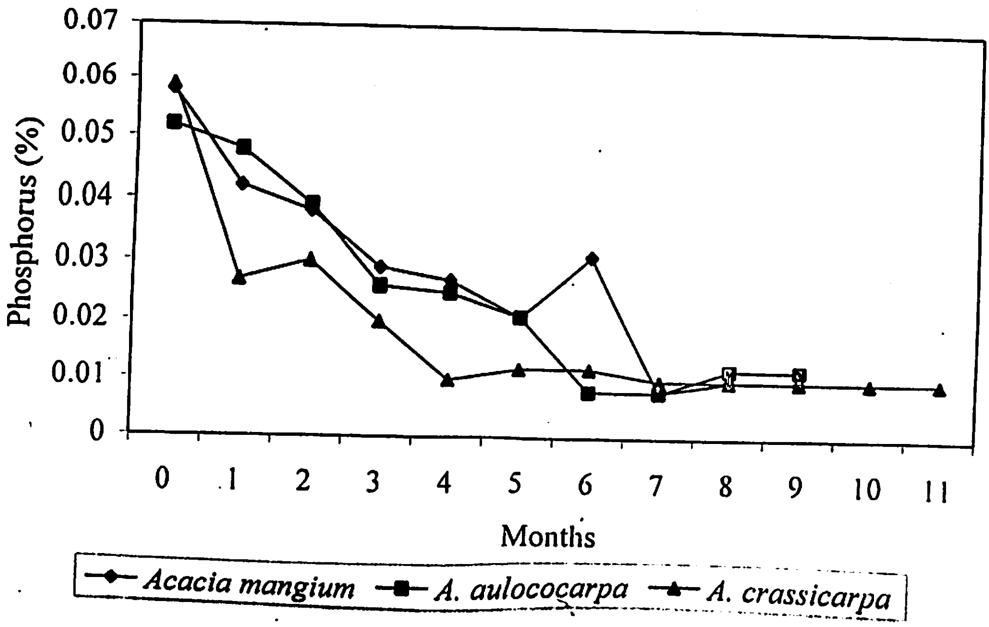


Fig. 24. Changes in the phosphorus concentration of leaf litter inside the plantation

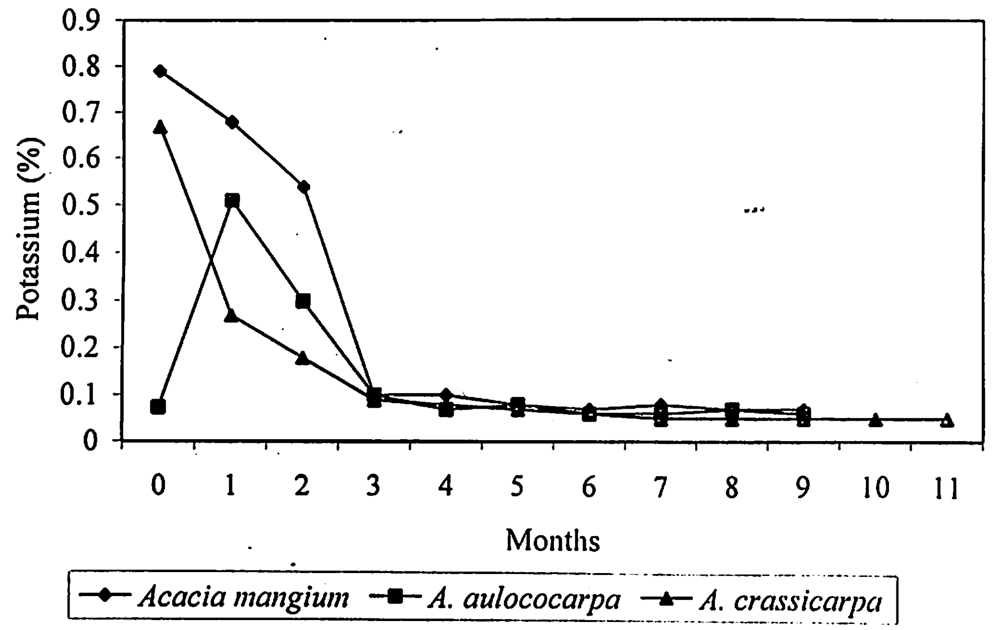


Fig. 25. Changes in the potassium concentration of leaf litter inside the plantation

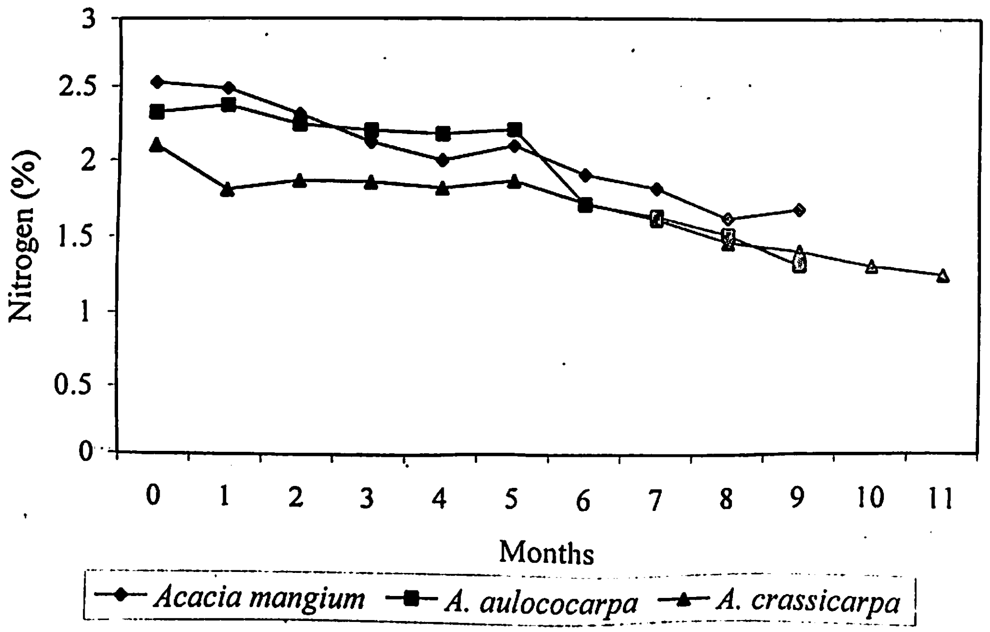


Fig. 26. Changes in the nitrogen concentration of leaf litter in open area

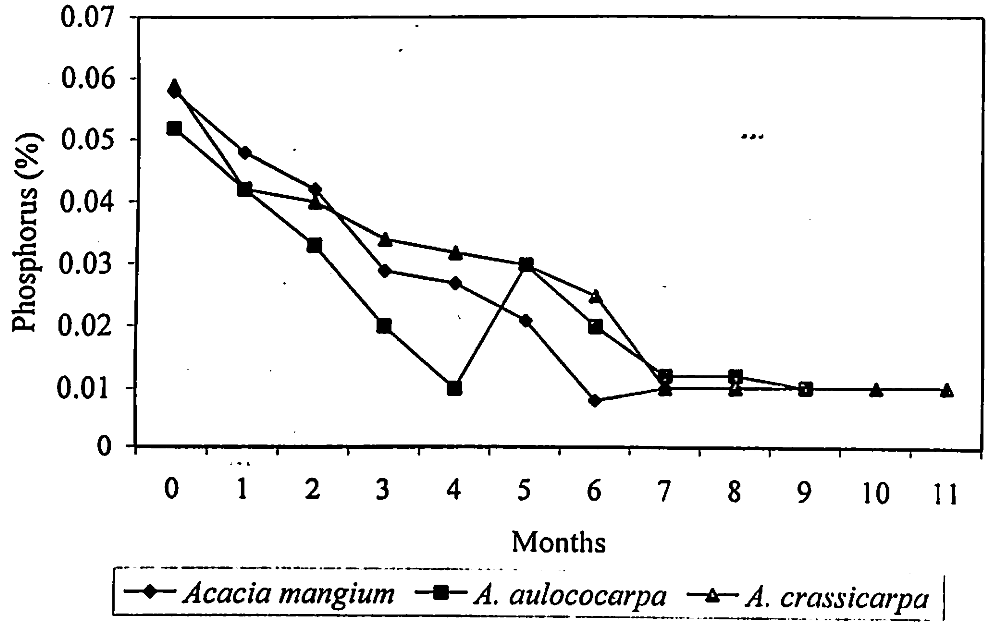


Fig. 27. Changes in the phosphorus concentration of leaf litter in open area

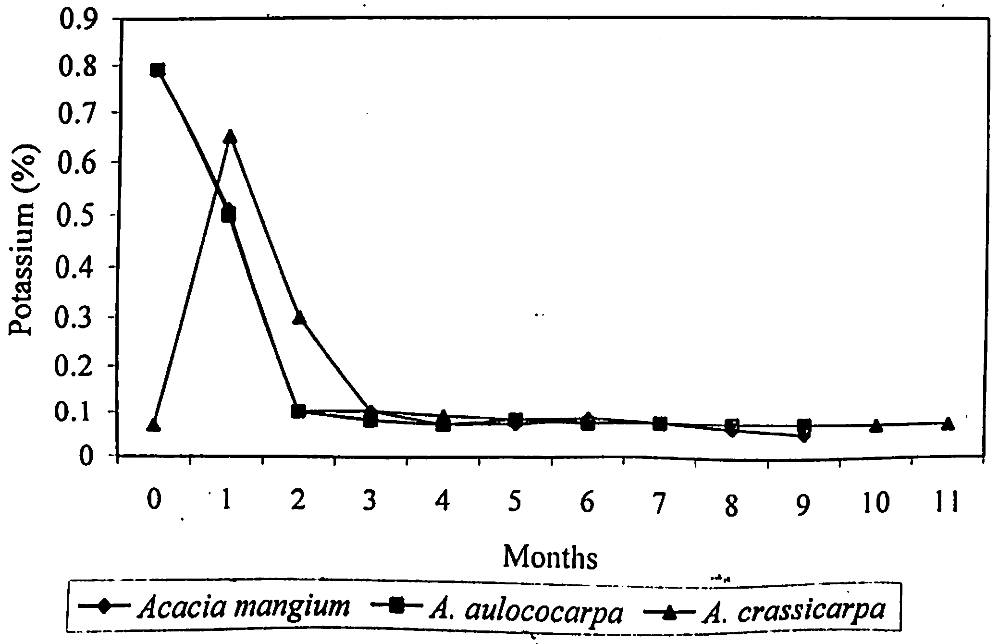


Fig. 28. Changes in the potassium concentration of leaf litter in open area

cent at the end of the study whereas in open area a decrease of 0.008 per cent was registered in the sixth month and after that the concentration of P remain unchanged till the end of the study (0.01%).

The residues of litter mass of *A. aulacocarpa* in the open area registered a decline in P content upto fourth month. After showing an increasing trend it declined and recorded a value of 0.01 per cent at the end while in the plantation it reached a value of 0.012 per cent at the end of the study. In the case of *A. crassicarpa*, litter retrieved from both open area and plantation exhibited similar values of P content from eighth month onwards and remained unchanged till eleventh month (0.01%).

4.2.6.3 Potassium

Initial K concentration was found to be maximum for *A. mangium* (0.79%) followed by *A. aulacocarpa* (0.74%) and *A. crassicarpa* (0.67%) (Fig. 25 and 28). In the case of *A. mangium*, potassium content of the residues sampled at various months obtained from both the study situations exhibited a gradual decline with slight fluctuations in between and it reached a lowest value of 0.68 per cent inside the plantation and 0.05 per cent in the open area.

Potassium content in the residues of *A. crassicarpa* from different study situations declined gradually from first month onwards and from seventh month it remained unchanged (0.05% in the plantation and 0.07% in the open area). In the case of *A. aulacocarpa* a gradual decline in K content was observed up to fourth month, in the two study situations. Inside the plantation during fifth and eighth months, slight increase in concentration of K was observed whereas in the open area slight increase in concentration was registered in the fifth month only after that it remains unchanged (0.07%).

4.2.7 Relative changes in the nutrient concentration

The relative changes in nutrient content of leaf litter of various species under different study situations are presented in Tables 18 to 20 and illustrated in Fig. 29 to 34.

4.2.7.1 Nitrogen

The relative concentration of nitrogen in the decomposing litter of *A. aulacocarpa* under both the study situations showed a slight increase over its initial value in the first month of sampling (103.45% in the plantation and 102.16% in the open area). In the subsequent months the relative concentration decreased gradually up to fourth month (Fig. 29 and 32). During the fifth month, the relative content of N in the residues from open area and plantation showed an increase in the value (95.26%) and then declined.

The litter residues of *A. mangium* showed a gradual decrease in their relative N concentration till the end of fourth month. In the fifth month, the residues from open area and plantation registered an increase in the relative content of N (88.54% in plantation and 83.0% in open area). In the subsequent months, relative N content declined gradually in the plantation and reached a lowest value of 62.85 per cent whereas in the open area it reached a value of 63.64 per cent at the end of eighth month and then increased to 66.4 per cent.

In the case of *A. crassicarpa,* relative N content declined gradually in two study situations and increased at the end of fifth month registering a value of 90.48 per cent in the plantation and 88.57 per cent in the open area. After the sixth month relative N content get decreased and reached a lowest value of 59.52 per cent for residues kept inside the open area. Whereas residues retrieved from the plantation exhibited an increase in relative N content (71.9%) during nineth month and then declined to a lowest value of 58.37 per cent.

4.2.7.2 Phosphorus

The relative changes of phosphorus in the residual mass of *A. aulacocarpa* from the plantation exhibited a declining trend. The relative P content registered a value of 15.38 per cent for sixth and seventh month (Fig. 30 and 33). At the end of eighth month the value increased to 23.08 per cent and remained the same for nineth month. In the case of litter collected from open area; relative P content experienced a

Table 18. Relative changes in the nutrient content of the residual mass (g) of *Acacia mangium* retrieved from different study situations at monthly intervals

Time (Month)	Plantation				Open area			
	Residual mass	N	P	K	Residual mass	N	P	K
0	18.76	100.00	100.00	100.00	18.76	100.00	100.00	100.00
1	13.18	99.21	72.41	86.07	8.70	98.42	82.76	64.56
2	7.43	92.49	65.51	68.35	1.63	91.30	72.41	12.66
3	2.44	90.90	50.00	12.66	0.93	83.79	50.60	12.66
4	0.57	87.35	46.55	12.66	0.16	79.05	46.55	8.86
5	1.98	88.54	36.21	10.13	0.08	83.00	36.21	8.86
6	1.38	87.35	53.45	8.86	0.51	75.09	13.79	10.13
7	0.62	83.00	13.79	10.13	0.14	71.54	17.24	8.86
8	0.03	63.24	17.24	8.86	0.12	63.64	17.24	7.59
9	0.06	62.85	17.24	8.86	0.08	66.40	17.24	6.33
10	NM	NA	NA	NA	NM	NA	NA	NA
11	NM	NA	NA	NA	NM	NA	NA	NA
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 19. Relative changes in the nutrient content of the residual mass (g) of *Acacia crassicarpa* retrieved from different study situations at monthly intervals

Time (Month)	Plantation				Open area			
	Residual mass	N	P	K	Residual mass	N	P	K
0	17.20	100.00	100.00	100.00	17.20	100.00	100.00	100.00
1	12.50	95.23	79.66	40.29	12.29	85.71	71.19	97.01
2	6.97	90.00	50.85	26.87	6.75	88.57	67.79	44.78
3	2.59	88.09	33.89	13.43	2.50	88.09	57.63	14.93
4	1.08	85.71	16.95	11.94	1.22	86.19	54.24	13.43
5	2.33	90.48	20.33	10.45	2.22	88.57	50.85	11.94
6	1.42	81.43	20.33	8.96	1.22	8.143	42.37	12.54
7	1.39	77.14	16.95	6.46	1.10	76.19	16.95	10.45
8	0.67	70.95	16.96	7.46	0.68	69.05	16.95	10.45
9	0.47	71.90	16.95	7.46	0.33	66.67	16.95	10.45
10	0.10	68.09	16.95	7.46	0.04	62.38	16.95	10.45
11	0.06	58.57	16.95	7.46	0.02	59.52	16.95	10.45
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 20. Relative changes in the nutrient content of the residual mass (g) of *Acacia aulacocarpa* retrieved from different study situations at monthly intervals

Time (Month)	Plantation				Open area			
	Residual mass	N	P	K	Residual mass	N	P	K
0	17.83	100.00	100.00	100.00	17.83	100.00	100.00	100.00
1	12.50	103.45	92.30	68.92	11.17	102.16	80.77	67.57
2	6.68	100.86	75.00	40.54	3.15	96.55	63.46	13.51
3	2.51	99.14	50.00	13.51	3.87	94.83	38.46	10.81
4	0.74	94.83	48.08	9.46	1.96	93.97	19.23	9.46
5	2.15	95.26	40.38	10.81	1.13	95.26	57.69	10.81
6	0.10	86.21	15.38	8.10	1.10	73.28	38.46	9.46
7	1.36	73.28	15.38	8.10	0.02	69.83	23.07	9.46
8	0.41	64.66	23.08	9.46	0.14	64.66	23.07	9.46
9	0.02	63.79	23.08	8.10	0.12	56.47	19.23	9.46
10	NM	NA	NA	NA	NM	NA	NA	NA
11	NM	NA	NA	NA	NM	NA	NA	NA
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

decrease in the first four months. In the fifth month, P increased to 57.69 per cent and then declined.

In the case of *A. crassicarpa*, relative P content in the open area as well as plantation decreased till sixth month with slight fluctuations in between. From seventh month onwards, till the end of the study, relative P content retrieved from plantation and open area remained the same (16.95%).

Relative P content of *A. mangium* litter collected from plantation showed a decrease till the end of fifth month. Sixth month registered an increase in relative P content (53.45%) and then decreased. During the last two months, the value was found to be the same (17.24%). In the case of litter obtained from open area, relative P content decreased for first sixth months and then registered a value of (17.24%) till the end of the study.

4.2.7.3 Potassium

The relative content of K in the litter residues of *A. aulacocarpa* obtained from plantation exhibited a decreasing trend with slight fluctuations in between. The lowest value obtained during the end of study was 8.1 per cent. In the open area relative K content decreased till fourth month then showed a slight increase and then declined (Fig.31 and 34). From sixth month till the end of the study a constant value of 9.46 per cent was observed.

In *A. crassicarpa* the relative concentration K for the litter obtained from plantation showed an initial decrease over the first sixth months. Last five months of the study exhibited a same value of 7.46 per cent. In case of litter retrieved from the open area exhibited a similar trend except with an increase in concentration during sixth month (12.54%). A constant value of 10.45 per cent was observed during the last six months of the study period.

The relative content of potassium reduced gradually in the litter residues of *A. mangium* retrieved from the plantation during first two months. Third and fourth

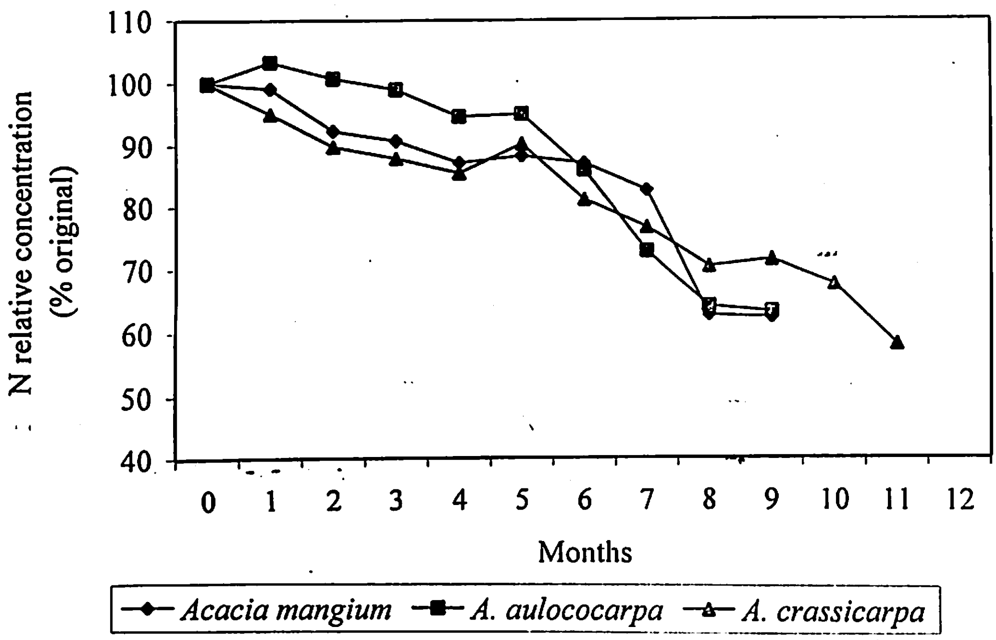


Fig. 29. Relative changes in the nitrogen concentration of leaf litter inside the plantation

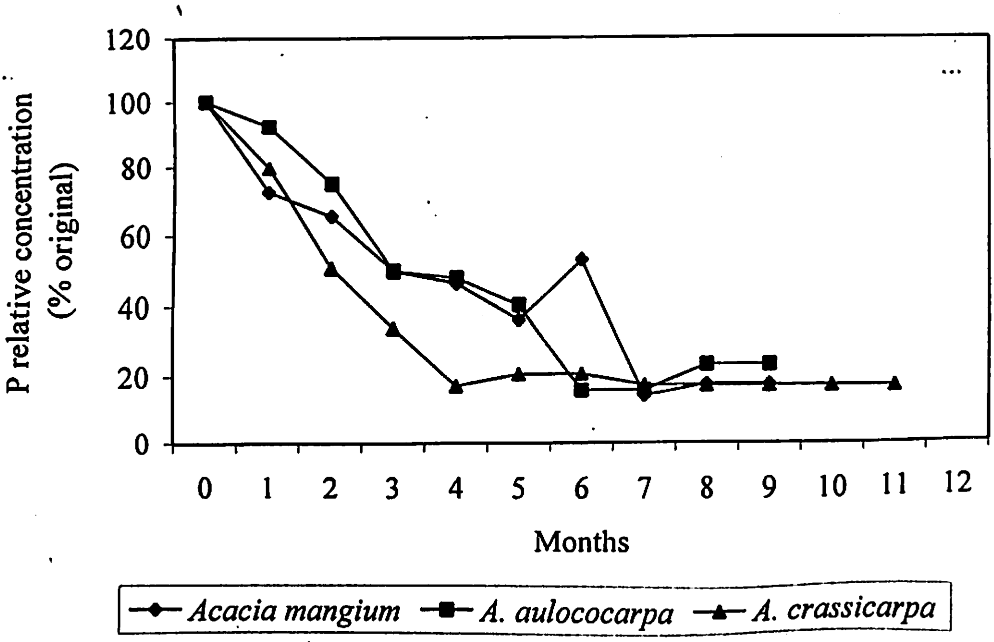


Fig. 30. Relative changes in the phosphorus concentration of leaf litter inside the plantation

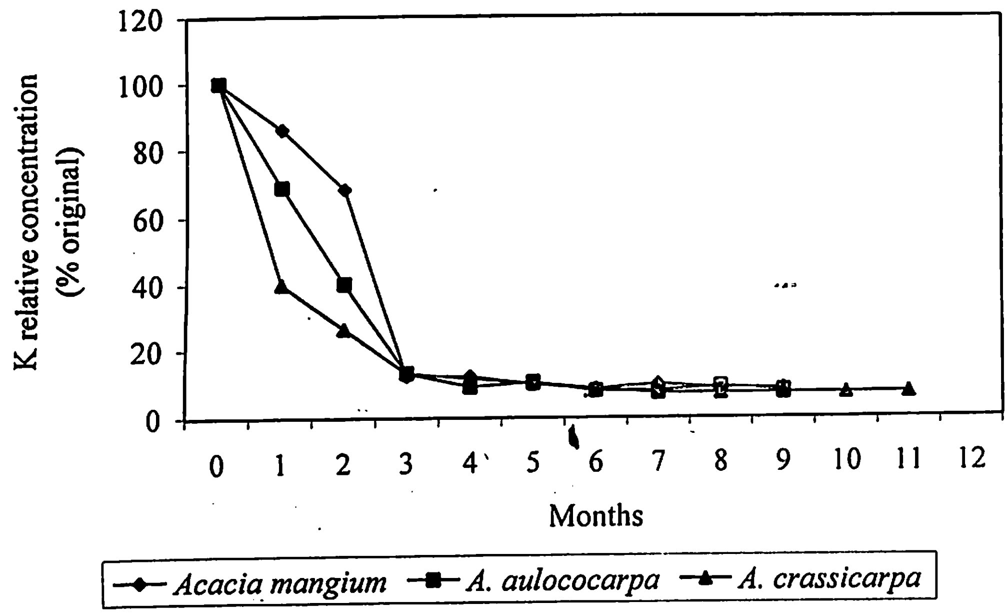


Fig. 31. Relative changes in the potassium concentration of leaf litter inside the plantation

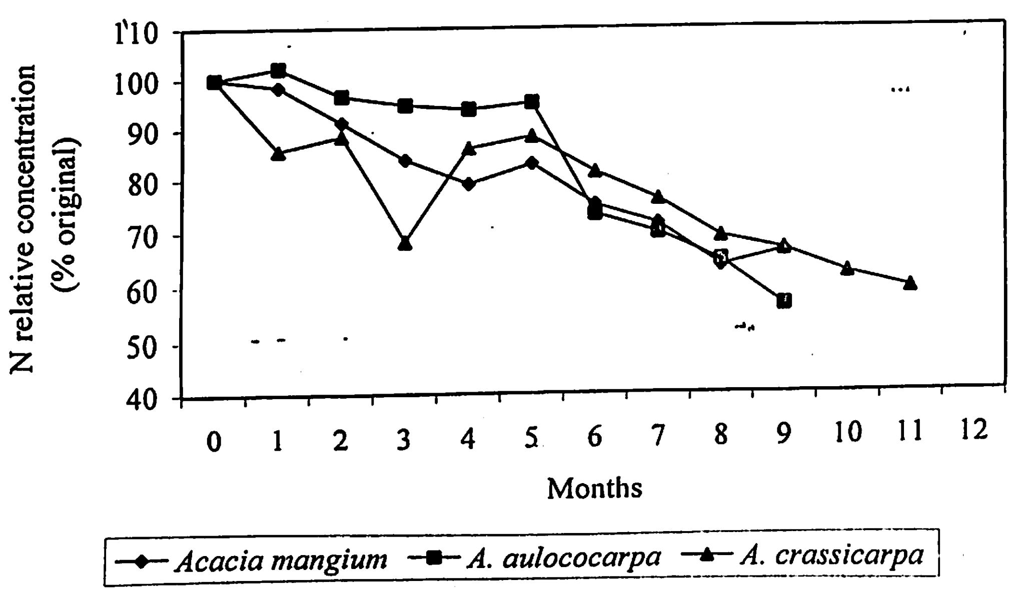


Fig. 32. Relative changes in the nitrogen concentration of leaf litter in open area

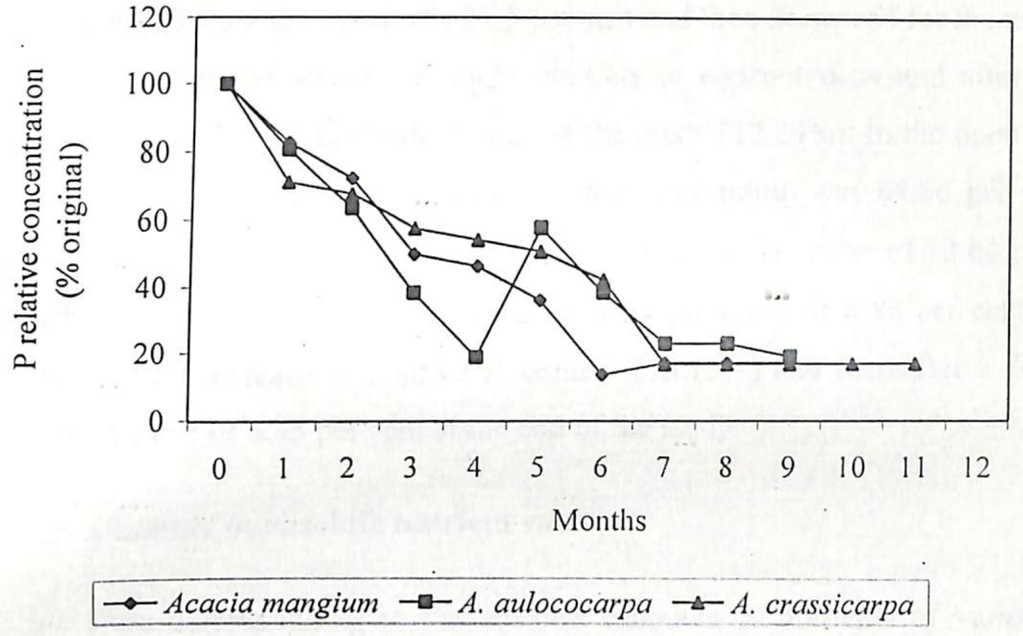


Fig. 33. Relative changes in the phosphorus concentration of leaf litter in open area

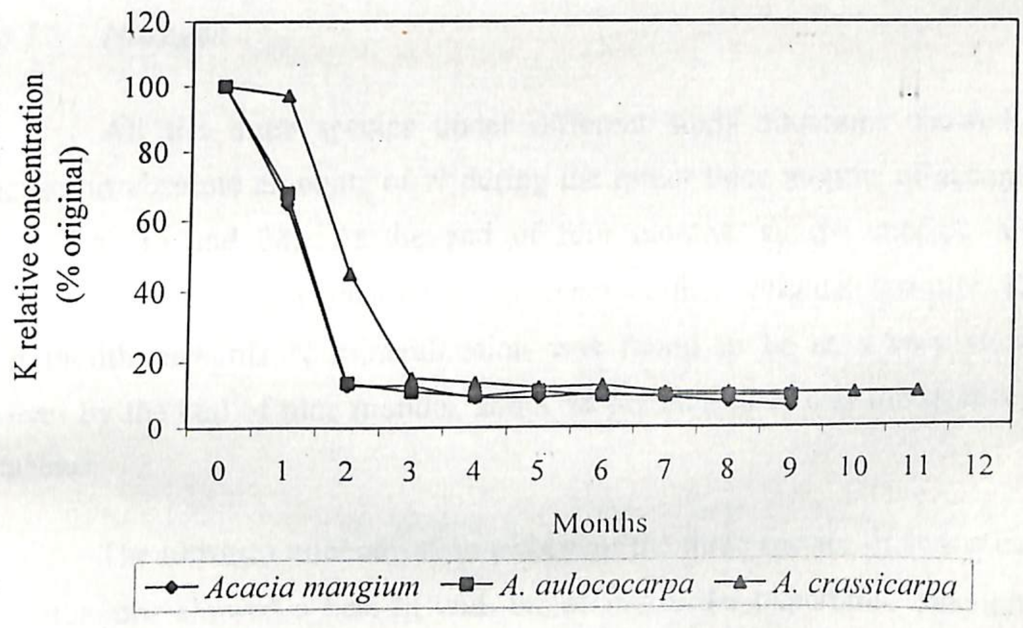


Fig. 34. Relative changes in the potassium concentration of leaf litter in open area

months registered a similar value of 12.66 per cent and then decreased for the next two months. Seventh month showed a slight increase in concentration and after that it remained the same for the last two months of the study (17.24%). In the open area at the end of first month the relative decrease in concentration was 64.56 per cent of initial K content. Second and third months exhibited a similar value of 12.66 per cent and fourth and fifth months also registered a constant value of 8.86 per cent. Sixth month showed an increase in relative K content (10.13%) and thereafter a decrease with a lowest value of 6.33 per cent at the end of the study.

4.2.8 Changes in absolute nutrient contents

Data corresponding to the absolute amounts of nutrients of various tree species under different study situations are presented in Tables 21 to 23 and illustrated in Fig. 35 to 40. The mathematical models relating the absolute amounts of different nutrients and time elapsed are furnished in Appendix III.

4.2.8.1 Nitrogen

All the three species under different study situations showed a rapid reduction in absolute amounts of N during the initial three months of decomposition period (Fig. 35 and 38). At the end of four months, all the species, inside the plantation and open area released 90 per cent of their original quantity. From the fourth month onwards N mineralization was found to be at a very slower rate. However by the end of nine months, about 98 per cent of N was minieralized for all the species.

The nitrogen mineralisation pattern of the three species of acacia under two study situations showed a best fit with the second order hyperbolic function with r^2 value of more than 0.980.

4.2.8.2 Phosphorus

Though P concentration showed no appreciable change in decomposing leaf material over time. Their absolute amounts were found to follow an initial rapid

Table 21. Monthly variation in the absolute amounts of nutrients in the leaf litter of *Acacia mangium* at different study situations

Time (Month)	Absolute amounts of nutrient (%)							
	Plantation				Open area			
	Residual mass (g)	N	P	K	Residual mass (g)	N	P	K
0	18.76	100.00	100.00	100.00	18.76	100.00	100.00	100.00
1	13.18	69.70	50.87	60.47	8.70	45.64	38.38	29.93
2	7.43	36.63	25.95	27.00	1.63	7.93	6.29	1.09
3	3.44	11.82	6.50	1.65	0.93	4.20	2.48	0.63
4	0.57	2.65	1.41	0.38	0.16	0.67	0.40	0.08
5	1.98	9.34	3.82	1.07	0.08	0.35	0.15	0.03
6	1.38	6.43	3.93	0.65	0.51	2.04	0.37	0.26
7	0.62	2.74	4.56	0.33	0.14	0.53	0.12	0.07
8	0.03	0.10	0.03	0.01	0.12	0.40	0.11	0.05
9	0.06	0.20	0.05	0.02	0.08	0.23	0.07	0.02
10	NM	NA	NA	NA	NM	NA	NA	NA
11	NM	NA	NA	NA	NM	NA	NA	NA
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 22. Monthly variation in the absolute amounts of nutrients in the leaf litter of *Acacia crassicarpa* at different study situations

Time (Month)	Absolute amounts of nutrient (%)							
	Plantation				Open area			
	Residual mass (g)	N	P	K	Residual mass (g)	N	P	K
0	17.20	100.00	100.00	100.00	17.20	100.00	100.00	100.00
1	12.50	69.21	57.89	29.29	12.29	61.25	50.87	69.32
2	6.97	36.47	20.60	10.89	6.75	34.76	26.60	17.57
3	2.59	13.27	5.10	2.02	2.50	12.80	8.38	2.17
4	1.08	5.36	1.06	0.75	1.22	6.11	3.73	0.95
5	2.33	12.26	2.76	1.42	2.22	11.43	6.56	1.54
6	1.42	6.72	1.68	0.74	1.22	5.78	3.00	0.89
7	1.39	6.23	1.36	0.60	1.10	4.87	1.08	0.67
8	0.67	2.76	0.66	0.29	0.68	2.73	0.67	0.41
9	0.47	1.96	0.46	0.20	0.33	1.28	0.33	0.20
10	0.10	0.39	0.09	0.04	0.04	0.15	0.03	0.02
11	0.06	0.20	0.06	0.03	0.02	0.07	0.02	0.01
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

Table 23. Monthly variation in the absolute amounts of nutrients in the leaf litter of *Acacia aulacocarpa* at different study situations

Time (Month)	Absolute amounts of nutrient (%)							
	Plantation				Open area			
	Residual mass (g)	N	P	K	Residual mass (g)	N	P	K
0	17.83	100.00	100.00	100.00	17.83	100.00	100.00	100.00
1	12.50	75.18	64.71	48.32	11.17	63.99	50.59	42.33
2	6.68	37.79	28.09	15.19	3.15	17.06	11.21	2.39
3	2.51	13.96	7.03	1.90	3.87	20.58	8.35	2.35
4	0.74	3.94	1.99	0.39	1.96	10.33	2.11	1.04
5	2.15	11.49	4.87	1.30	1.13	6.04	3.66	0.69
6	0.10	0.48	0.09	0.04	1.10	4.52	2.37	0.58
7	1.36	5.59	1.17	0.62	0.02	0.08	0.03	0.01
8	0.41	1.49	0.53	0.22	0.14	0.50	0.18	0.07
9	0.02	0.7	0.03	0.009	0.12	0.38	0.13	0.06
10	NM	NA	NA	NA	NM	NA	NA	NA
11	NM	NA	NA	NA	NM	NA	NA	NA
12	NM	NA	NA	NA	NM	NA	NA	NA

NM - No residual mass available
NA - Decomposition was almost completed - sample was not sufficient for analysis

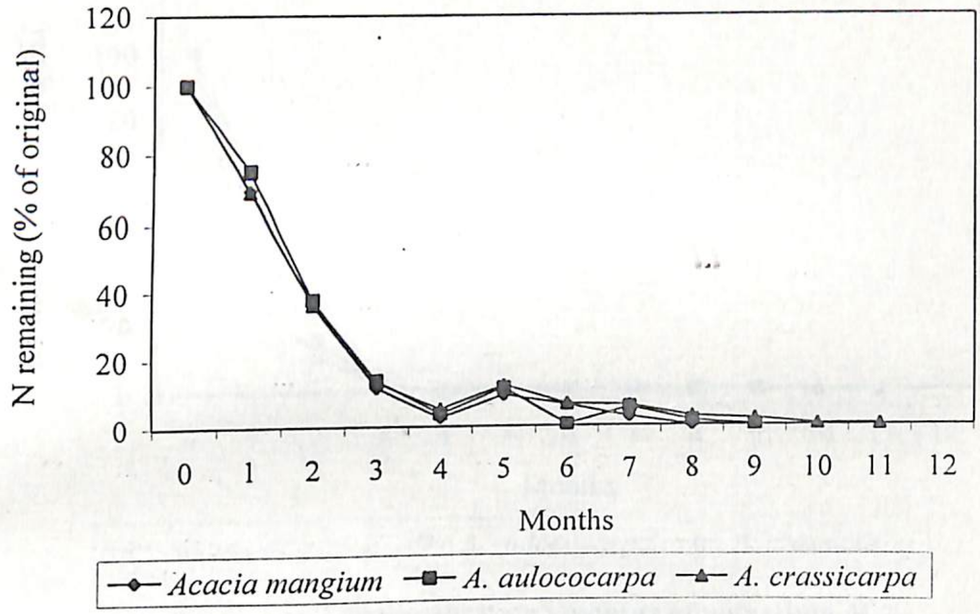


Fig. 35. Changes in the absolute amounts of nitrogen of leaf litter inside the plantation

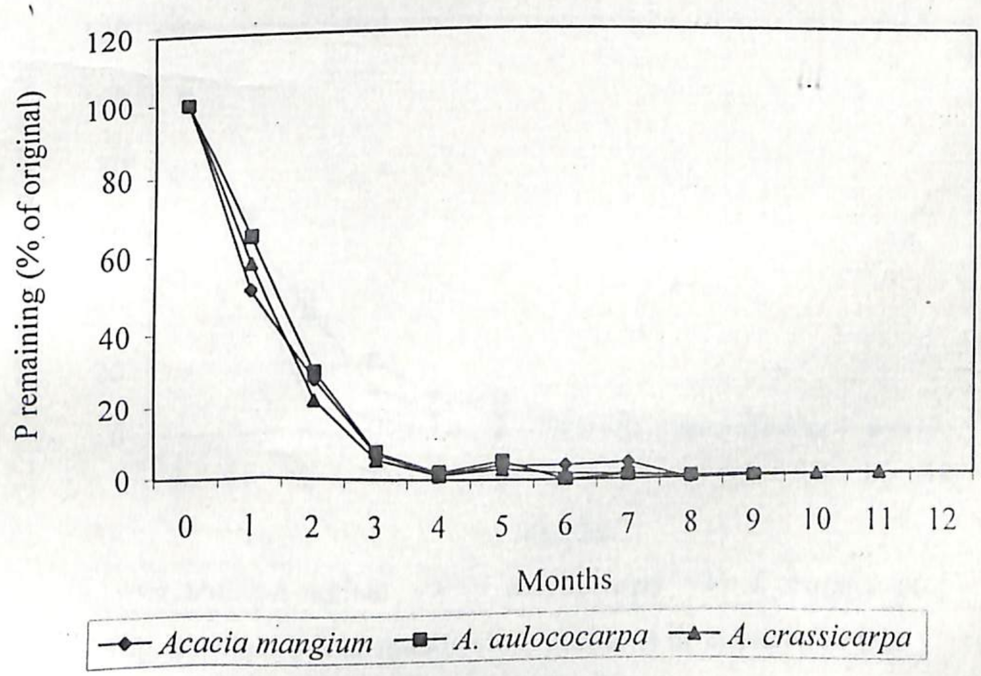


Fig. 36. Changes in the absolute amounts of phosphorus of leaf litter inside the plantation

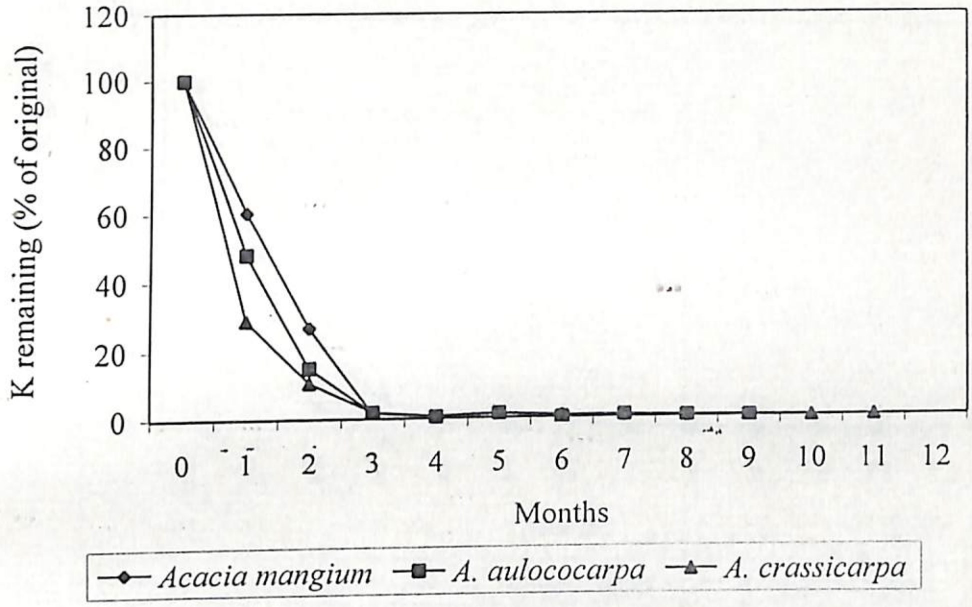


Fig. 37. Changes in the absolute amounts of potassium of leaf litter inside the plantation

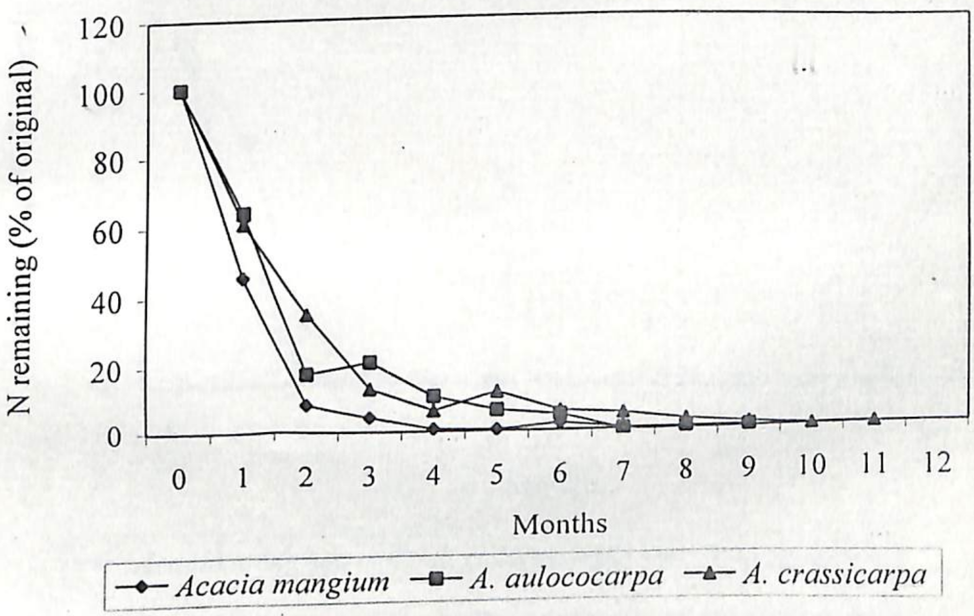


Fig. 38. Changes in the absolute amounts of nitrogen of leaf litter in open area

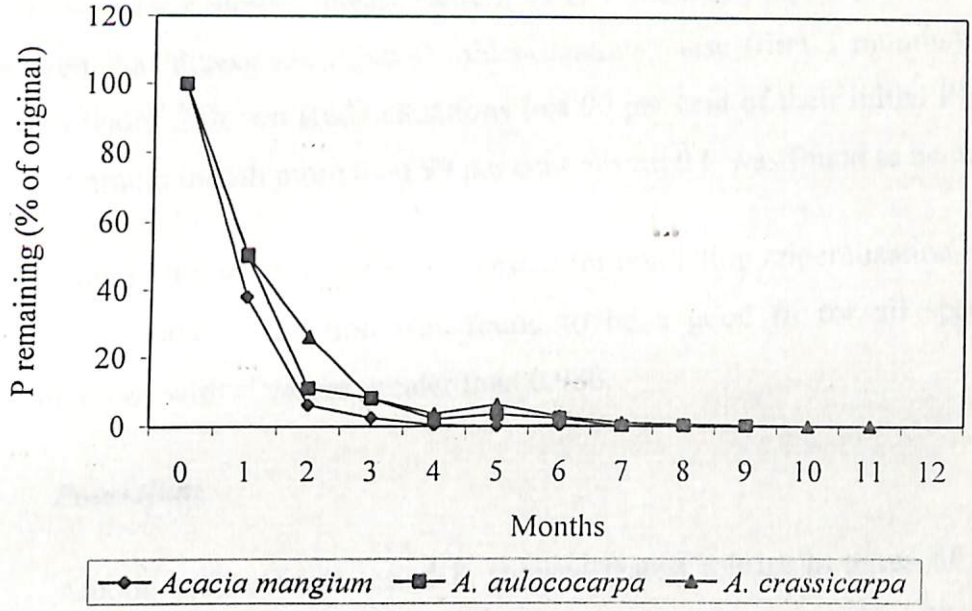


Fig. 39. Changes in the absolute amounts of phosphorus of leaf litter in open area

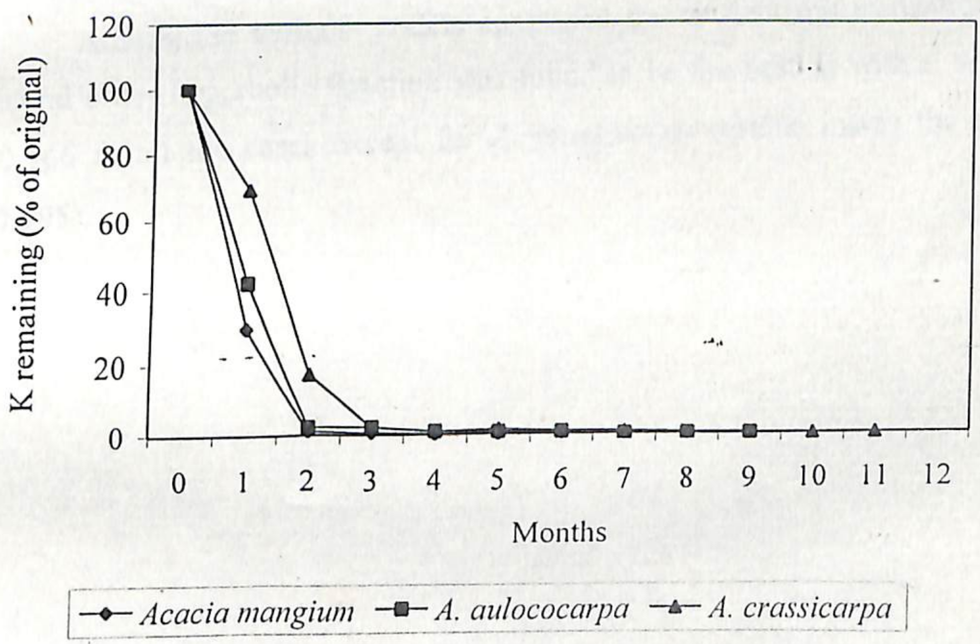


Fig. 40. Changes in the absolute amounts of potassium of leaf litter in open area

release followed by a slower release pattern as is evidenced from Fig. 36 and 39. It could be seen that during the rapid P mineralization phase (first 3 months), all the three species under different study situations lost 90 per cent of their initial P content. At the end of nineth month more than 99 per cent of initial P was found to be released.

Among the several models suggested for predicting mineralisation of P, the second order hyperbolic function was found to be a good fit for all species for different situations with r^2 values greater than 0.980.

4.2.8.3 Potassium

Among the nutrients tested K showed fastest release in terms of absolute quantity with regard to all the species under two study situations (Fig. 37 and 40). Interestingly, initial absolute K content exhibited a reduction of 97 per cent at the end of three months for various species under different study situations.

Among the various models suggested for nutrient mineralization pattern, the second order hyperbolic function was found to be the best fit with r^2 value more than 0.966 in all the cases except for *A. crassicarpa* residue inside the plantation (r^2 = 0.995).

Discussion

DISCUSSION

In tropical plantations, litterfall and litter decomposition plays a vital role in determining the growth and productivity of the trees. The production, composition and subsequent decomposition of litter is of major importance in studies of energy flow, nutrient cycling and primary production (Waring and Schlesinger, 1985). Tree components in many land use practices, absorbs nutrients from the deeper layer and deposits in the upper layer through the process of nutrient cycling (Ovington, 1959). In modern plantation forestry practices, a sound knowledge of the litter production, decomposition and nutrient release patterns from the decaying litter is very essential for the proper nutrient budgeting of the tree plantations.

The present series of studies were carried out in College of Forestry, Vellanikkara to assess the amount of litter production, rate of decomposition and the nutrient release pattern of three species of acacia viz., *A. mangium*, *A. crassicarpa* and *A. aulacocarpa*. Salient findings are discussed hereunder.

5.1 LITTER PRODUCTION

The annual production of litter in the 5 year old *A. crassicarpa*, *A. aulacocarpa* and *A. mangium* stands were estimated to be of the order of 12.76 t ha^{-1}, 14.18 t ha^{-1} and 20.64 t ha^{-1}, respectively. Kunhamu *et al*. (1994) observed an annual litter production of 12.93 t ha^{-1} in *A. auriculiformis* stand. Similar observation was also reported by Sankaran *et al*. (1993) in *Acacia auriculiformis* plantation at Thrissur with annual litter production of 12 t ha^{-1}. William and Gray (1974) also reported litter production rates ranging from 5.5 to 15.3 t ha^{-1} for the equatorial rain forests.

The higher annual litter production values of the three species of acacia when compared to that observed by Sankaran *et al*. (1993) and Kunhamu *et al*. (1994), can be attributed to the heavy and interlocked canopy. Favourable temperature and rainfall conditions prevailing in this region and the higher productivity also favour a heavy litter yield (Kunhamu *et al*., 1994).

The three species of acacia viz., *A. crassicarpa, A. aulacocarpa* and *A. mangium* showed a tremendous monthly variation in litter fall with a distinct peak in December. Litter obtained during the December month was contributed by leaf as well as pods and twigs. The maximum twig fall during this period may be due to the high wind velocity (15.17 km/hr). December-February also coincides with the peak pod/seed maturity in acacia species. However the three species exhibited variability in their monthly litter production with a distinct peak in December. Litter fall studies in the evergreen plantations such as *Acacia nilotica* and *Eucalyptus tereticornis* also suggested a similar trend, with bulk production in the winter season (Gill *et al.*, 1987).

Attempts to correlate litter fall patterns with climatological parameters suggested no strong relationship (r^2 value for rainfall - 0.23). This shows that climatological parameters play a limited role in litter fall of *Acacia crassicarpa, A. aulacocarpa* and *A. mangium* (Kunhamu *et al*., 1994).

5.1.1 Litter nutrient concentration and nutrient return

Seasonal variations in litter nutrient contents of the three species of acacia are presented in Tables 6 to 8 and Figs. 6 to 14. For all the three species litter nitrogen percentage showed peaks in December and June (Figs. 6, 9, 12). The relatively high nutrient contents during December can probably be attributed to the abundance of pods/seeds in the litter which are potent nutrient sinks. Higher content of nitrogen had been reported for black wattle (*Acacia mearnsii*) litter during the period of heavy pod/seed fall (Venkataraman *et al*., 1983). A similar trend was also observed by Kunhamu *et al*. (1994) in *Acacia auriculiformis* stands.

Regarding the phosphorus content, *A. aulacocarpa* and *A. mangium* exhibited a peak in July whereas *A. crassicarpa* showed a peak in June. Comparatively good rain fall and associated higher litter decay rate enable the efficient recycling of nutrients, which constitute the probable reason for the high litter phosphorus content during this period. Higher phosphorus content during the rainy months (June-July) could also be associated with the prevailing favourable growth conditions and the consequent increase in nutrient absorption (Sharma and Pande, 1989).

Increased concentrations of nitrogen and phosphorus, observed during June, July could be due to lesser retranslocation of these nutrients before abscission and may also be due to the addition of nutrients through precipitation. The comparatively low concentration of nitrogen and phosphorus in the total litter during February may be due to greater translocation of these nutrients before litter fall. Retranslocation is found to be an important source of N, P and K for new growth as reported by Maggs (1985). Nutrient retranslocation mechanism in other species was also reported by various workers (Negi, 1984; Kushalpa, 1993; Das and Ramakrishnan, 1985 and Martin *et al.* 1996). They reported that concentration of different nutrients in the leaf litter was less than that of green leaves due to retranslocation before abscission. The findings of the above studies are well in conformity with that of the present study.

Potassium showed a peak value during September-August period. This incidentally represents the period of profuse flowering in acacia species and naturally the litter might have contained a high fraction of floral parts. The floral parts probably contain more of potassium (Crawford, 1976). Thus high concentration of potassium may be attributed to presence of floral parts. However, potassium registered a second peak during December-January, implying the higher relative potassium contents of pods/seeds and a proportionately higher return to the soil through litter fall.

Nutrient return through different components of litter indicated that for the three species leaf litter returned maximum quantity of all nutrients when compared to twig + bark and fruit components (Table 9). Out of the total N returned through litter in different species around 93 per cent was contributed by leaf litter. Nutrient return study on unit area basis (kg/ha/yr) indicated that leaves returned maximum quantity of all nutrients when compared to twigs and fruits. Ambasht and Srivastava (1994) also reported that out of the total N returned through litter in *C. equisetifolia*, 85 per cent to 95 per cent was contributed by foliage litter. Maximum return of various nutrients through leaves in other species have also been reported by Venkataraman *et al.* (1983); Malhotra *et al.* (1987); George and Varghese (1990) and Martin *et al.* (1996). Present study revealed that among different nutrients, N was returned in highest quantity followed by K and P (Table 9).

The three species returned maximum amount of nitrogen when compared to potassium and phosphorus. Studies on nutrient return through litter in various other species (George, 1982; Singh *et al.* 1984; Vitousek, 1984; Maggs, 1985 and Singh *et al.* 1993) also showed that N was returned in higher amounts in comparison with other nutrients in the litter. Similar findings are obtained in the present study also.

5.2 LEAF LITTER DECOMPOSITION

5.2.1 Rates of leaf litter decomposition

The difference in rates of decomposition for the three species of acacia is evident from the present study. However, in general all the three species exhibited relatively a faster rate of decomposition during the period of study. All the species lost more than 90 per cent of the initial mass at the end of 4 months of exposure for decomposition. Gopikumar *et al*. (2001) also reported a comparable faster rate of decomposition for *A. mangium* in a study conducted at Vellanikkara where more than 90 per cent of the initial mass was decomposed within three months. Physico-chemical properties of the leaf litter which combined with the favourable environmental conditions of the tropics like heavy rainfall and temperature could be the major factor for the faster rate of decomposition of the three species of acacia in the present study.

5.2.2 Rates of decomposition as affected by field conditions

The rates of decomposition in plantation and open area were more or less similar, indicating the poor influence of field conditions on the decomposition of leaf litter. However faster rate of decomposition was observed in open area compared to plantations. Faster rate of decomposition in the open area could be attributed to better exposure of soil to sunlight, rainfall and temperature when compared to plantation where the floor is densely covered by canopy of trees and shrubs. A similar observation was also made by Gopikumar *et al*. (2001) in *Acacia mangium* for a study conducted in home garden as well as in open area at Vellanikkara of Thrissur district (Kerala).

5.2.3 Pattern of leaf litter decomposition

Pattern of decomposition for all the three species under two study situations followed a biphasic pattern with an initial rapid decomposition followed by a slower phase. For all the three species seventy five per cent of litter decomposed within a period of three months. Similar decomposition pattern in two phases had been, reported by Kunhamu (1994) in studies on the decomposition of some deciduous tree species. Singh *et al.* (1993) in their studies using sal, teak and poplar also observed similar decomposition pattern. The possible reason for the initial high decomposition for the three species could be the favourable environmental conditions for decomposition associated with the presence of readily digestible water soluble compounds in the litter and high density of the decomposer population. 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. This is in accordance with the findings of Berg and Staaf (1981), Kunhamu (1994) and Gopikumar *et al*. (2001) who opined that the later slow decomposition phase was due to the labile carbon components and biodecay resistant refractory fractions.

5.2.4 Factors affecting leaf litter decomposition

5.2.4.1 Effect of litter quality on the rate of decomposition

5.2.4.1.1 Initial nitrogen and C:N ratio

The initial N content of litter kept inside the plantation and open conditions were maximum for *A. mangium* (2.53%) followed by *A. aulacocarpa* (2.32%) and *A. crassicarpa* (2.1%). Consequently, *A. mangium* exhibited a faster rate of decomposition both inside the plantation and open area. This strongly suggests that the rate of decomposition is positively influenced by the initial N concentration of the leaf litter. This is in accordance with the studies conducted by Gopikumar *et al*. (2001) in *A. mangium*. Kumar and Deepu (1992) also 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 emphasized by Constantinides and Fownes (1994) and Jamaludheen (1994).

C:N ratio has long been regarded as a good predictor of the rate of decomposition (Melin, 1930 and Bocock, 1964). In the present study also *A. mangium* with lower C:N ratio exhibited a faster rate of decomposition compared to *A. crassicarpa* under two study situations. This strongly suggests that C:N ratio in *A. mangium*, *A. crassicarpa* and *A. aulacocarpa* are negatively correlated with the rate of decomposition. The studies by Singh and Gupta (1977), and Meentemeyer (1978) have clearly revealed that plant litter with high initial nitrogen content and low C:N ratios decompose rapidly.

5.2.4.1.2 Lignin and lignin : nitrogen ratio

The influence of lignin content on the rate of decomposition is evident from the data presented in Table 14. The *A. mangium* litter having a lower initial lignin (22.91%) decomposed faster followed by *A. aulacocarpa* (23.17%) and *A. crassicarpa* (24.73%). Similar observations were also made by Barry *et al.* (1989), Berg *et al*. (1981), Kunhamu (1994) and Gopikumar *et al*. (2001) in various litter decomposition studies.

In the present study, lignin content was found to increase during the subsequent sampling intervals for all the species under different study situations and consequently a slower rate of decay towards the end of decomposition. Negative linear relationship between lignin concentration and rate of mass loss was also reported by Melillo *et al.* (1982) and Berndse *et al.* (1987).

5.2.4.2 Effect of weather parameters on the rate of decomposition

The influence of favourable conditions on decomposition, especially high temperature and moisture content has already been established by Madge (1965). Witkamp and Olson (1963) reported that bacterial and fungal activities are enhanced due to substrate moisture and temperature in bags resulting increased rate of decomposition. In the present study, an increased rate of decomposition was observed during the initial period of the study i.e. July, this period with abundant rainfall and relative humidity, might have enhanced the microbial proliferation and subsequent rapid mass loss. However, no significant relationship could be established between the atmospheric temperature, relative humidity and rainfall with the rate of decomposition. Influence of soil temperature on the rate of decomposition has already been established by Gupta and Singh (1977), Madge (1965) and Gopikumar *et al*. (2001).

5.2.5 Decay rate coefficients

In the present study the decay rate coefficients for various study situations were found to be different for the three species. The K value was highest for *Acacia aulacocarpa* both in open area (0.601) and plantation (0.514). For *Acacia mangium* it was 0.512 inside the plantation and 0.585 in the open area. In *Acacia crassicarpa* decay rate coefficient recorded a value of 0.472 in plantation and 0.484 in open area. Sankaran *et al.* (1993) also found variation in K values for different study sites. However, the decay rate coefficients in the present study were found to be higher in relation to K values reported by Jamaludheen (1994) for *Acacia auriculiformis* and Gopikumar *et al*. (2001) for *A. mangium*.

It was also observed that the predicted half life values were of shorter duration (1.15 to 1.47 months). Gopikumar *et al*. (2001) also observed comparable values in *A. mangium*. In the present study, half life periods varied between the two study situations. A similar observation had been made by Sankaran *et al.* (1993) in the half life periods for *A. auriculiformis* leaf litter which had ranged from 5.9 to 11.6 months under different site conditions.

5.2.6 Nutrient release pattern

Nutrient release from the decomposing litter is dynamic. Nutrient release from the decomposition of litter generally fluctuates, characterized by an initial accumulation (immobilization) followed by a rapid release and a final slower release phase. Coinciding nutrient release with peak nutrient demand is an important challenge in plantations. Different types of nutrient release patterns among various species are mostly due to the variation in the chemical quality of different leaf litter. Presence of various microbial types and their population and the prevailing soil conditions also results in an apparent fluctuation in the nutrient release under various study situations. Similar conclusion was also made by Sankaran (1993) in studies on teak, albizia and eucalyptus.

Nitrogen

In the present study, N concentration in the leaf litter kept for decomposition was lower when compared to fresh leaf samples. Leaf litter are supposed to have a lower concentration of nutrients as major share of which is retranslocated into the plant system before their abscission (Sharma and Pande, 1989).

Variation in the N concentration of the three species under different study situations is evident from the data presented in Tables 15, 16 and 17. The litter retrieved from the plantations registered a decline in N concentration for *A. mangium* and *A. crassicarpa*. However *A. aulacocarpa* showed a slight increase and then declined. The conversion of carbon to CO_2 due to faster oxidation and leaching of soluble carbon compounds and the subsequent weight loss would have resulted in increased N concentration (Kumar and Deepu, 1992). The increased concentration of nitrogen during the decomposition could also be due to addition of nitrogen through precipitation (Kunhamu, 1994; Gopikumar *et al*., 2001). The decrease in N content could be attributed to leaching of water soluble nitrogenous substances from the leaf litter (Nykvist, 1963; Vidyasagaran *et al*., 2002) and the higher demand for nitrogen for the intense microbial activity during the initial stages of decomposition.

The change in absolute amounts of nitrogen in the decomposing litter of various species under different study situations were not uniform. The absolute amount of nitrogen showed increases during the period of decomposition. This type of absolute increases of nitrogen is frequently reported. Increases can be attributed partly to microbial immobilization and hence redistribution of nutrients between the litter layers. Berg and Soderstorm (1979) found that increases of nitrogen in decomposing litter were correlated with increases in fungal biomass. Inputs of nitrogen in through fall and fine litterfall (Bocock, 1964; Jorgensen *et al.*, 1980) and through asymbiotic nitrogen fixation (Baker and Attiwill, 1985) also contributed to absolute increases of nitrogen in decomposing litter.

Phosphorus

The P content of the decomposing litter of different species under different study situations, exhibited a gradual decrease during the initial months followed by a slight increase and a constant phase towards the end of the study. Similar trend was observed by Gopikumar *et al*. (2001) in *A. mangium*. 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). Relatively constant and slower phase towards the end may be due to lower retranslocation efficiency during wet season as reported by Miller *et al.* (1979).

Absolute amounts of P showed an initial rapid and a subsequent slow release phase. Greater changes in absolute amounts could not be observed as the concentration changes were not substantial and faster mass loss occurred for all the three species in different study situations (Upadhyay and Singh, 1989).

Potassium

In the present study K concentration for different species under various study situations was found to decline drastically during different months. Heavy rainfall and associated microbial activities during this period might have caused considerable leaching of K from the litter bags. Potassium being a mono valent ion, is weakly bound to adsorption sites and is highly water soluble (Bocock, 1964; Attiwill, 1968 and Gosz *et al.*, 1973). In the three species studied, absolute amounts of K followed a rapid declining trend which is comparable with their respective mass loss.

Summary

SUMMARY

Litter production and decomposition are the two primary mechanisms through which the nutrient pool in the forest ecosystem is maintained. Large quantities of leaf litter 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. 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 expansion of plantations of exotic tree species and the increased use of fertilizers to establish them have prompted interest in how nutrients cycle in these plantations relative to native ecosystems.

The present series of studies were carried out in College of Forestry, Vellanikkara to assess the amount of litter production, rate of decomposition and the nutrient release pattern of three species of acacia viz., *A. mangium*, *A. crassicarpa* and *A. aulacocarpa*. Salient findings are summarised hereunder.

1) The annual litter production from the three species of acacia studied were higher when compared to early observations made in *Acacia auriculiformis*. Favourable temperature and rainfall conditions prevailing in this region and the higher productivity favoured a heavy litter yield.
2) Seasonal litter fall patterns of the three species exhibited a high amount of variability. In general, it followed a monomodal distribution pattern with a distinct peak in December for the three species.
3) Attempts to correlate litter fall patterns with climatological parameters suggested no strong relationship.
4) Seasonal variations in the litter nutrient contents was observed for the three species with peaks for nitrogen during December and January. For phosphorus *Acacia aulacocarpa* and *A. mangium* exhibited peak in July and *A. crassicarpa* in June. Potassium showed peak value during September-August period.

5) Nutrient return through different components of litter indicated that for the three species leaf litter returned maximum quantity of all nutrients when compared to twig + bark and fruit components. The three species returned maximum amount of nitrogen when compared to potassium and phosphorus.
6) All the species lost more than 90 per cent of the initial mass at the end of 4 months of exposure for decomposition.
7) A characteristic biphasic pattern of biomass decomposition was observed with a rapid initial phase followed by slow latter phase.
8) The rate of decomposition was faster in the litter of the three species studied due to high initial nitrogen content and low C:N ratio.
9) Negative linear relationship between lignin concentration and rate of mass loss was evident for the three species in two study situations.
10) Only a poor correlation between weather parameters and rate of decomposition was observed. However soil moisture content was found to influence the rate of decomposition in a positive manner.
11) Decay rate coefficients for various study situations were found to be different for the three species of acacia.
12) Fluctuation in the nitrogen concentration of residual mass of the three species under different study situation was evident during the course of study. The litter retrieved from the plantations registered a decline in N concentration for *A. mangium* and *A. crassicarpa*. However *A. aulacocarpa* showed a slight increase and then declined.
13) The phosphorus content of the decomposing litter of the three species under different study situations exhibited fluctuations during the course of investigation.
14) Potassium concentration for different species under various study situations was found to decline drastically during different months.

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Appendices

APPENDIX-I

Weather parameters during the study period (2000 June to 2001 May)

Months	Weather parameters								
	Rainfall (mm)	Mean RH. (%)	Mean max. temperature (°C)	Mean min. temperature (°C)	Highest maximum (°C)	Lowest min. (°C)	Evaporation (mm)	Mean wind spread (km/hr)	Soil temperature 5 cm depth (14.00 hrs)
June 2000	676.2	87	28.4	23.1	32.8	21.0	87.8	3.4	31.0
July	354.0	82	28.8	21.9	31.2	20.5	104.3	3.8	34.5
August	518.8	87	29.1	22.6	31.8	21.2	95.9	3.4	32.7
September	198.1	81	30.7	23.0	32.6	21.5	101.1	3.2	33.6
October	262.2	80	30.7	22.7	33.4	20.6	101.1	2.7	35.1
November	41.3	66	33.3	23.1	34.4	18.6	123.4	5.7	38.4
December	11.2	59	30.4	22.0	33.2	17.0	161.5	7.8	31.6
Jan 2001	0	56	32.6	23.2	35.2	20.5	199.3	8.0	37.5
February	12.2	67	34.5	22.9	36.2	18.4	142.0	4.2	43.0
March	4.4	69	34.9	24.0	37.0	22.4	171.0	4.1	44.0
April	243.1	75	34.2	24.7	38.4	22.5	128.2	3.5	42.9
May	192.6	81	32.3	24.5	34.5	22.0	121.7	3.3	37.3

APPENDIX-II

Decay coefficients and half life values of decomposing litter mass of different species of acacia under various study situations

Species	Study situation	Decay rate coefficient (K)	r^2	Half life (months)
Acacia aulacocarpa	Plantation	-0.514941	0.93100	1.35
	Open area	-0.601749	0.92065	1.15
Acacia crassicarpa	Plantation	-0.472785	0.934929	1.47
	Open area	-0.484265	0.944089	1.43
Acacia mangium	Plantation	-0.512112	0.93045	1.35
	Open area	0.585362	0.6120	1.18

APPENDIX-III

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

Species	Study situation	Nutrient	Equation	Coeff. of A	Coeff. of B	Coeff. of C	r^2
1	2	3	4	5	6	7	8
Acacia mangium	Plantation	N	Y=A+B/X+C/X*X	-0.9663	0.8010	-0.8008	0.9827
			Y=A+B*X+C*X*X	0.9384	-0.2989	0.2268	0.9270
		P	Y=A+B*X+C/X	0.3432	-0.4706	0.6568	0.8671
			Y=A+B/X+C/X*X	-0.7530	0.5829	-0.5828	0.9867
			Y=A+B*X+C*X*X	0.8517	-0.2940	0.2346	0.8784
		K	Y=A+B/X+C/X*X	-0.1215	0.7103	-0.7102	0.9788
			Y=A+B*X+C*X*X	0.8990	-0.3206	0.2580	0.9091
			Y=A*B^X	0.9523	0.3760	0.0000	0.8866
			Y=A*e^[B*X]	0.9523	-0.9781	0.0000	0.8866
	Open area	N	Y=A+B/X+C/X*X	-0.8702	0.4961	-0.4960	0.9807
			Y=A+B*lnX	0.1946	-0.9081	0.0000	0.9041
			Y=A*B^[1/X]*X^C	0.3770	0.9980	-0.2272	0.8941
		P	Y=A+B*X+C/X	0.2008	-0.2941	0.7992	0.8980
			Y=A+B/X+C/X*X	-0.7855	0.4209	-0.4208	0.9852
			Y=A*B^[1/X]*X^C	0.3978	0.9974	-0.2933	0.9648
			Y=A*e^[(X-B)/2]	0.8834	0.8533	0.1002	0.9609
			Y=A*e^[(lnX-B)^2/C]	0.1001	-0.4859	-0.4115	0.9599
		K	Y=A+B*X+C/X	0.1387	-0.2062	0.8613	0.9259
			Y=A+B/X+C/X*X	-0.6423	0.3178	-0.3177	0.9823
			Y=A+B*lnX	0.1649	-0.9125	0.0000	0.9587
			Y=A*B^[1/X]*X^C	0.1419	0.9975	-0.2972	0.9077

Contd.

Appendix-III. Continued

1	2	3	4	5	6	7	8
Acacia aulacocarpa	Plantation	N	Y=A+B/X+C/X*X	-0.1036	0.8600	-0.8598	0.9832
			Y=A+B*X+C*X*X	0.9604	-0.3039	0.2293	0.9329
		P	Y=A+B/X+C/X*X	-0.1148	0.7489	-0.7488	0.9881
			Y=A+B*X+C*X*X	0.9147	-0.3135	0.2472	0.9221
		K	Y=A+B/X+C/X*X	-0.9687	0.5487	-0.5486	0.9863
			Y=A+B*X+C*X*X	0.8306	-0.3077	0.2534	0.8513
			Y=A+B*X+C/X	0.2766	-0.4020	0.7234	0.8561
	Open area	N	Y=A+B/X+C/X*X	-0.8134	0.6953	-0.6952	0.9826
			Y=A+B*X+C*X*X	0.8873	-0.2851	0.2172	0.8885
			Y=A+B*X+C/X	0.4296	-0.5848	0.5704	0.8420
		P	Y=A+B*X+C/X	0.2967	-0.4188	0.7033	0.8607
			Y=A+B/X+C/X*X	-0.8639	0.5528	-0.5527	0.9861
			Y=A+B*lnX	0.2110	-0.9014	-0.0000	0.8845
		K	Y=A+B*X+C/X	0.2059	-0.3019	0.7941	0.8676
			Y=A+B/X+C/X*X	-0.8634	0.4497	-0.4496	0.9708

Contd.

Appendix III. Continued

1	2	3	4	5	6	7	8
Acacia crassicarpa	Plantation	N	Y=A+B/X+C/X*X	-0.6934	0.7653	-0.7652	0.9866
			Y=A*B^X	0.9933	0.6056	0.0000	0.9097
			Y=A*X^(B*X)	0.5136	-0.1961	0.0000	0.9012
			Y=A*e^(B*X)	0.9933	-0.5015	0.0000	0.9097
			Y=A*e^[(X-B)/2]	0.3490	-0.9729	-0.6073	0.9109
		P	Y=A+B/X+C/X*X	-0.9043	0.6331	-0.6330	0.9853
			Y=A*B^X	0.6192	0.5397	0.0000	0.9156
			Y=A*e^(B*X)	0.6192	-0.6167	0.0000	0.9156
			Y=A*B^X*X^C	0.5077	0.5652	-0.7957	0.9147
			Y=A*e^[(X-B)/2]	0.2241	0.2711	0.7008	0.9119
			Y=A*e^[(lnX-B)^2/C]	0.9250	-0.4672	-0.4540	0.9062
		K	Y=A+B*X+C/X	0.1494	-0.1789	0.8506	0.9420
			Y=A+B/X+C/X*X	-0.4626	0.3217	-0.3216	0.9953
			Y=A*B^X	0.3927	0.5189	0.0000	0.9239
			Y=A*e^(B*X)	0.3927	-0.6559	0.0000	0.9239
			Y=A+B*lnX	0.1836	-0.8936	0.0000	0.9740
			Y=A*B^X*X^C	0.2723	0.5650	-0.1466	0.9411
			Y=A*e^[(lnX-B)^2/C]	0.6706	-0.4828	-0.4554	0.9301
	Open area	N	Y=A+B/X+C/X*X	-0.6030	0.6874	-0.6873	0.9882
			Y=A*B^X	0.1200	0.5592	0.0000	0.8954
			Y=A*X^(B*X)	0.5749	-0.2298	0.0000	0.9102
			Y=A*e^(B*X)	0.1200	-0.5812	0.0000	0.8954
			Y=A*e^[(X-B)/2]	0.8430	-0.2858	-0.2876	0.9207

Contd.

Appendix III. Continued

1	2	3	4	5	6	7	8
Acacia crassicarpa	Open area	P	Y=A+B/X+C/X*X	-0.6682	0.4788	-0.5786	0.9928
			Y=A*B^X	0.1205	0.4824	0.0000	0.9439
			Y=A*X^(B*X)	0.4711	-0.2868	0.0000	0.9488
			Y=A*e^(B*X)	0.1205	-0.7289	0.0000	0.9439
			Y=A*B^X*X^C	0.1319	0.4724	0.3642	0.9390
			Y=A*e^[(X-B)/2]	0.2368	-0.6349	-0.3251	0.9570
			Y=A+B/X+C/X*X	-0.1180	0.7402	-0.7401	0.9663
			Y=A*B^X	0.7104	0.4700	0.0000	0.9177
			Y=A*e^(B*X)	0.7104	-0.7550	0.0000	0.9177
			Y=A*B^X*X^C	0.6145	0.4861	-0.5811	0.9116
			Y=A*e^[(X-B)/2]	0.4477	0.1176	0.2970	0.9088

APPENDIX-IV

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

Sl.No.	Equation	Explantation
1	Y=A+B/X+C/X*X	Second order hyperbolic function
2	Y=A*B^X	Power function
3	Y=A*X^(B*X)	Super geometric function
4	Y=A*e^(B*X)	Exponential model
5	Y=A*e^[(X-B)/2]	Normal function
6	Y=A*B^X*X^C	Hoerl function
7	Y=A*e^[(lnX-B)^2/C]	Log normal function
8	Y=A+B*X+C/X	Line and reciprocal model
9	Y=A+B*lnX	Logarithmic model
10	Y=A+B*X+C*X*X	Parabolic function
11	Y=A*B^(1/X)*X^C	Modified hoerl function

LITTER PRODUCTION AND DECOMPOSITION STUDIES IN SELECTED SPECIES OF ACACIA

By

SUHYB, P. J.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Agriculture
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ABSTRACT

An experiment was conducted at College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur during the period from 1999-2001 to study the litter production, nutrient return, litter decomposition and nutrient release pattern of three species of acacia viz., *Acacia mangium* Wild., *Acacia aulacocarpa* A. Cunn. ex Benth. and *Acacia crassicarpa* A. Cunn. ex Benth.

Litter fall of the three species followed a monomodal distribution pattern with a distinct peak in December for the three species. Nutrient return through different components of litter indicated that for the three species, leaf litter returned maximum quantity of all nutrients. The three species returned maximum amount of nitrogen when compared to potassium and phosphorus. A characteristic biphasic pattern of biomass decomposition was observed with a rapid initial phase followed by slow latter phase. Negative linear relationship between lignin concentration and rate of mass loss was evident for the three species in two study situations. Only a poor correlation between weather parameters and rate of decomposition was observed. Fluctuation in the nitrogen and phosphorous concentration of residual mass of the three species under different study situation was evident during the course of study. Potassium concentration for different species under various study situations was found to decline drastically during different months. The nitrogen, phosphorous and potassium mineralisation pattern of the three species of acacia under two study situations showed a best fit with the second order hyperbolic function.