NUTRIENT CONTENT AND DECOMPOSITION OF LEAF BIOMASS OF SELECTED WOODY TREE SPECIES

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Forestry

FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY
COLLEGE OF FORESTRY
VELLANIKARA, THRISSUR

1994

Dedicated to
my loving parents,
wife, sisters, and brothers

DECLARATION

I hereby declare that the thesis entitled **"Nutrient Content and Decomposition of Leaf Biomass of Selected Woody Tree Species"** 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, associateship, fellowship or any other similar title, of any other University or Society.

Vellanikkara,

2.2.1995.

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CERTIFICATE

Certified that the thesis entitled **"Nutrient Content and Decomposition of Leaf Biomass of Selected Woody Tree Species"** is a record of research work done independently by **Mr. Kunhamu, T.K.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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ACKNOWLEDGEMENTS

My unreserved gratitude and indebtedness goes to Dr. K. Gopikumar, Associate Professor, College of Forestry and Chairman of my advisory committee for the erudite support and valuable guidance rendered throughout the course of my study. His personal attention, timely suggestions and constant encouragement made it possible for me to complete this task successfully.

It is with immense pleasure that I record my deep sense of gratitude and sincere thanks to Dr. C.C. Abraham, Associate Dean, College of Horticulture and member of the advisory committee for his constant help in way of extending the facilities available at his disposal for conducting the present study and for the valuable time he spared during the preparation of this manuscript.

My sincere thanks are due to Dr. K. Sudhakara, Associate Professor, College of Forestry and member of advisory committee for the keen interest and valuable suggestions he has provided throughout the course of my study.

I am extremely grateful to Smt. K. Leela, Professor, College of Horticulture and member of my advisory committee for the whole hearted cooperation and the valuable advice extended to me during the study.

I am deeply obliged to Dr. P.A. Wahid, Special Officer (i/c), College of Forestry for allowing me to use the facilities available at his disposal for the timely completion of this study.

My special thanks are due to Dr. N.N. Potti, Professor and Dr. P.K. Sushama, Assistant Professor, College of Horticulture whose wisdom and knowledge were of great help to me especially during the chemical analysis.

I am grateful for the help rendered by Mr. Nandakumaran, Associate Professor, College of Veterinary and Animal Sciences for the assistance provided in the lignin estimation.

My sincere and heartfelt gratitude is also due to Sri. V.K. Raju, Associate Professor, College of Horticulture for the help extended by way of photographic work.

I am greatly indebted to Mr. M.K. Hussain and Mr. K.S. Bhaskaran for permitting me to establish my work in their home gardens.

Among my friends Santhosh, Gopan and Rajesh were of great help and they made my task lighter. Help received from Madhu, Anoop, Sabu, Jamal, Vinod, Hegde, Shereef and many friends from College of Horticulture too are gratefully remembered. They all gave me more than what I expected quite willingly.

I express my sincere thanks to all the staff members, and non teaching staff of College of Forestry for their earnest and whole-hearted cooperation throughout the course of my research programme.

The award of the fellowship by Kerala Agricultural University is gratefully acknowledged.

My profound appreciation to Mr. O.K. Ravindran, C/o Peagles, Mannuthy, for the care and interest he has taken in typing the manuscript neatly.

Above all the moral support and constant encouragement extended by my ever loving parents, wife, sisters and brothers are deeply acknowledged with great sense of devotion and gratitude.

KUNHAMU, T.K.

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Introduction

INTRODUCTION

The homestead gardens in Kerala have recently gained wider recognition in the international agroforestry scenario owing to their unique performance as one of the important sustainable land use systems. The intensive multistorey combinations of crops and trees along with livestock are the dominant form of land use pattern in Kerala. However, some of the land use practices such as unscientific manurial and fertilization practices, intensive use of inorganic fertilizers, cropping systems, harvesting methods, lack of erosion control measures etc., have adversely affected the fertility status, structure, texture and other physico-chemical attributes of these soils. Under these circumstances, the use of organic manures particularly leaf litters, has received wider recognition primarily in view of their capacity to maintain long term fertility of the soil.

Through experience, the incorporation of leaf biomass was found to be very much successful and hence, widely adapted for improving the soil nutrient status without much deleterious effect on the physico-chemical composition of the soil. Wide varieties of trees are found to be grown in the home gardens of Kerala which are retaining substantial amounts of nutrients in their leaf biomass. Unlike commercially manufactured products, these leaf biomass carry no label giving specification regarding it's chemical composition and quality. This poses great problems in cases where leaf biomass play a vital role in the functioning of small scale low external input technology systems.

Tree species vary in their rate of leaf biomass decomposition and nutrient release pattern which is primarily a function of the chemical quality and prevailing weather conditions. Knowledge of the rates of leaf biomass decomposition and nutrient release pattern of different species will help to adapt a proper manurial package for various systems.

Hence, the present series of studies were undertaken to compare some of the most commonly used leaf biomass of forest tree species with regard to their nutrient content and rate of decomposition in a typical selected home garden around Vellanikkara.

Review of Literature

REVIEW OF LITERATURE

Incorporation of leaf litters produced by forest trees and shrubs supply both major and minor nutrients to soil through organic matter which are mainly responsible for improving physical and chemical properties of the soil in any type of ecosystem. This is one of the reasons in maintaining aggregate stability and inherent fertility of the forest soil. The research work carried out in various parts of the country and abroad have clearly established the fact that application of leaf biomass will help in sustainable production of crops grown in homesteads and farmlands, through their role in maintaining better soil stability and helping in better nutrient cycling process. The literature on some of the important factors about the decomposition of leaf biomass of various tree species are reviewed and arranged under the following heads.

2.1 Leaf biomass 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 is therefore an important aspect in maintaining the fertility status of the soil (Jordan and Herrera, 1981; Vitousek, 1981; and Anderson and Swift, 1983).

The use of leaf biomass by small scale farmers in developing countries has not only increased the food crop yields many fold by increasing the soil fertility, but also, improved physico-chemical attributes of the soil. In low input agroforestry systems, leaf litter incorporation offers a strong base for low cost sustainable agricultural production (Budelman, 1989).

2.1.1 Decomposition studies in forest ecosystems

Litterfall and decomposition are two primary mechanisms by which a stable nutrient content of the forest ecosystem is maintained. The litter on the forest floor acts as an input-output system for nutrients (Das and Ramakrishnan, 1985) and the rates at which the forest 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 of tropical forest ecosystems where vegetation depends on the recycling of nutrients contained in the plant detritus (Singh, 1968; Cole and Johnson, 1978 and Prichett and Fisher, 1987).

In recent years, there has been an increase in the number of studies related to litter dynamics. Although, a majority of these deal with temperate forests (Das and Ramakrishnan, 1985; Pande and Sharma, 1986; Gill et al., 1987 and Harmon et al., 1990), the studies on mineral nutrient dynamics of tropical ecosystems seem to be scanty.

Litter decomposition is the primary mechanism by which organic matter and nutrients are returned to the soil for the re-absorption of plants (Aber and Melillo, 1980). Nutrients are released from the decomposing organic matter by a variety of physical and biological processess (Ebermayer, 1976).

2.1.2 Rate of decomposition

Leaf biomass decomposition rates have been well studied and determined for a wide variety of species throughout the world. It is clear that litter of different species do not decompose at the same rate even under similar environmental conditions (Alexander, 1977).

2.1.2.1 Effect of ecological variations on decay rates

The rate of decomposition of leaf biomass varies with the plant material and the prevailing environmental conditions. The decomposition rates are reported to be higher ranging from 0.45 to 1.5 per cent per day for tropical forests

(Olson, 1963 and Cornforth, 1970). In temperate forests litter decompose at a slower rate. The lowest rates of decomposition have been reported for Californian pine forests ranging from one to three per cent per annum (Olson, 1963). However, in general, the leaf decomposition rates reported for coniferous forests 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 broadleaf litter as compared to conifer litter (Bray and Gorham, 1964).

Hopkins (1966) compared the rates of leaf decomposition under varying environmental conditions. While it may take only 0.1 to 0.6 years for complete decomposition in moist semi deciduous and moist evergreen forests in the tropical environment, it may take more or less one year in temperate deciduous forests (Ovington, 1962), 1.6 years in subtropical forests (Jenney et al., 1949), three to five years in coniferous forests of Britain 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 Quercus langinosa and Pinus roxburghii and found that after a period of one year the per cent weight remaining was 48.7 and 32.1 for P. roxburghii and Q. langinosa respectively, indicating the fact that subtropical and temperate tree leaves decompose slowly even at the tropical condition owing to their inherent resistance to microbial activity.

Lee and Young (1985) compared the decay rates of *Shorea curtisii* and *Pinus carebaea* in Malaysia under evergreen dipterocarp forests and pine forests. Weight loss after 16 weeks was 39 and 19.5 per cent for shorea in dipterocarp and pine forests respectively, whereas the respective figures for pine was 13.6 and 10.3 per cent. Singh (1969) reported that generally three to five months are required for almost complete decomposition of leaf litter of important trees of tropical deciduous forests of Varanasi.

2.1.2.2 Species variations in decay rates

Litter production and decompositions dynamics in moist deciduous forests of India was studied by Kumar and Deepu (1992) and found that the decomposition of all the species tried was completed within a period of five to eight months. Of all the six species investigated, *Pterocarpus marsupium* litter decomposed most rapidly. *Tectona grandis*, *Dillenia pentagyna* and *Terminalia paniculata* recorded slower litter decomposition rates compared to *Grewia tiliaefolia* and *Xylia xylocarpa*. Interestingly, a faster decay rate was reported for *Tectona grandis* in the dry forests of Western Nigeria by

Egunjobi (1974). He found that complete mineralisation of the litter occurred within six months.

Bahuguna *et al*. (1990) conducted decay studies on *Shorea robusta* and *Eucalyptus camaldulensis* plantations at Dehradun, India. They reported that at the end of 12 months *Shorea robusta* showed 65 per cent decomposition whereas *Eucalyptus camaldulensis* decomposed at a faster rate recording 85 per cent. They concluded that high decay rates in Eucalyptus was due to high initial leachability of potassium. However, Munshi *et al*. (1987) reported that turn over time for the complete decomposition of *Shorea robusta* of a deciduous forest in Bihar, was found to be 144 days.

Decay studies of *Shorea maxwelliana* at peninsular Malaysia reported a rapid weight loss of upto 98.5 per cent after four to five weeks. The rate of weight loss was affected by species and to some extent by rate of covering with soil (Gong, 1982).

Laboratory incubation studies under controlled condition were tried with litters of *Eucalyptus marginata* (Jarrah) and *Eucalyptus diversicolor* (Karri) by O'Connel (1990). He found that decomposition was highest during autumn and spring and lowest in summer. Due to the better substrate quality and ability to conserve moisture, the decomposition of

Karri leaf litter was reported to be faster compared to Jarrah leaf litter.

Maheswaran (1988) in a study in tropical rain forest of SriLanka reported that the dominant species _Cullenia ceylanica_ leaves were reduced to 63 per cent at the end of one year. A marked variation in decay rates with species was also noted in wet lands of south east Missouri (Wylie, 1987). He stated that leaf litters of _Quercus palustris_ lost 25 to 38 per cent of original dry weight in 12 months with a calculated K values of 0.38 to 0.72 per year. Litter of _Nelubo lutea_ lost 80 per cent of original dry weight in eight to nine months with K values of 1.54 to 2.08 per year.

An exponential relationship between loss of leaf litter mass and time was established by Godeas (1987) using decomposing _Pinus taeda_ leaves. Incorporation of organic matter into the soil was to the range of 2.99 g/m^2. Long term decomposition studies on 12 temperate litter types were conducted by Mc Claugherty (1986). He concluded that a single exponential model is inappropriate for long term decay studies. The quantity of initial mass remaining after five years varied from 17 per cent in red mapple to 75 per cent for hemlock.

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

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

Rout and Gupta (1987) studied the leaf biomass decomposition by measuring CO_2 evolution rates from the soil on three deciduous tree species viz., Anogeissus latifolia, Grewia oppositifolia and Lannea coromandelica and two shrubs viz., Carissa spinarum and Rhus parviflora. Decay rates were correlated with various chemical constituents of the litter.

The decomposition per cent was seen to be different with species being highest for *G. oppositifolia* (57.2%) and lowest for *R. parviflora* (31.5%). The concentration of nitrogen, lignin and C:N ratio had significant effect on decomposition.

2.1.2.3 Effect of stand age on decay rates

Decomposition rates and changes in nutrient content of needle were examined in a stand of Douglas fir of age sequence 11, 24, 75 and 97 years in Western Washington. Litter bags were collected after 3, 6, 12 and 24 months. The maximum decomposition rates occurred in the 24 year old stand. The mineralisation pattern followed a maximum loss for potassium followed by P, Mg, Ca and Mn. Nitrogen exhibited the lowest rate of mineralization (Edmonds, 1979).

Bargali *et al*. (1993) observed the patterns of weight loss and nutrient release from decomposing leaf litter in Eucalyptus plantations of varying ages. Analysis of variance indicated significant difference in weight loss between age and time. The most rapid weight loss occurred in one year old plantation and found to be decreased with progress in age. They also found that rates of decomposition were significantly correlated with initial nutrient concentration.

Attempts were made by Bernhard (1987) to analyse the changes in soil organic matter owing to leaf biomass incorporation in natural stands. In general, fresh leaf biomass of *Acacia senegal* showed a high carbon mineralisation rate while old litter was more resistant. The soluble carbon content in the litter was too low. In *Eucalyptus camaldulensis*, carbon mineralisation was moderate in fresh and old leaves.

2.1.3 Decomposition studies in agroecosystems

The tree component in any agroforestry system is also very important in production of biomass. Properly designed agro-silvicultural systems are those in which the organic matter loss under the agricultural crop component is compensated by a gain under the tree component.

It is apparent that the trees used in agroforestry vary widely in their quality and rates of decomposition (Wilson *et al*., 1986). Leaves of *Leucaena leucocephala* decompose and disappear within a few weeks, while, those of *Cassia siamea*, at an intermediate rate. It is also note worthy that *Gmelina arborea*, *Acacia mangium* and many *Eucalyptus* species are relatively slow in decaying.

Under the same climatic and soil conditions at Ibadan, Nigeria, the rate of decomposition of prunings of various agroforestry species was in the order, *Leucaena leucocephala* which recorded maximum followed by *Glyricidia sepium*, *Cassia siamea* and *Flemingia congesta* (Yamoah *et al.*, 1986).

Arias (1988) compared the decay rates of common tree components in agro ecosystem in Colombia. The half life of litter was 60 days for *Albizia carbonaria*, 80 days each for *Glyricidia sepium* and *Sesbania grandiflora*, 120 days each for *Erythrina sp*. and *Cajanus cajan* and 170 days for *Cassia grandis*. For Albizia, Sesbania and Gliricidia over 80 per cent of N, P and K were released within 170 days.

Decomposition studies in a tropical agroforestry system revealed that during 274 day exposure of litter bags in the field, the mass loss in *Leucaena sp*., *Populus deltoides*, *Eucalyptus sp*. and *Prosopis juliflora* was 86.3, 75.6, 60.5 and 69.0 per cent respectively (Bhardwaj *et al.*, 1992).

2.1.4 Factors affecting biomass decomposition

The decomposition of organic materials and the release of mineral nutrients from the decaying leaf biomass is mainly the result of complex interactions between microbial populations and activities, which in turn, is affected by many of the following factors.

2.1.4.1 Substrate quality

Substrate quality, as defined by chemical composition of the decomposing material, has long been recognized as a critical factor determining the rates of decay (Waksman and Jenney, 1927 and Meentemayer, 1978).

2.1.4.1.1 Water soluble substances

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

High initial rate of weight loss from Alfalfa leaves was followed by lower rates possibly as a result of leaching during initial stages (Jenney _et al_., 1949). The content of water soluble organic material vary greatly with the species. The content of water soluble materials in the leaves of _Fraxinus excelsior_ was 32 per cent, while in _Quercus petraea_ it was only 18 per cent (Gilbert and Bocock, 1960).

In the Hubbard Brook forest, Gosz _et al_. (1973) found a marked difference in the weight losses of litters of yellow birch, sugar mapple and beech leaves by the end of first month as a result of intense leaching of soluble organic materials. Lossaint (1953) examined the litter decay of nine species and showed that higher the content of nitrogen and water soluble matter including calcium, the more rapid will be the rate of decomposition. Studies in scots pine and lodgepole pine revealed that mass loss rates were positively correlated with concentration of water soluble substances and nitrogen and negatively correlated with those of lignin (Berg and Landmark, 1987).

2.1.4.1.2 Initial nitrogen

Nitrogen content of the plant material has been shown to be an important factor controlling the rates of decomposition in most of the species (Cowling and Merrill 1966 and Aber and Melillo, 1980). Several studies have demonstrated that the addition of supplementary nitrogen to natural litter materials (Mahendrappa, 1978) and incorporated crop residues (Allison and Cover, 1960) can enhance their rate of decomposition.

Fresh plant materials vary considerably in their nitrogen content. Tropical tree leaf biomass has a higher N content than that of temperate forests (Nye, 1961). Nitrogen content of deciduous leaves is relatively higher than that of conifers (Alway *et al*., 1933).

Studies by Kumar and Deepu (1992) using six deciduous tree species revealed that *Pterocarpus marsupium*, *Grewia tiliaefolia* and *Xylia xylocarpa* showed faster initial rate of decomposition owing to their high initial N contents. Similar trend was also attained by Aber and Melillo (1982) in their studies on decomposition using various tree species. Bahuguna *et al*. (1990) conducted a study using *Shorea robusta* and *Eucalyptus* species. Eucalyptus showed a higher initial nitrogen (1.12%) and consequent faster mineralisation compared to Shorea which incidentally had a lower N content (0.57%).

2.1.4.1.3 Carbon:nitrogen ratio

The C:N ratio of plant residue plays a crucial role in biomass decomposition. 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. As the readily metabolized substances are exhausted, the nutrient limitation shifts from nitrogen to carbon (Knapp *et al*., 1983). They suggested that decomposition was N regulated during the initial decay period and by C during the prolonged incubation.

Barry et al. (1989) conducted elaborate studies on eight species to identify the best predictors of litter decay rates. In all the species they tried to correlate the initial N content, the C:N ratio and lignin:nitrogen ratio with decomposition rates. They concluded that C:N ratio and nitrogen 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 microbes and also to release nitrogen for plant use. A laboratory study was made in Ukraine to compare chemical processes in decomposition of Scots pine litter at C:N ratios of 20, 15 and 10. The highest degree of decomposition was observed at a C:N ratio of ten (Bondar, 1975).

2.1.4.1.4 Lignin

Several studies have indicated that the initial lignin content of the litter exerts more control over rate of decomposition than does nitrogen (Bollen, 1953; Fogel and Cormack, 1977 and Melillo et al., 1982).

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

Berndse et al. (1987) studied the effect of lignin and nitrogen on the decomposition of litter in nutrient poor ecosystems. They derived a negative linear relationship between lignin concentration and rate of mass loss under conditions when both carbon and nitrogen are limiting.

2.1.4.1.5 Lignin:nitrogen ratio

The effect of chemical composition of leaf litters on decomposition was studied by Pande and Singh (1982) in an oak conifer forests of Himalayas. They found that the influence of nitrogen decreased with time, whereas, that of lignin increased. A combination of these two factors contributed 59 per cent in annual weight loss of litters.

Melillo et al. (1982) observed that the decay rate constants for hardwood forests in New Hampshire ranged from 0.08 to 0.47 and were found to be negatively correlated with initial lignin:nitrogen ratio. The amount of biomass remaining showed an inverse linear relation with their nitrogen content, which in turn was negatively correlated with the initial lignin concentration.

Kumar and Deepu (1992) calculated the lignin: nitrogen ratio of five deciduous tree species from Kerala, peninsular India. They observed that Dillenia pentagyna, Terminalia paniculata and Tectona grandis showed a high lignin:nitrogen ratio indicating the lower rate of mineralization. Biomass decomposition and nutrient dynamics were monitored by Edmonds (1987) under four ecosystems in Washington. He concluded that decomposition constant was closely related to initial lignin:nitrogen ratio than the lignin alone.

2.1.4.1.6 Ligno cellulose index

Leaf litter decay studies by Melillo and Aber (1989) on red pine has clearly demonstrated the influence of lignin on the late decomposition phase. They used the ratio of lignin concentration in leaf litters to the concentration of lignin plus acid soluble carbohydrates in the litter as an index of plant material's susceptibility to microbial attack and this was referred to as lignocellulose index (LCI). After conducting elaborate studies using several tree species, they concluded that different leaf materials of different LCI's incorporated into the soil reach a common LCI value ranging from 0.7 to 0.8. Till the attainment of this range, decay rate is a function of initial litter quality and other factors of decomposition. But once the litter materials pass through the "decay filter" all litter materials are reduced to a least common denominator in terms of chemical quality.

2.1.4.1.7 Polyphenol

Plant contain a variety of poly hydroxy phenols constituting five to fifteen per cent of their dry weight. There are strong evidences regarding the influence of these substances on controlling rate of decomposition (Edwards and Heath, 1963).

An inverse relationship between polyphenol concentration and the rate of decomposition due to feeding activities of soil animals has been well established by Satchell and Lowe (1967). DeMoral and Muller (1969) also noticed high content of polyphenols in Eucalyptus leaves which hindered their decomposition rate. Vallis and Jones (1973) noted that the legume *Desmodium intortum* recorded three per cent less mineralisation rate compared to *Phaseolus atropurpurens*, though the two species recorded uniform nitrogen and lignin content. This was proved to be because of high content of polyphenols in the biomass.

2.1.4.2 Effect of environmental factors on decomposition

Moisture and temperature are reported to be the two most important abiotic factors controlling the rate of biomass decomposition under natural conditions (Van Der Drift, 1963; Singh and Gupta, 1977 and Moore, 1986).

2.1.4.2.1 Moisture

The positive influence of moisture on activities of microbes, particularly arthropods, was established by Madge (1965). He also revealed that during wet season there were more animal populations on the leaf disks than during the dry season.

In tropical grasslands, Gupta and Singh (1977) reported highest disappearance at the rate of 36.25 to 52.85 per cent from July to October, when there was maximum rainfall. A weight loss of only 14.78 to 25.5 per cent has been recorded during the remaining five dry months. A high rate of litter decay during rainy season in tropical condition has also been observed by Singh et al. (1980). Leaf decay rates were found to be a linear function of water potential, and approached maximum near 40°C (Moore, 1980).

Decomposition studies in a deciduous broad leaved forest indicated that soil moisture conditions have a greater effect on decomposition rate compared to chemical composition of the litter (Ishii et al., 1982). Hutson and Veitch (1985) established a linear relationship between decomposition constant and mean annual rainfall of 600 to 1800 mm per year.

Weight loss was found to be correlated with intensity and distribution of rainfall. Studies on an altitudinal transit in the Himalayas showed that decomposition rate increased with increasing litter moisture and air temperature (Upadhyay and Singh, 1986).

The effect of seasonal temperature and moisture variations on the rate of decomposition of eucalyptus leaf litter collected from two climatically different regions of Victoria were studied by Orsborne and Macauley (1988). Dry weight losses were found to be positively correlated with soil moisture content. Of the two regions the one with 31 to 40 per cent moisture at 25°C air temperature characterised a maximum weight loss when compared to the region with low soil moisture status (soil moisture 18.5 to 20 per cent at 30°C air temperature).

Luizao and Schubart (1987) conducted leaf decomposition studies in Central Amazon. They stated that litter decomposition was faster in wet season. One half of the litter disappeared in about 32 days during wet season as against 218 days during dry season. They suggested that the intense termite activity in the rainy season was responsible for more than 40 per cent removal of decomposing leaves.

In general, fungi and actinomycetes are relatively tolerant to low moisture potentials. Catabolic activity of the total microbial biomass may be limited at moisture potentials below -1000 to -5000 KPa (Wilson and Griffin, 1975). Under anaerobic (saturated) conditions, decomposition is dependent on anaerobic bacteria which are said to be less efficient as compared to aerobic organisms (Yoshida, 1975 and Patrick, 1982). Thus, decomposition proceeded at a slower rate in high (more than 100 to 150%) and low (less than 30 to 50%) moisture content situations (deBoois, 1974).

2.1.4.2.2 Temperature

Olson (1963) reported that presence of low content of carbon in highly productive tropical forests whereas in cool temperate forests, a high level of carbon was observed. He further pointed out that in sub alpine forests temperature tended to affect the biological activity resulting in lower rates of biomass decomposition. Rate of decomposition in warm tropical rain forest was found 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).

In a laboratory experiment with grass litter, Floate (1970) observed that the amounts 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.

Decay studies of Chamaecyparis obtusa and Quercus serrata leaves placed in vinylon-net bags revealed that temperature was the more important factor in determining the decomposition rate in relation to species and type of leaves (Inagawa, 1972). Marked influence of temperature on biomass decomposition is primarily because of its effect on microbial populations. The mesophylic bacteria, actinomycetes and fungi require temperature below 45° C for their optimum activities while the thermophilic bacteria require a temperature range of 45°C to 60°C (Alexander, 1977).

The combined effect of high temperature and moisture is more pronounced than that of temperature alone (Jenney et al., 1949). They reported a heavy weight loss in Alfalfa leaves under high temperature and moisture conditions in tropical climate. The microbial activity is favoured during summer due to high moisture and temperature thus accelerating the rate of decomposition (Witkamp and Van der Drift, 1961).

2.1.5 Patterns of biomass decomposition

The general kinetics of biomass decomposition follow a biphasic process (Berg and Staaf, 1981). This involves a period of rapid catabolic stage followed by a period of slow

CO_2 evolution. The rapid catabolic process involve the metabolization of readily digestible water soluble compounds such as amino acids, proteins, simple sugars and polysaccharides (Alexander, 1977). During the later period, more biodegradation resistant compounds were found to be metabolized (Brady, 1984). Evolution of some amount of CO_2 during the slow decay period is the result of the catabolism of microbial polymers synthesised during their initial decomposition (Bocock, 1964). Some readily metabolized substances may not be catabolized during the initial rapid decomposition phase because of their physical protection from contact with decomposer community.

A typical biphasic pattern of biomass decomposition was noticed by Singh et al. (1993). Among the four species studied, the annual dry weight loss (% of original) of leaf litter was maximum for sal (87%) followed by teak (72%), poplar (50%) and eucalyptus (50%). The weight loss of sal was rapid during the first 3 to 6 months. Almost a similar trend was observed in teak. There was a slow rate of decomposition of eucalyptus as compared to other species. Poplar showed a steady rate of decomposition during first six months.

Olson (1963) tried to predict the decomposition rates of various species using mathematical models. Such models will help to predict the rate of decay and also serves as an index of rate of decomposition of added leaf biomass.

2.2 Nutrient release patterns

Although the rate at which the nutrients are released from the litter is generally governed by the rate of decomposition, various nutrients are found to be released at different rates and may exhibit differential release patterns (Singh and Gupta, 1977 and Swift et al., 1979). Experiments by Dalton et al. (1952) suggested that the organic matter added to the soil as an amendment is effective in increasing the availability of soil phosphates. Easily decomposable organic matter is more effective in this regard compared to organic substances that decompose slowly.

The rate and extent of loss of dry matter, P, Mg, Ca, K and Na during decomposition of plant materials were studied in mature Eucalyptus obliqua forest in Australia (Attiwill, 1968). Maximum loss was accounted 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. Rapid decrease in potassium content was noticed in the decomposing cacao leaves by Humphrier and Rodrigues (1945).

Decomposition rates and changes in the nutrient content of needles and leaf litters were examined in Douglas fir, Western hemlock, Pacific silver fir and Red alder under various ecosystems in Western Washington by Edmonds (1980). The pattern of loss of elements from litter bags after two years exhibited lot of variation with regard to ecosystems. In general, all the species recorded maximum mineralisation and leaching of K followed by Mg, Ca, P, N and Mn in Red alder; Mg, Ca, P, Mn and N in Douglas fir; Ca, Mg, N, Mn and P in Western hemlock and Mg, Ca, Mn, P and N in Pacific silver fir.

In Scots pine, P was found to be the most limiting element for microbial activity during the initial phase. There appeared to be little initial leaching from the litter and the differential behaviour of these elements could largely be explained by their concentration in litter in relation to the needs of microorganisms and to their solubility. Potassium and Mg were found to be released at the rates similar to weight loss of organic matter (Staaf and Berg, 1982). The same authors also conducted long term studies on the nutrient release pattern of Scots Pine. They found that nutrients were retained (to a weight loss of about 75 per cent) in the order of Mn followed by Ca, K, Mg, S, N and Phosphorus. During the first 18 months there was a net increase in N and P, followed by a net decrease which emphasised the fact that P was the most limiting element for microbial activity.

Shukla and Singh (1984) demonstrated the nutrient release patterns in *Shorea robusta* in a tropical sal forest. They found that the Ca content of the litter declined throughout the year while P concentration remained almost stable. The concentration of all the elements particularly K and Mg showed small variations during the year.

In Himalayan Oak-conifer forest, the total annual release of nutrients on the site through decomposition was related to total input through litter fall which amounted to 56 per cent of N, 83 per cent Ca and 97 per cent for water soluble compounds (Pandey and Singh, 1984).

Baker and Attiwill (1985) compared the nutrient release patterns in *Eucalyptus obliqua* and *Pinus radiata.* In pine, N was immobilised for 2 years but Eucalyptus leaves showed a net N release after one year. Moreover, about 20 per cent of P was found to be lost in the first three months after which there was a little change. Potassium and Na reduced rapidly in the initial stages but during the later stages, the change was found to be poorly correlated with mass loss. Ca and Mg losses were comparable with loss of organic matter.

In *Alnus nepalensis* growing in Eastern Himalaya, the initial labile fraction of nutrients declined in the sequence potassium followed by P, Ca and N. Half life was said to be short for K (2.4 months) and P (2.7 months) but approximately 10 times longer for nitrogen (21 months) as reported by Sharma and Ambasht (1987).

Studies of Bahuguna *et al*. (1990) on nutrient release patterns in plantation of *Shorea robusta* and *Eucalyptus camaldulensis* growing on similar eco-climatic and edaptic condition in Dun Valley indicated that elemental mobility in decomposing shorea litter was highest for Mg followed by K, P, Ca and N whereas for eucalytpus K recorded a faster mobility followed by Mg, P, Ca and N.

Stohlgren (1988) tried to account the nutrient release in Giant sequoia, White fir, Sugar pine and Incent cidar. There was a marked species variation in nutrient release patterns. Nitrogen immobilisation was pronounced in all the species at varying degree. Phosphrous was strongly immobilized by sequoia and temporarily by White fir. Potassium and Mg were quickly released in all the species. Ca was immobilized by sugar pine while quickly released in incent cidar leaf litter. Strong linear or negative exponential relationship was found to exist between initial concentrations of N, P, K and Ca and per cent of original biomass remaining.

Prasad *et al*. (1991) reported that incubation of tree leaves viz. sal, teak eucalyptus, subabul mixed with soil and remained for 12 months, increased the available P, K and exchangeable Ca and Na significantly. In general, the magnitude of nutrient availability increased with increase in the quantity of tree leaves. Bargali *et al*. (1993) described the patterns of nutrient release in decomposing leaf litters of Eucalyptus in tarai belt of central Himalaya. Nitrogen and P concentration showed an increase in their content. Towards the end of decomposition, the concentration of nutrients were about two fold higher than the initial content. Potassium was found to be actively leached resulting in lower concentrations as compared to the original litter.

The dynamics of 12 elements in decomposing leaf biomass of jack pine, paper birch, trembling aspen and northern pine oak were examined in north western Wisconsin by Bockheim et.al (1991). The concentration and absolute amounts of N, Ca, S, Zu, Mn, Fe, Cu, and Al generally increased after one year of decomposition. Sometimes the levels of P, K, Mg and B in the decaying leaf litter was found to be decreased. Two way analysis of variance tests revealed significant difference in dry matter content and concentration of most of the elements and this was said to be a function of species and time.

The changes in nitrogen, P, Ca and S in the decomposing biomass generally followed a three-phase process as described by Berg and Staaf (1981). A cubic function described the initial loss, accumulation and final release phase of these nutrients in the decomposing leaf litter.

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

Materials and Methods

MATERIALS AND METHODS

3.1 Study site

3.1.1 Location

The present study was conducted in College of Forestry, Kerala Agricultural University, Vellanikkara during the period 1992-94. The experimental area selected was a mixed dense homestead garden located at Vellanikkara, Trichur district, Kerala lying between 10°31' N latitude and 76° 10' E longitude at an elevation of 22.0 m above msl. The details of climatic and soil conditions are furnished below.

3.1.2 Climate

The area constituting the experimental home garden enjoys a warm humid tropical climate and had received a total annual rainfall of 2931.8 mm, the bulk during the south-west monsoon season of 1993. The wettest months were June, July and August. The mean maximum temperature recorded at the nearby agrometeorological laboratory (100 metre away) varied from 36.2°C (March) to 28.5°C (July). The mean lowest temperature varied from 24.7°C (May) to 22.8°C (January).

3.1.3 Soil

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

3.1.4 Field description

The experiment was laid out in the home garden of about one to two acres where different varieties of horticultural crops were planted and maintained in a very intensive manner (Plates I and II). The area was dominated by coconut and arecanut. A variety of tree crops such as mango, nutmeg, tamarind, annona, guava, moringa, bilimbi etc. were sparsely arranged in the available spaces. Other fruit crops such as banana and papaya and root crops like amorphophallus, colocasia, turmeric etc. were the dominant components of the ground vegetation. The field also supported a variety of forest tree species like Tectona grandis, Alstonia scholaris, Garuga pinnata, Azadirachta indica, Bombax ceiba etc.,which are irregularly distributed, mostly towards the boundary of the plot. Most of the tree crops have been trained with pepper, the Erythrina-pepper association being very common. The trees, herbs and shrubs were so closely arranged that only filtered sunlight was reaching the ground.

3.1.4.1 Cultural practices

Most of the horticultural crops were maintained as per the POP recommendations (1994) of the Kerala Agricultural

Plates I&II Panaromic view of the mixed dense home garden representing the study area

Plate I

Plate II

University. Two weedings were carried out in the year; one at the onset of south west monsoon and the other in the month of October. Soil working was done during November. Soil fertility was maintained mainly by the addition of farm yard manure and compost. Fertility has not been much affected through harvesting because the system is mainly perennial.

3.2 Field experiment

The study involves assessment of rates of leaf biomass decomposition and the nutrient flux associated with five woody perennials common to the locality, namely, Schleichera oleosa (Lour.), Oken, Pongamia pinnata (L.) Pierre, Macaranga peltata (Roxb) M.-A., Terminalia paniculata Roth. and Bridelia retusa (L.) Spreng. The description of these species are furnished below.

a. Schleichera oleosa (Lour.) Oken   Family: Sapindaceae

Commonly known as poovam. It is a medium sized to large, deciduous tree which grows upto 32 m in height and is found throughout India upto an altitude of 900 m (Plate III). It is an ornamental tree often grown for its timber and oil. It is also an excellent host for lac insects. The timber is very strong, but not very durable when left in exposed conditions. Macassar oil is extracted from the seeds. The oil cake has good manurial value. Young leaves are used as fodder and leaf manure. The green leaves contain crude protein (10.37%),ether extract (1.93%), crude fibre (32.34%), N-free extract (40.21%) and Gallo-tannic acid (5.09%).

b. Pongamia pinnata (L.) Pierre (Family: Fabaceae)

It is commonly known as Indian Beech and locally called as "Ungu". It is a medium sized tree with a short bole and spreading crown (Plate IV). A fatty oil called pongan oil extracted from the seeds of this tree, is used in leather industry. Wood is easily attacked by insects and hence not desirable for long term use. The leaves are rich in nitrogen and are popularly used as green manures. Green manuring with the leaves is reported to reduce incidence of root-knot nematodes in vegetables.

c. Macaranga peltata (Roxb) M.-A (Family: Euphorbiaceae

Locally called as Vatta. It is a small to medium sized tree distributed throughout India, especially in the hilly tracts. Bark is dark grey, and leaves are peltate (Plate V). The tree reproduces freely and comes up plentiful in old clearings. It is highly resistant for severe pruning and puts forth flushing growth within two to three months. The loppings are extensively applied as green manures to paddy field along the west cost. The leaves are rich in nitrogen and potassium. The wood is light and suitable for

Plates III-VII   View of the tree species included in the study

Plate III *Schleichera oleosa* (Poovam)

Plate IV *Pongamia pinnata* (Ungu)

Plate V *Macaranga peltata* (Vatta)

Plate VI *Terminalia paniculata* (Maruthu)

Plate VII *Bridelia retusa* (Mulkayani)

matches and paper pulp. A reddish gum keno is extracted from the bark which is used for sizing paper.

d. Terminalia paniculata Roth. (Family: Combretaceae)

A large deciduous tree found in the tropical semi-evergreen and moist deciduous forests of the western ghats upto an elevation of 1200 m (Plate VI). The timber is excellent for constructional purposes and is frequently used as a substitute for teak. The branches are extensively lopped and incorporated into the soil as leaf manure.

e. Bridelia retusa (L.) Spreng. (Family: Euphorbiaceae)

This is commonly known as Mulkayini or Mulluvenga. It is a medium sized tree grows upto 18 m in height, armed with strong conical spines, found throughout India upto an altitude of 1000 m (Plate VII). Bark is grey or brown exfoliating in irregular flakes. Leaves are rigidly coriaceous, lanceolate or ovate. The tree yields medium quality timber of great demand. The leaves are good cattle feed and loppings are conventionally used as leaf manures.

3.2.1 Leaf biomass decomposition

For studying the rates of leaf biomass decomposition, mesh bag technique as described by Bocock and Gilbert (1957) was employed. Fresh leaves of all the five species were collected from the premises of study area and air dried for 48 hours. Representative samples from each species were drawn for the estimation of moisture content before incorporating into soil.

Each sample containing 100 g of fresh leaves was filled in nylon bags (mesh size 2 mm x 2 mm) of size 30cm x 25 cm (Plate VIII). The sides of the bags were properly sealed. Seventy two bags of each species were laid out in three replications. The total number of bags used for the study was 360. All the bags were placed randomly in the field on 5th of July 1993. A thin layer of soil of 2 cm thickness was spread over the trays to avoid misplacements and the bags were labelled properly.

Samples were taken at fortnightly intervals starting from 20th of July, 1993. Three samples of each of these species were retrieved from the field by carefully removing the accumulated soil and litter over the bags. Samples were taken to the laboratory immediately. After removing the extraneous materials like arthropods, fine roots and other soil particles, the samples were carefully washed under running water and finally rinsed with distilled water.

The contents of the bags were transferred to paper bags, oven dried at 70°C for 48 hours and then recorded the mass using a precision balance.

Plate VIII Nylon litter bag used for the decomposition study

Plate VIII

3.2.2 Chemical analysis of the detritus

The fresh leaves and the residues after drying were powdered in Willey mill. The fine powder was used for the estimation of various nutrient elements like N, P, K. Ca, Mg and S. Total carbon was analysed both in fresh samples and also residues at three sampling intervals. Similarly lignin content was also estimated for fresh samples and for samples retrieved on sixth and tenth months. The standard procedures adopted for the chemical analysis are described hereunder.

3.2.2.1 Total carbon

The total carbon was estimated by the standard method as suggested by Gaur (1975) by igniting the samples at 550°C for six hours in a muffle furnace.

3.2.2.2 Nitrogen

Nitrogen content was determined in fresh leaves and the residues sampled at monthly intervals by digesting 0.1 g of the samples in 5 ml of concentrated sulphuric acid using hydrogen peroxide. Nitrogen in the digest was estimated colorimetrically using Nessler's reagent (Wolf, 1982). The colour was read in UV spectrophotometer at 410 nm.

3.2.2.3 Phosphorus

One gram of the leaf sample was digested with diacid mixture and a known aliquot was used to determine the phosphorus content using the Vanadomolybdo phosphoric yellow colour method (Jackson, 1958). The colour was read in the UV spectrophotometer at a wave length of 410 nm.

3.2.2.4 Potassium

The potassium content was estimated in a known aliquot of the diacid extract using a flame photometer.

3.2.2.5 Calcium

0.05 ml of the diacid extract was made upto 25 ml along with one ml of strontium chloride solution and Ca was estimated directly using Atomic absorption spectrophotometer.

3.2.2.6 Magnesium

Mg was also estimated from the above extract using the atomic absorption spectrophotometer.

3.2.2.7 Sulphur

Sulphur was estimated in the diacid extract following the turbidometry using $BaCl_2$. The turbidity was read at 410 nm.

3.2.2.8 Lignin content

The method suggested by Van Soest (1966) for the estimation of acid detergent fibre and lignin was used here also. For lignin assay, one gram of leaf sample was weighed to which 100 ml of cold acid-detergent solution (prepared by adding 20 g of cetyl trimethyl ammonium bromide to one litre of IN H_2SO_4) and 2 ml of decaline were added which was then refluxed for 60 minutes. The sample was then filtered, washed with acetone, dried overnight and then weighed to determine the acid detergent fibre. H_2SO_4 (72%) was poured into this dried samples and intermittently stirred. After filtering this solution, the sample was dried over night and weighed. This was then kept in a muffle furnace for 3 hours at 600°C and again weighed. The difference in weight was used for the estimation of lignin.

3.2.3 Soil analysis

Representative soil samples from the experimental area was taken at periodic intervals and analysed for soil moisture and pH as per standard procedures (Jackson, 1958). Due care was taken to sample the soil just below the litter bag.

3.2.4 Statistical analysis

The observations recorded on leaf biomass decomposition was statistically analysed by using the method suggested by Panse and Sukhatme (1978). The decomposition rate was also statistically correlated with weather parameters and soil properties.

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

$$X/X^{o} = e^{-kt}$$

where,

X = the weight remaining at time t

X° = the original mass

e = base of the natural logarithm

k = the decay rate coefficient

t = time

Half lives ($t_{0.5}$) of decomposing litter were estimated from the k-values using the equation suggested by Bockheim *et al.*, 1991.

$$t(0.5) = \text{In } (0.5)/-k$$

$$= -0.693/-k$$

For the estimation of nutrients remaining in the decomposing leaf biomass, a method suggested by William (1990) was used. Twenty five regression models were tried to characterise nutrient mineralisation over time.

Results

RESULTS

Leaf biomass decomposition and nutrient release patterns were studied for five tropical tree species namely *Schleichera oleosa* (Lour.) Oken, *Pongamia pinnata* (L.) Pierre, *Macaranga peltata* (Roxb) M.-A.,*Terminalia paniculata*. Roth and *Bridelia retusa* (L.) Spreng. The results are outlined below.

4.1 Leaf biomass decomposition

4.1.1 Rates of biomass decomposition

The data related to the decomposition of leaf biomass of five woody tree species at fortnightly intervals are presented in table 1. All these species generally showed a faster rate of decomposition. Statistical analysis of the decomposition data corresponding to the end of first month revealed significant difference among the species. At the end of first month, the percentage of initial weight remaining in the litter bags was maximum for *S. oleosa* (77.07%) followed by *T. paniculata* (68.12%), *P. pinnata* (64.75%), *B. retusa* (60.65%) and *M. peltata* (49.96%).

Decomposition data corresponding to second month also showed a significant difference among the species. *P. pinnata* retained a higher percentage of initial mass (56.63%) followed

Table 1. Variation in the decomposition rate of tree species at fortnightly intervals

Fort-Nights	Tree species									
	S. oleosa		*P. pinnata*		*M. peltata*		*T. paniculata*		*B. retusa*	
	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)
0	38.36	100.00	46.62	100.00	34.70	100.00	34.12	100.00	44.50	100.00
1	33.04	86.14	35.51	76.18	22.47	64.75	23.44	68.71	32.82	73.76
2	29.56	77.07	30.18	64.75	17.34	49.96	23.24	68.12	26.99	60.65
3	22.32	58.19	28.49	61.13	11.01	31.72	18.88	55.34	15.78	35.48
4	19.77	51.53	26.40	56.63	10.33	29.76	14.32	41.97	8.11	18.22
5	10.24	26.71	18.07	38.75	5.47	15.75	11.29	33.09	3.61	8.12
6	3.84	10.00	17.25	37.00	3.82	11.01	2.68	7.85	2.27	5.10
7	3.40	8.87	16.70	35.83	3.61	10.40	1.77	5.18	1.40	3.15
8	3.03	7.91	14.47	31.04	3.58	10.30	1.34	3.93	1.35	3.03
9	2.91	7.59	14.39	30.86	3.49	10.05	0.96	2.81	1.16	2.61
10	2.53	6.60	12.25	26.28	3.50	10.08	0.95	2.78	1.05	2.37
11	2.42	6.31	11.88	25.48	3.31	9.55	0.64	1.87	1.01	2.28

Contd.

Table 1 (Contd.)

Fort-Nights	S. oleosa		P. pinnata		M. peltata		T. paniculata		B. retusa	
	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)	Mass remaining (g)	Relative mass (%)
12	1.63	4.24	11.03	23.67	3.12	8.99	0.59	1.75	0.98	2.19
13	1.35	3.52	10.58	22.69	2.79	8.03	0.53	1.56	0.92	2.07
14	1.05	2.75	10.46	22.44	2.92	8.42	0.47	1.37	0.84	1.90
15	0.96	2.49	7.44	15.95	1.93	5.57	0.45	1.34	0.80	1.81
16	0.90	2.35	6.93	14.86	1.42	4.10	0.38	1.10	0.80	1.80
17	0.91	2.37	4.64	9.95	1.08	3.11	0.35	1.03	0.66	1.48
18	0.77	2.01	3.37	7.22	0.97	2.78	0.35	1.02	0.64	1.44
19	0.70	1.82	3.04	6.52	0.91	2.63	0.34	1.00	0.64	1.44
20	0.68	1.76	3.01	6.46	0.89	2.56	0.33	0.98	0.63	1.43
21	0.65	1.69	2.84	6.08	0.89	2.56	0.32	0.94	0.54	1.21
22	0.59	1.53	2.71	5.82	0.91	2.61	0.30	0.90	0.51	1.15
23	0.52	1.36	2.69	5.78	0.77	2.21	0.29	0.84	0.44	1.00
24	0.49	1.29	2.65	5.68	0.70	2.03	0.21	0.64	0.34	0.76

Tree species

CD(0.05) = 0.026   SEM $\pm$ 0.009

by *S. oleosa* (51.33%), *T. paniculata* (41.97%) and *M. peltata* (29.76%). *B. retusa* recorded a higher mass loss with only 18.22 per cent of original mass remaining at the end of two months.

A rapid reduction in the mass remaining in the litter bags was noticed among all the species at the end of three months of exposure for decomposition. More than 60 per cent of the initial mass was lost for all the species. Maximum decomposition was noticed for *B. retusa* while the least was noticed for *P. pinnata* at the end of three months. The difference in the decomposition rate of other species during this period was not statistically significant.

After four months of exposure to decomposition, *B. retusa* and *T. paniculata* recorded no significant difference between their mass loss rates. The data clearly indicated that these two species had lost more than 96 per cent of their original mass. Similarly *S. oleosa* and *M. peltata* were on par with respect to their rates of decomposition. These two species recorded more than 89 per cent of mass loss during the same period. Interestingly, *P. pinnata* showed a significant difference compared to all the remaining species and recorded the lowest decay rate (31.04 per cent mass remaining).

From 4th month onwards *P. pinnata* and *M. peltata* showed slower decay rates compared to the other three species. However, the difference between the two species was significant. All the remaining species were found to be on par.

The rate of decomposition was relatively very slow for *P. pinnata* from 8th month onwards. The same trend was continued till the end of the study. At the end of the study period, i.e. after one year, *T. paniculata* registered maximum rate of decomposition with only 0.64 per cent of original mass remaining in the litter bags. The undecomposed mass remaining for the other species were 0.76 per cent for *B. retusa*, 1.29 per cent for *S. oleosa* and 2.03 per cent for *M. peltata*. *P. pinnata* was characterised by the slowest decomposing rate with 5.68 per cent of original mass remaining at the end of one year.

4.1.2 Pattern of biomass decomposition

The general pattern of biomass decomposition for the different species is illustrated in figure 1. It follows a biphasic pattern with an initial rapid decomposition period followed by a slower decomposition phase. For species such as *S. oleosa*, *T. paniculata* and *B. retusa*, 90 per cent of biomass decomposed within a period of three months. Thereafter, they

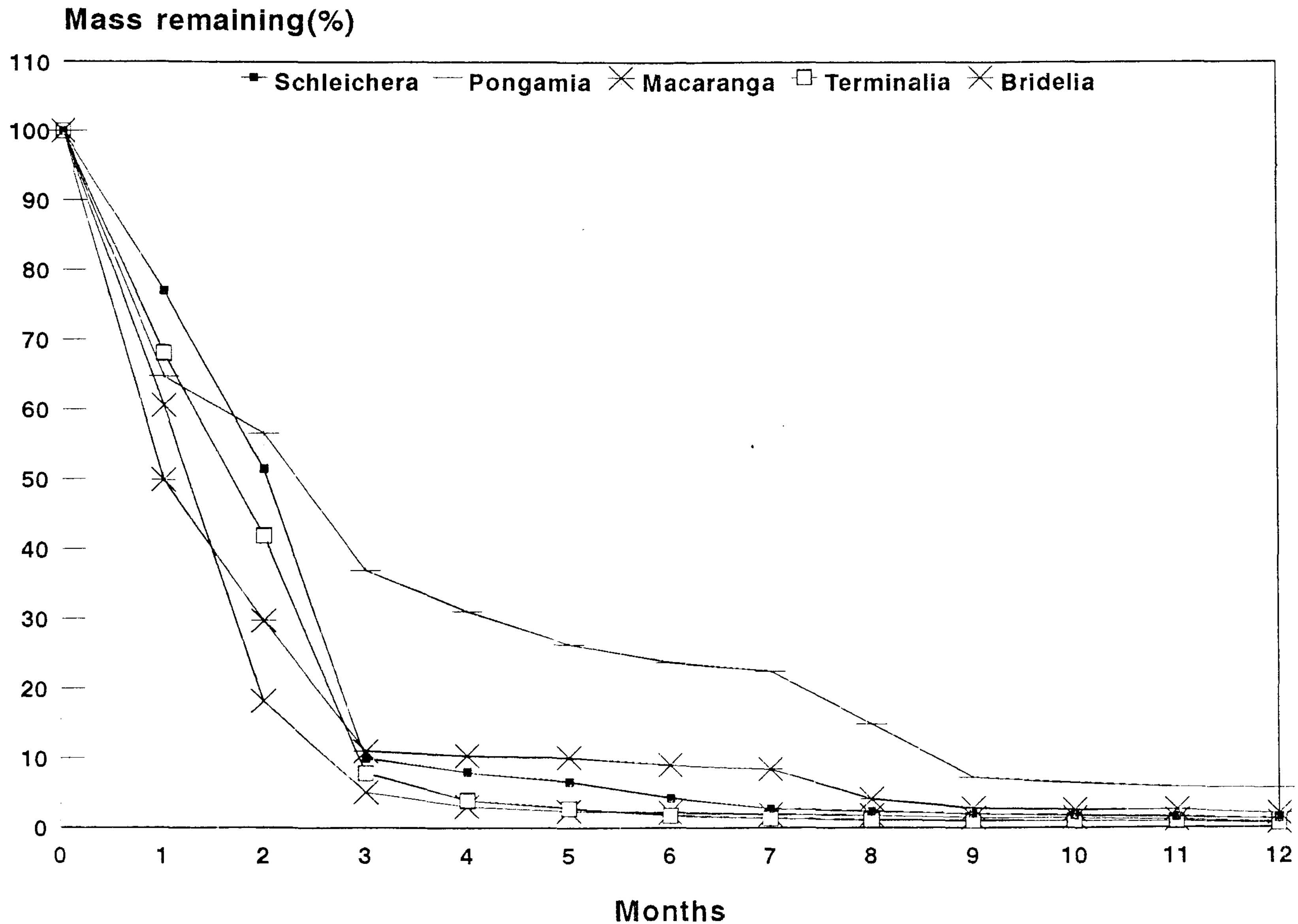

Fig. 1 Monthly variation in the rate of decomposition of leaf biomass

followed a gradual declining trend till the end of the study. Almost a similar trend was noticed for *P. pinnata* and *M. peltata* also. However, *P. pinnata* resumed the slow second phase from the second month onwards and declined gradually till the last month.

4.1.3 Decomposition model

The statistically analysed data for the decay rate coefficient (k) for different species are furnished in appendix-I. Higher k values were recorded for *T. paniculata* (0.2570) and *B. retusa* (0.2469) followed by *S. oleosa* (0.2168 and *M. peltata* (0.1901). *Pongamia pinnata* registered the lowest value (0.1297).

To determine the temporal pattern of decomposition of various species, regression equations were fitted by relating the per cent mass remaining in the litter bags with time elapsed and the results are depicted in figures 2 to 6. This clearly indicates the decay models for different species. The single exponential equation showed a good fit for all the species with r^2 values ranging from 0.93 to 0.99 with most of the values exceeding 0.95.

Attempts were also made to correlate the periodic decomposition rates of different species with time elapsed. A high degree of negative correlation was found to exist between

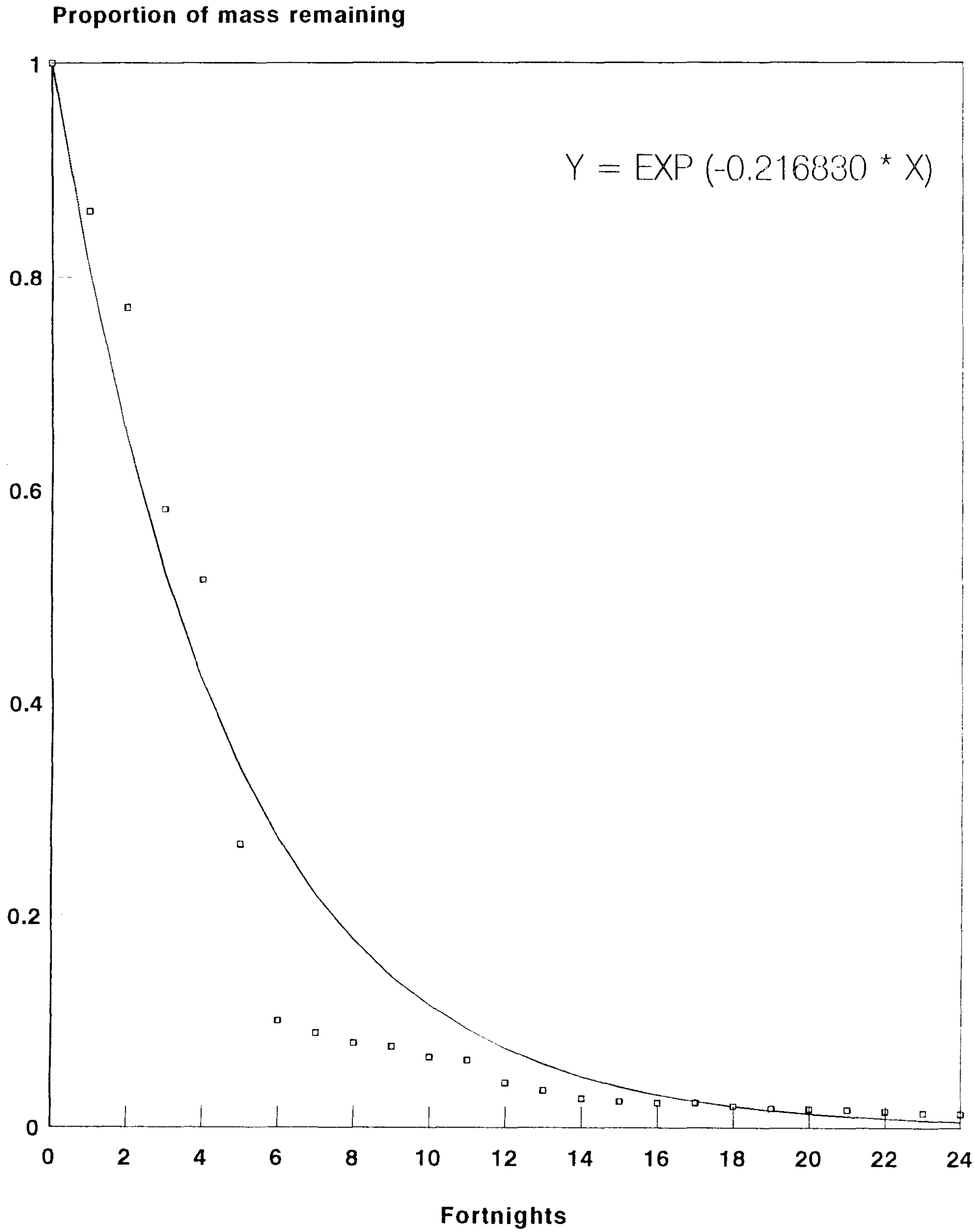

Fig. 2 Leaf biomass decay model for *Schleichera oleosa*

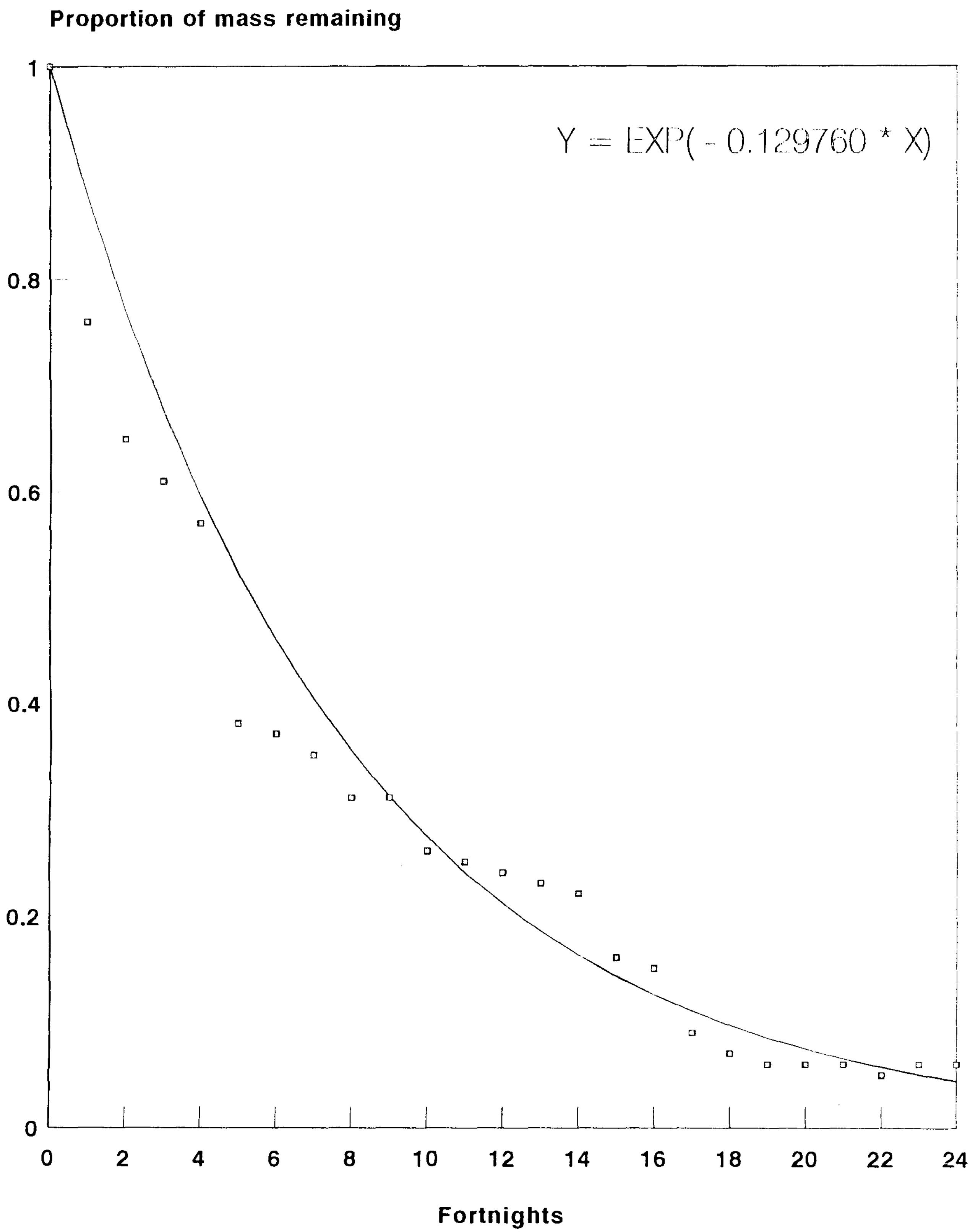

Fig. 3 Leaf biomass decay model for *Pongamia pinnata*.

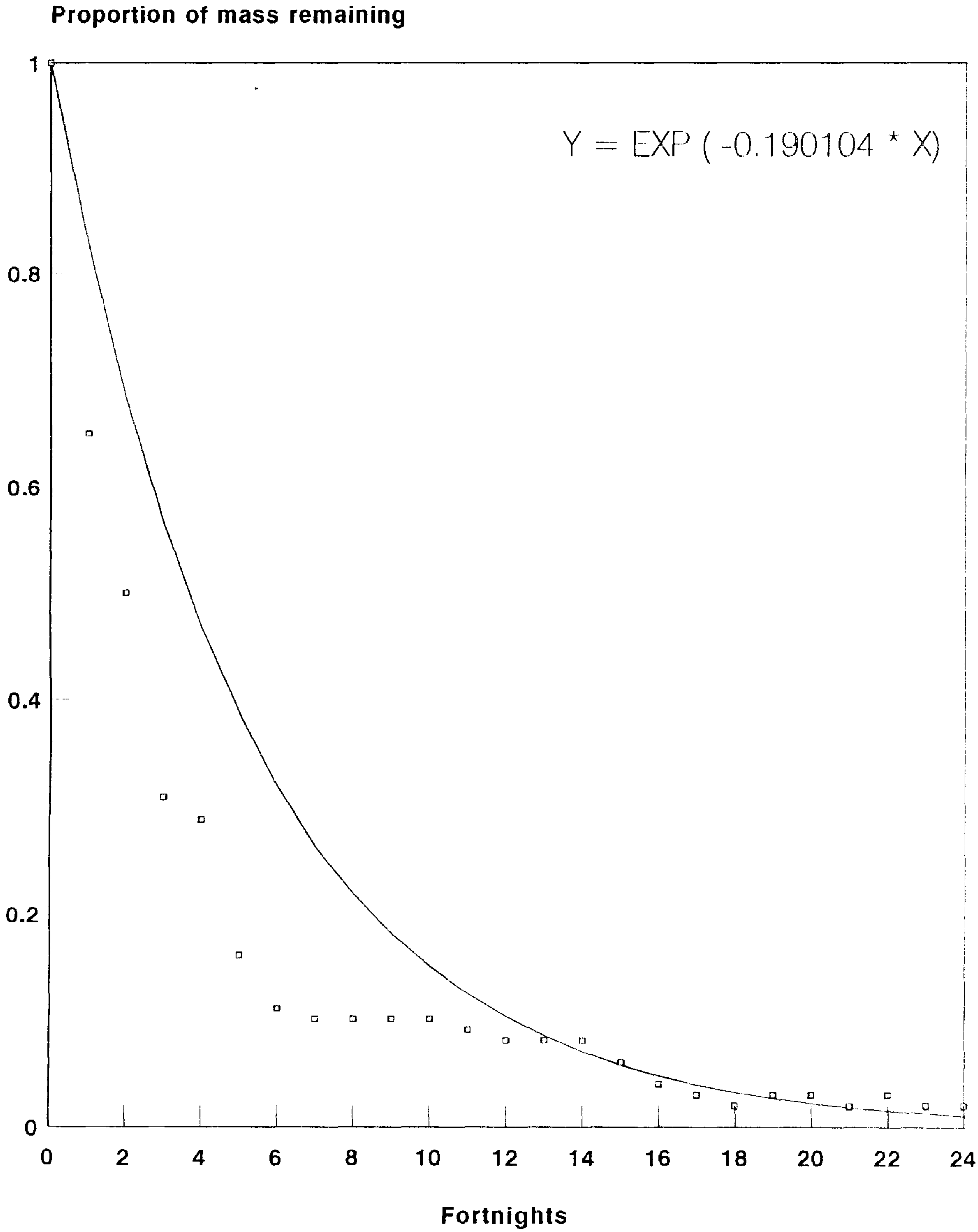

Fig. 4 Leaf biomass decay model for *Macaranga peltata*.

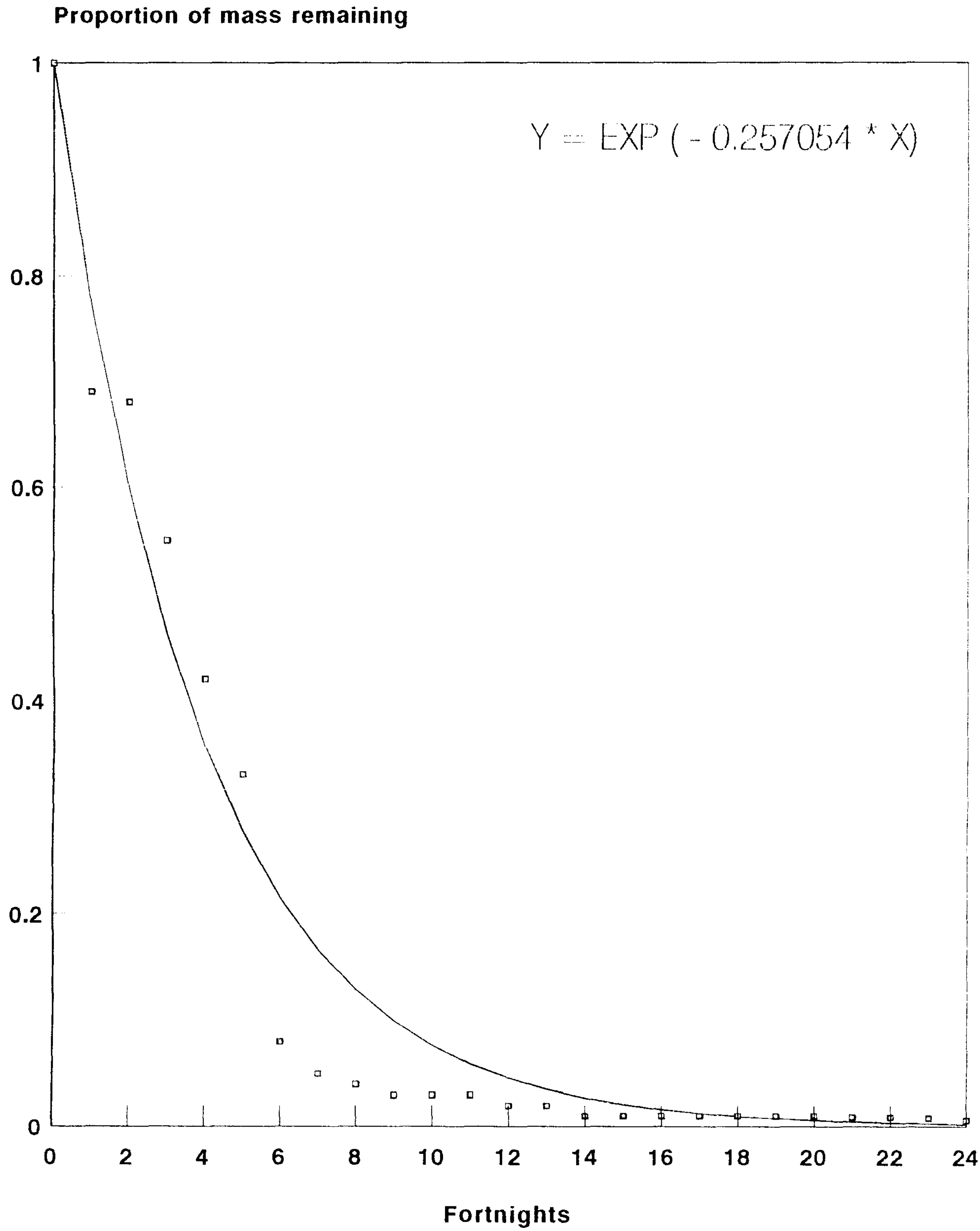

Fig. 5 Leaf biomass decay model for *Terminalia paniculata*.

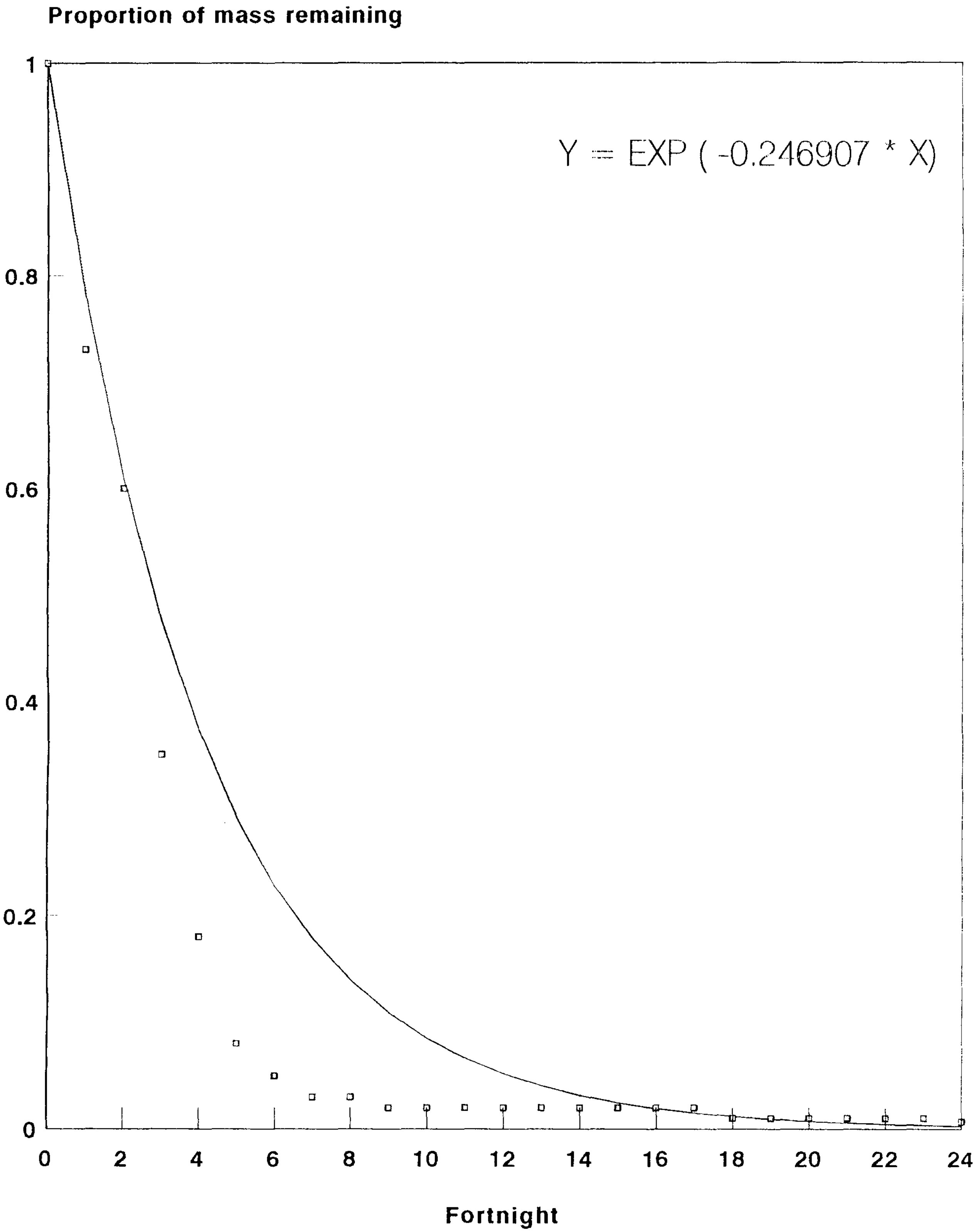

Fig. 6 Leaf biomass decay model for *Bridelia retusa*.

species decomposition and time elapsed with correlation coefficients of -0.7468, -0.9383, -0.770, -0.7371 and -0.6456 for S. oleosa, P. pinnata, M. peltata, T. paniculata and B. retusa respectively.

The data furnished in appendix-I also provide the predicted half life (time taken to decompose 50 per cent of the initial mass) values for various species. The relative half life values were maximum for P. pinnata (5.34 fortnights) followed by M. peltata (3.70 fortnights), S. oleosa (3.20 fortnights), B. retusa (2.80 fortnights) and T. paniculata (2.70 fortnights).

4.1.4 Factors affecting leaf biomass decomposition

The various factors affecting the leaf biomass decomposition are summarised here under.

4.1.4.1 Nitrogen content and C:N ratio

The periodic data corresponding to total carbon content, nitrogen content and C:N ratio of various species are furnished in table 2. It appears that initial N content and initial C:N ratio failed to establish any relationship with rates of decomposition for different species. However, initial carbon content was found to be maximum for M. peltata (45.50%) and P. pinnata (44.91%) but the difference was not

Table 2. Total carbon, nitrogen content and C:N ratio of decomposing leaf samples at various sampling intervals

Species	Initial			Ist month			5th month			10th month		
	C%	N%	C:N	C%	N%	C:N	C%	N%	C:N	C%	N%	C:N
S. oleosa	39.73	3.08	12.9	37.2	3.61	10.3	10.91	2.48	4.4	7.82	2.06	3.8
P. pinnata	44.91	4.83	9.3	24.9	3.42	7.3	21.57	3.48	6.2	12.34	1.82	6.8
M. peltata	45.5	3.67	12.4	25.9	3.08	8.4	13.0	2.21	5.9	8.96	1.83	4.9
T. paniculata	24.7	2.17	11.4	21.6	2.23	9.7	12.42	2.79	4.6	8.29	1.93	4.3
B. retusa	38.1	3.70	10.3	21.5	2.50	8.6	6.88	1.68	4.1	7.06	2.14	3.3
F test	**	**		**	**		**	**		**	**	
CD (0.05)	0.25	0.16		0.40	0.16		0.81	0.03		0.03	0.02	

** Significant at 1 per cent level

significant. Interestingly lower C:N ratio has been reported for P. pinnata (9.3) in the fresh leaf samples. C:N ratio was maximum for S. oleosa (12.9). The data also revealed that there is a gradual declining trend in C:N ratio in the subsequent sampling dates for all the species. However, in the final sampling, ie., during 10th month, P. pinnata showed a higher C:N ratio (6.8).

It could also be seen from the data that the percentage reduction in C:N ratio at the end of 10th month is in the order of 70.55 per cent for S. oleosa, 67.97 per cent for B. retusa, 62.28 per cent for T. paniculata, 60.46 per cent for M. peltata and 26.89 per cent for P. pinnata.

4.1.4.2 Lignin content

The result of the chemical analysis for lignin content of all the species with regard to various sampling periods are tabulated in table 3 and the trend is depicted in figure 7. P. pinnata registered a very high lignin content in fresh samples (21.19%) which was found to be further increased to 29.74 per cent during the 6th month and 36.70 per cent during 10th month of sampling. On the other hand, B. retusa was found to record the lowest values 10.02 per cent in the fresh samples and 13.53 per cent and 16.50 per cent respectively during the 6th and 10th months of sampling. A consistant

Table 3. Lignin content (per cent) of the decomposing leaf biomass at different sampling intervals

Species	Initial	Ist month	10th month
S. oleosa	16.03	18.40	25.53
P. pinnata	21.19	29.74	36.70
M. peltata	16.14	20.19	23.84
T. paniculata	17.24	17.26	17.29
B. retusa	10.02	13.53	16.50
F test	**	**	**
CD	1.82	1.82	1.81

** Significant at 1 per cent level

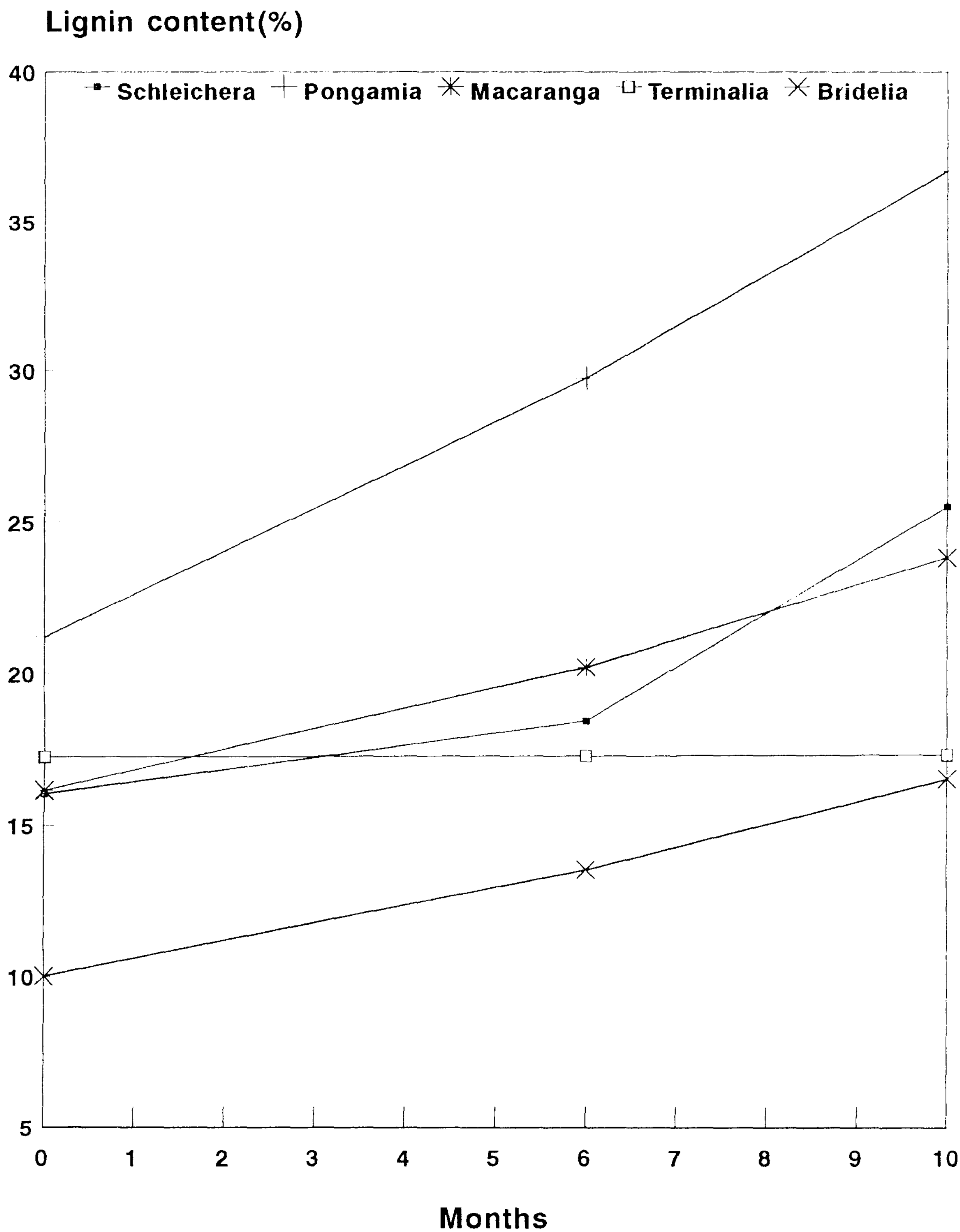

Fig. 7 Changes in lignin content in the decomposing leaf biomass

increase in lignin content is obvious in the initial, mid and final sampling dates for all the species studied.

During the last sampling period lignin content of other species was in this order of 25.53 per cent for S. oleosa, 23.84 per cent for M. peltata and 17.26 per cent for T. paniculata.

4.1.5 Environmental factors

The weather data during the study period are furnished in appendix-II. Attempts were made to correlate important weather variables such as mean monthly rainfall, mean maximum and minimum temperatures, RH and number of rainy days, with rates of decomposition for different species. Very feable correlation existed for all the parameters tested with coefficients ranging from 0.06 to 0.61 which was found to be non significant.

4.1.6 Soil factors

4.1.6.1 Soil moisture content

The moisture content of the study area at monthly intervals are presented in table 4. It could be seen from the table that higher moisture was retained in the soils just below the litter bags of different species during the initial three months and subsequently from October to December soil

Table 4. Moisture content of soils collected below the litter bags of various species at monthly intervals

Months of sampling		Tree species				
		S.oleosa	*P.pinnata*	*M.peltata*	*T.paniculata*	*B.retusa*
1	July	30.75	32.64	27.78	29.35	33.70
2	Aug.	30.93	29.73	26.18	27.48	31.52
3	Sept.	25.29	21.28	21.62	21.45	22.09
4	Oct.	15.68	16.59	16.77	17.90	17.37
5	Nov.	21.27	19.02	18.44	16.67	18.36
6	Dec.	12.16	10.64	18.56	18.15	11.82
7	Jan.	4.64	20.67	6.24	7.38	9.49
8	Feb.	3.25	5.47	3.45	5.04	4.92
9	Mar.	17.52	18.65	16.78	16.94	18.08
10	Apr.	12.58	9.78	10.69	9.90	9.07
11	May	15.29	17.82	15.69	11.31	16.42
12	June	31.76	33.14	30.91	34.20	33.24

moisture was found to be reduced to lower levels. January and February recorded the lowest soil moisture contents for all the species. With the onset of south west monsoon, i.e., from May-June soil moisture values tended to increase significantly.

In the present study, no significant correlation was found to exist between soil moisture content and rates of decomposition of P. pinnata, M. peltata and T. paniculata. However, S. oleosa and B. retusa recorded a very high positive significant correlation with 'r' values of 0.734 and 0.705 respectively.

4.1.6.2 Soil pH

The pH values of the soils under decomposing leaf biomass for different species are tabulated in table 5. Soil pH did not show any marked variation at any period of decomposition. Similarly no significant relationship could be established between pH and the rate of decomposition. However, it appeared that pH registered relatively lower values in the mid and final sampling periods.

Table 5. pH of the soils collected below the litter bags of various species at periodic intervals

Species	Months of sampling			
	Initial	1	6	12
S. oleosa	6.8	6.9	6.6	6.3
P. pinnata	6.7	6.9	6.2	6.4
M. peltata	6.7	6.6	6.4	6.6
T. paniculata	6.9	6.3	6.7	6.7
B. retusa	6.8	6.7	6.3	6.7
F test	NS	NS	NS	NS
CD	--	--	--	--

NS - Non significant

4.2 Nutrient release patterns

4.2.1 Changes in nutrient concentrations

The observations on changes in the nutrient concentrations of decomposing leaf biomass of various species are presented in table 6 and illustrated in figures 8 to 13.

4.2.1.1 Nitrogen

The nitrogen concentrations in the fresh samples was maximum for *P. pinnata* (4.83%) and least for *T. paniculata* (2.17%). A faster decline in N concentration was observed for all the species except for *S. oleosa* after one month (Fig.8). A rapid increase in N concentration was noticed for almost all species during the second month. *P. pinnata* recorded a higher content (4.34%) during this month.

From second month onwards a considerable reduction in N concentration was found to exist for all the species. During the third month, *P. pinnata* retained a higher content (3.0%) while *B. retusa* showed the lowest N content (1.36%). Fourth and fifth month registered a gradual increase in concentration for different species. However, all the species generally showed a decline in concentration for the remaining periods.

Table 6. Changes in nutrient concentration in the decomposing leaf biomass of various tree species at monthly intervals

Species	Time (months)	Biomass remaining (g)	Nutrient concentration (%)					
			N	P	K	Ca	Mg	S
	0	38.36	3.08	0.16	1.12	3.28	1.55	0.15
	1	29.56	3.61	0.14	0.16	3.81	1.26	0.17
	2	19.76	3.96	0.16	0.15	3.18	0.87	0.19
	3	3.83	2.29	0.12	0.05	1.90	0.65	0.20
Schleichera oleosa	4	3.03	2.37	0.10	0.14	2.08	0.68	0.11
	5	2.53	2.48	0.11	0.14	2.29	0.61	0.13
	6	1.62	1.67	0.08	0.11	1.97	0.60	0.08
	7	1.05	1.98	0.12	0.13	1.83	0.52	0.10
	8	0.90	2.17	0.13	0.09	1.48	0.55	0.12
	9	0.77	3.22	0.14	0.18	2.07	0.63	0.23
	10	0.68	2.06	0.14	0.14	1.92	0.58	0.23
	11	0.59	2.04	0.16	0.11	1.45	0.47	0.23
	12	0.49	1.64	0.16	0.07	1.32	0.41	0.19

Contd.

Table 6 (Contd.)

Species	Time (months)	Biomass remaining (g)	Nutrient concentration (%)					
			N	P	K	Ca	Mg	S
	0	46.62	4.83	0.14	0.44	3.67	1.20	0.32
	1	30.18	3.42	0.13	0.12	3.21	0.85	0.29
	2	26.40	4.74	0.12	0.12	2.15	0.80	0.25
	3	17.25	3.00	0.10	0.16	4.33	1.07	0.23
	4	14.47	3.13	0.13	0.12	2.81	0.87	0.23
Pongamia pinnata	5	12.25	3.48	0.10	0.08	4.18	0.63	0.17
	6	11.03	2.70	0.10	0.09	1.94	0.60	0.13
	7	10.46	2.11	0.13	0.12	3.04	0.70	0.11
	8	6.93	2.54	0.12	0.14	3.18	0.68	0.13
	9	3.36	2.41	0.13	0.10	3.70	0.72	0.25
	10	3.01	1.82	0.14	0.05	1.25	0.50	0.22
	11	2.71	1.81	0.15	0.05	1.19	0.47	0.17
	12	2.64	1.83	0.15	0.04	1.20	0.25	0.19

Contd.

Table 6 (Contd.)

Species	Time (months)	Biomass remaining (g)	Nutrient concentration (%)					
			N	P	K	Ca	Mg	S
	0	34.71	3.67	0.15	0.90	3.32	0.90	0.24
	1	17.34	3.08	0.17	0.18	3.85	0.83	0.24
	2	10.33	4.00	0.17	0.17	3.16	0.82	0.21
	3	3.82	2.03	0.14	0.08	2.70	0.93	0.26
	4	3.5	2.91	0.14	0.05	1.90	1.00	0.21
Macaranga peltata	5	3.50	2.21	0.14	2.20	2.91	1.13	0.20
	6	3.12	2.69	0.13	0.18	2.60	0.95	0.19
	7	2.92	2.37	0.15	0.19	2.58	0.95	0.23
	8	1.42	1.86	0.17	0.21	1.98	0.93	0.19
	9	0.97	2.23	0.16	0.20	2.43	0.82	0.21
	10	0.89	1.83	0.16	0.14	1.88	0.75	0.16
	11	0.90	1.51	0.17	0.12	2.46	0.65	0.15
	12	0.70	1.48	0.16	0.08	1.74	0.57	0.15

Contd.

Table 6 (Contd.)

Species	Time (months)	Biomass remaining (g)	Nutrient concentration (%)					
			N	P	K	Ca	Mg	S
	0	34.12	2.17	0.12	0.44	2.55	0.80	0.11
	1	23.24	2.23	0.10	0.16	2.78	0.95	0.10
	2	14.32	3.04	0.10	0.17	4.10	1.00	0.14
	3	2.68	1.59	0.09	0.07	4.38	1.12	0.13
	4	1.34	1.67	0.09	0.11	2.76	0.87	0.14
Terminalia paniculata	5	0.95	2.79	0.10	0.12	2.56	0.67	0.13
	6	0.59	2.19	0.08	0.06	2.36	0.62	0.11
	7	0.46	1.62	0.08	0.07	1.80	0.63	0.09
	8	0.38	1.66	0.10	0.11	1.91	0.67	0.16
	9	0.35	2.07	0.13	0.17	2.15	0.75	0.15
	10	0.33	1.93	0.12	0.08	1.69	0.53	0.16
	11	0.30	1.46	0.14	0.07	1.27	0.43	0.16
	12	0.21	1.90	0.12	0.04	1.25	0.45	0.10

Contd.

Table 6 (Contd.)

Species	Time (months)	Biomass remaining (g)	Nutrient concentration (%)					
			N	P	K	Ca	Mg	S
	0	44.50	3.70	0.13	0.88	3.10	1.78	0.12
	1	26.99	2.50	0.14	0.26	4.60	1.28	0.15
	2	8.11	3.16	0.14	0.15	4.38	0.85	0.21
	3	2.27	1.36	0.08	0.20	3.98	1.08	0.07
	4	1.34	1.36	0.06	0.13	4.03	0.95	0.05
Bridelia retusa	5	1.05	1.68	0.07	0.04	3.65	0.63	0.08
	6	0.97	1.39	0.06	0.05	2.83	0.63	0.06
	7	0.84	2.14	0.09	0.08	3.54	0.60	0.11
	8	0.80	2.14	0.12	0.13	2.93	0.72	0.12
	9	0.64	2.05	0.12	0.09	2.73	0.73	0.13
	10	0.64	2.14	0.13	0.11	2.70	0.62	0.15
	11	0.51	1.92	0.13	0.08	2.66	0.33	0.16
	12	0.34	1.45	0.14	0.05	2.06	0.33	0.15

At the end of the study period, the respective N concentration in the residues were in the order of 1.90 per cent in *T. paniculata*, 1.83 per cent *P. pinnata*, 1.64 per cent in *S. oleosa*, 1.48 per cent in *M. peltata* and 1.45 per cent in *B. retusa*.

4.2.1.2 Phosphorus

P. pinnata leaf litter recorded the maximum content of initial P (0.19%) while the minimum was recorded by *T. paniculata* (0.12%). Phosphorus content in *P. pinnata* showed a steady decline upto third month (Fig.9). There onwards it recorded a gradual increase. *M. peltata* also followed more or less similar trend with a steady increase in concentration from 4th month onwards. A gradual increase in concentration was noted for *B. retusa* for the initial two months and then declined drastically in the following two months. It registered lowest value (0.06%) in the fourth and sixth month. Thereafter, it showed a steady increase upto the 12th month. *T. paniculata* with a lowest initial concentration showed a decreasing trend upto 4th month and thereafter showed a gradual increase. However, compared to other species, it registered the lowest value (0.12%) at the end of one year.

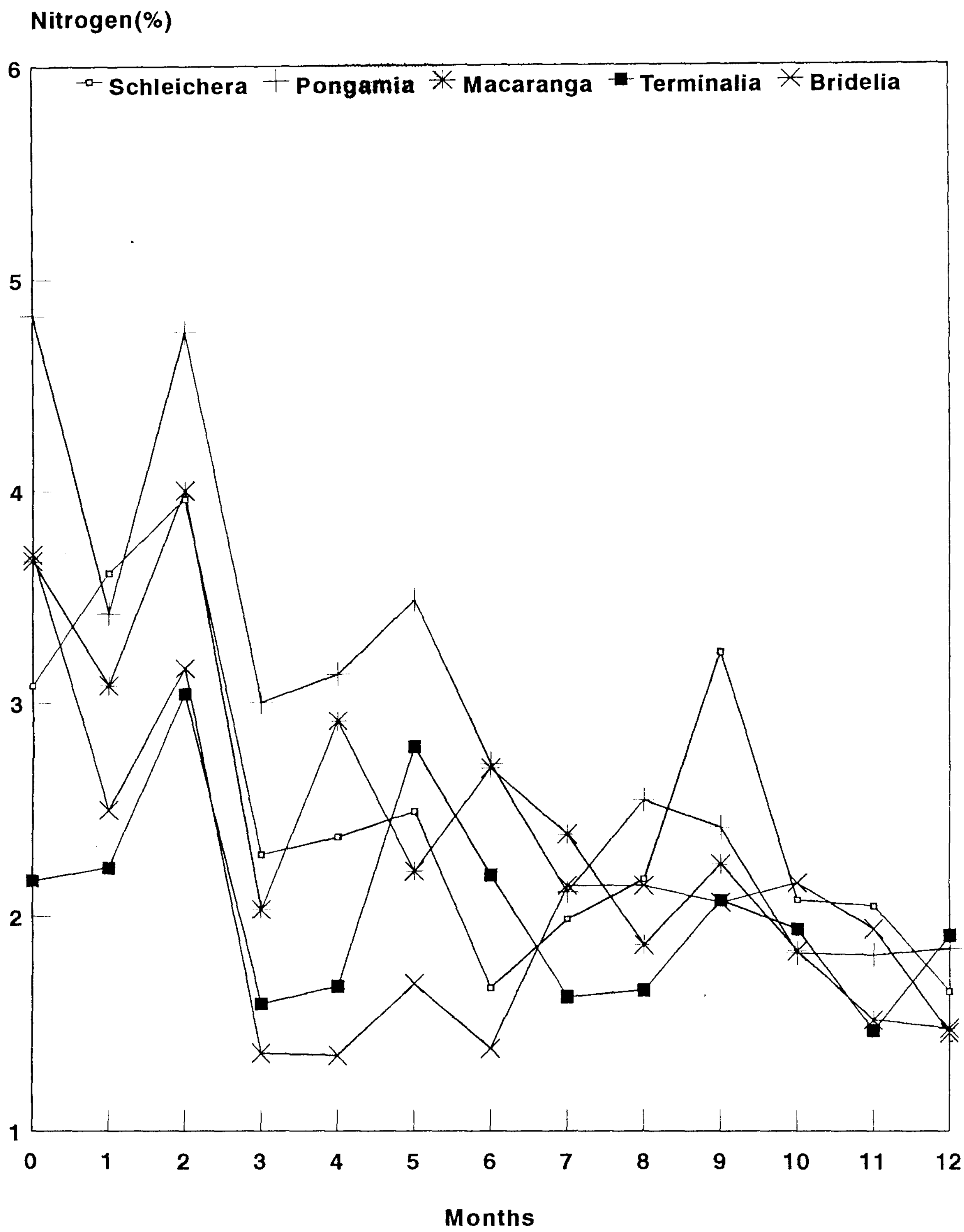

Fig. 8 Changes in nitrogen concentration in the leaf biomass

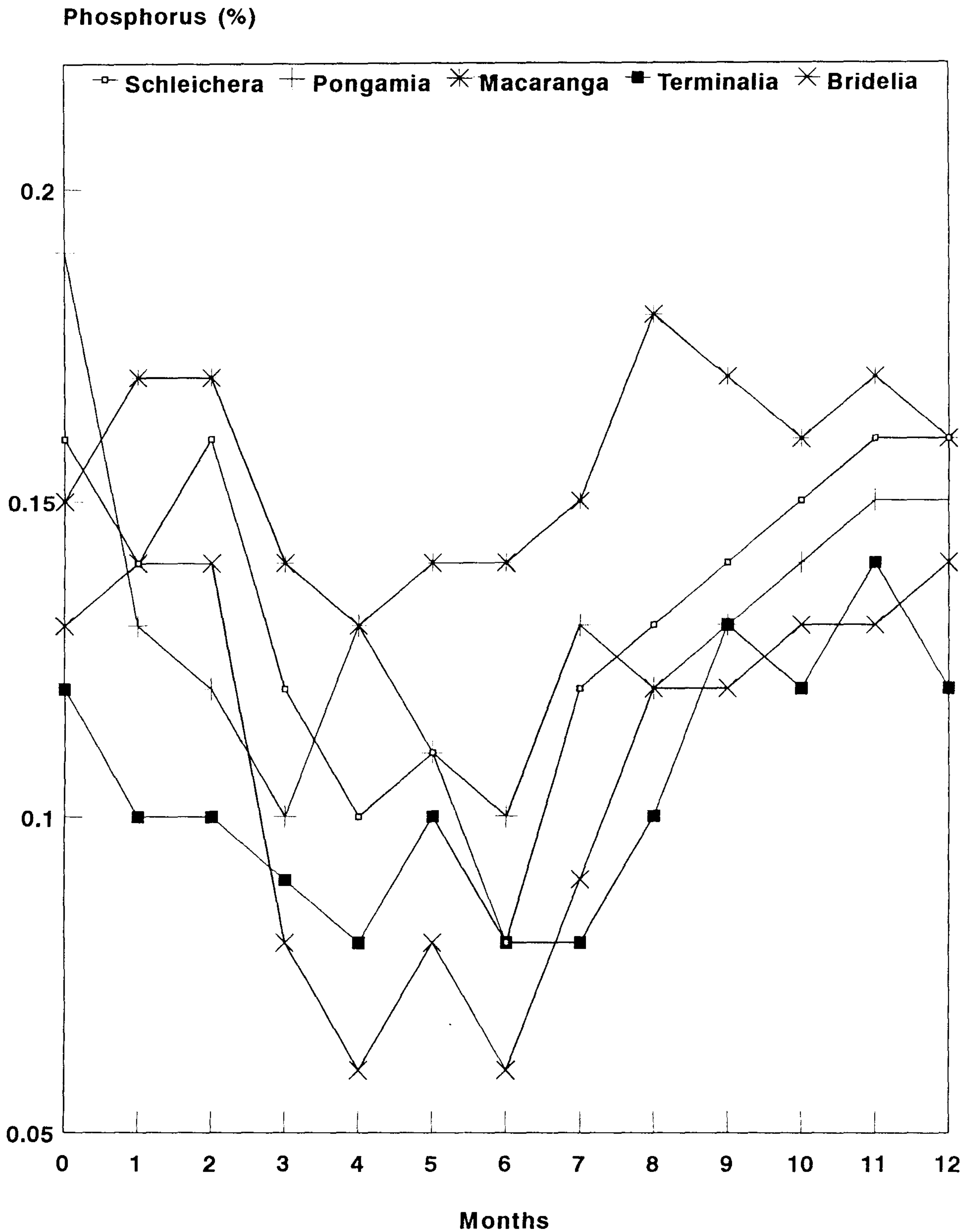

Fig. 9 Changes in phosphorus concentration in the leaf biomass

4.2.1.3 Potassium

Initial K concentration was maximum for *S. oleosa* and minimum for *T. paniculata* (Table 6). It is also evident from the table that all the species showed a marked decline in K concentration in the first month itself (Fig.10). The K content of different species fluctuated within a narrow range during the remaining sampling intervals. At the end of one year, *P. pinnata* and *T. paniculata* showed the lowest concentration (0.04%) followed by *B. retusa* (0.05%), *S. oleosa* (0.07%) and *M. peltata* (0.08%).

4.2.1.4 Calcium

Calcium concentration in the fresh sample was highest for *P. pinnata* (3.66%) while the lowest was recorded by *T. paniculata* (2.55%). The graphical presentation in figure 11 also illustrates the fluctuations in concentration of Ca over time. *S. oleosa* and *B. retusa* followed an increase in concentration during first month and then found to be decreased gradually during the remaining periods. *T. paniculata*, though with a lower initial concentration increased steadily upto the third month and thereafter followed a similar trend as that of *S. oleosa* and *B. retusa*. The data also revealed that *M. peltata* followed a declining trend from first month onwards. However, it showed an

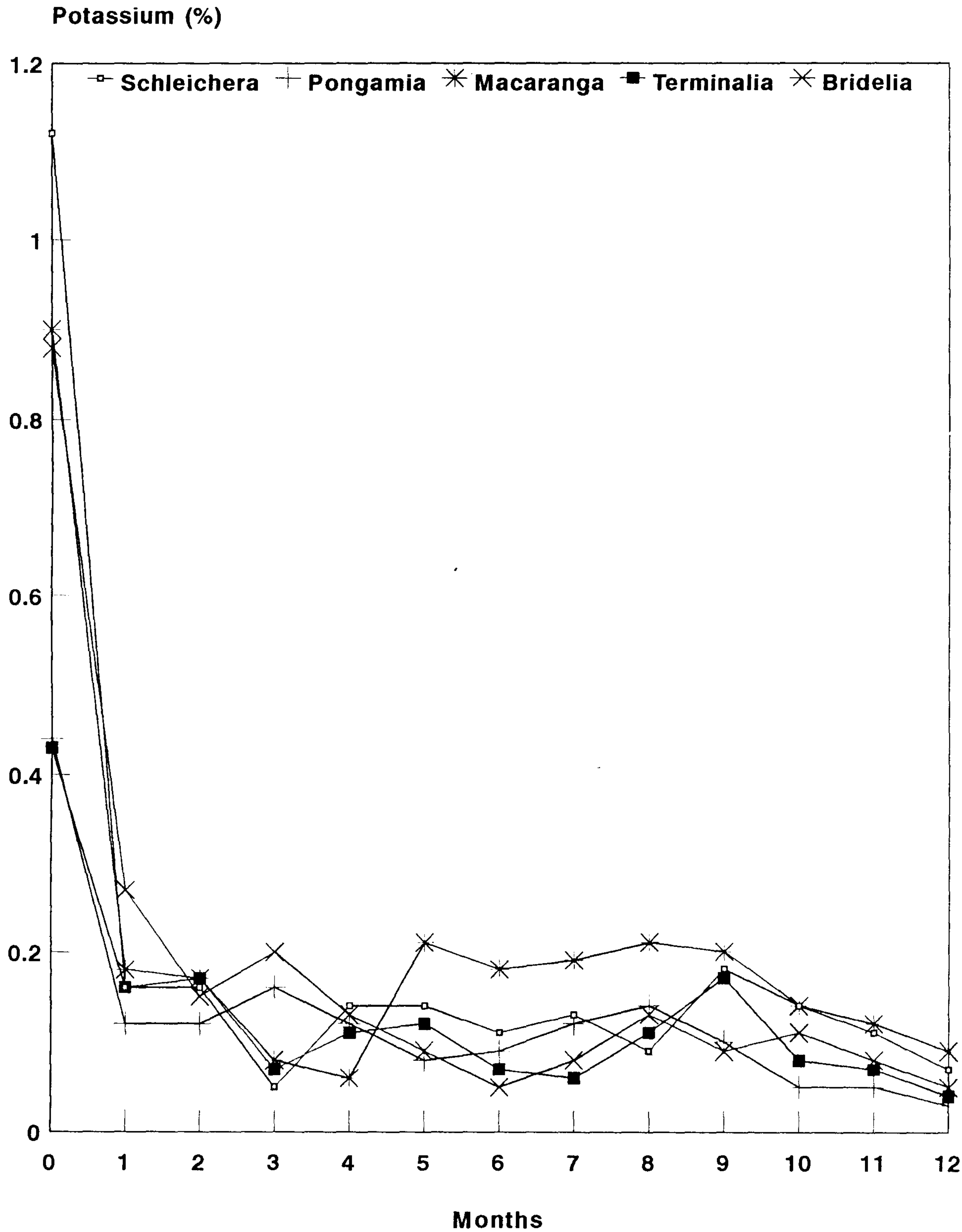

Fig. 10 Changes in potassium concentration in leaf biomass

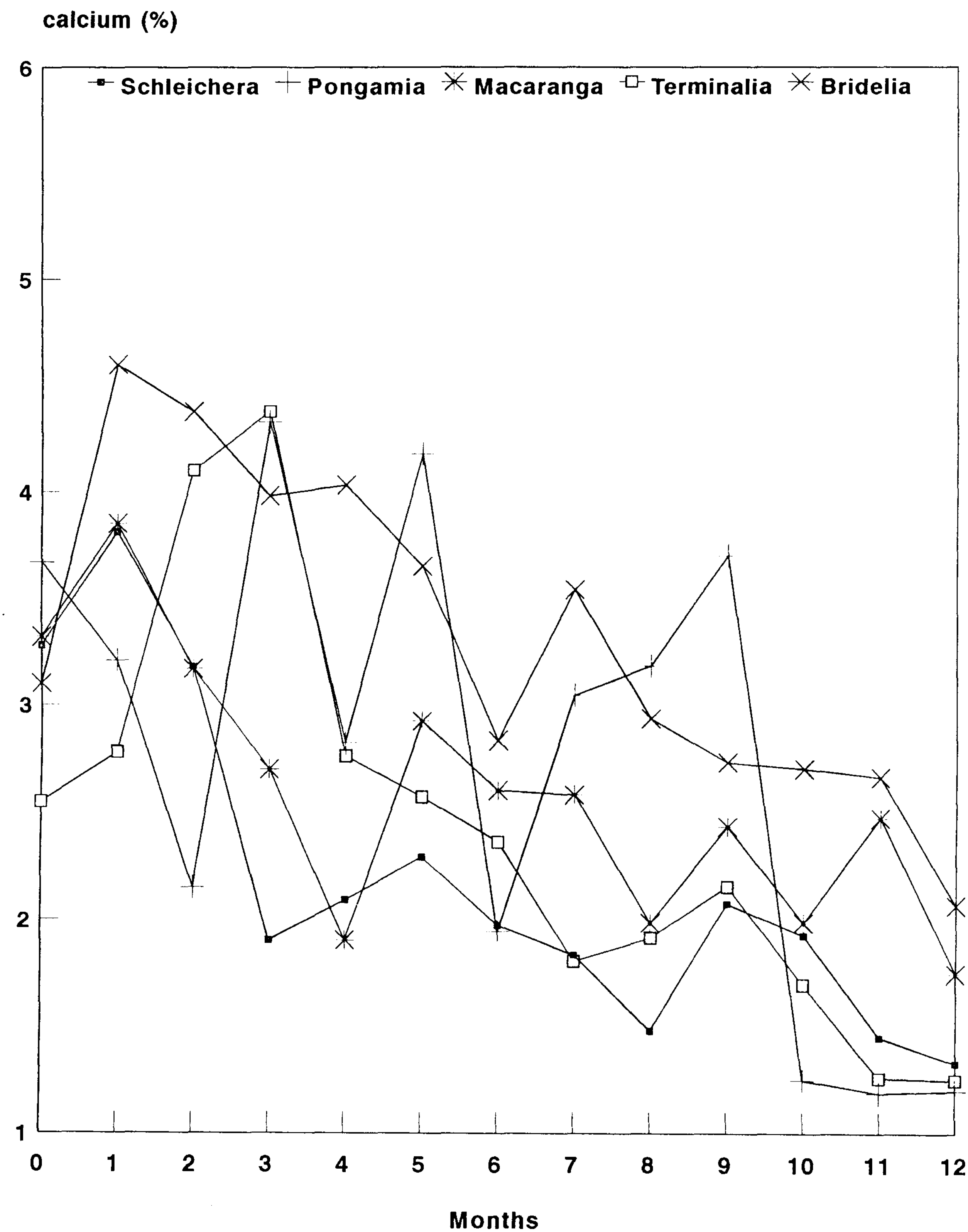

Fig. 11 Changes in calcium concentration in the leaf biomass

increase in Ca content during the fifth month. *P. pinnata* also showed high fluctuations in Ca content and recorded lowest value among all the species at the end of 12 months (1.20%).

4.2.1.5 Magnesium

The observations on monthly changes in the Mg content of the decomposing leaf samples are furnished in table 7. Among the five species tested, *B. retusa* marked a higher Mg concentration for the fresh samples (1.78%) while *T. paniculata* registered the lowest value (0.08%). With respect to changes in concentration over time, Mg followed more or less a similar trend as that of Ca for different species (Fig.12). However, *P. pinnata* showed a gradual declining trend. Species such as *B. retusa*, *S. oleosa* and *P. pinnata* were found to exhibit a rapid decrease in Mg concentration during the initial three months. Inspite of lower initial concentrations, *M. peltata* showed a steady increase from the second month onwards upto the fifth month and then declined gradually. *S. oleosa*, *T. paniculata* and *B. retusa* showed gradual declining trends with respect to Mg content.

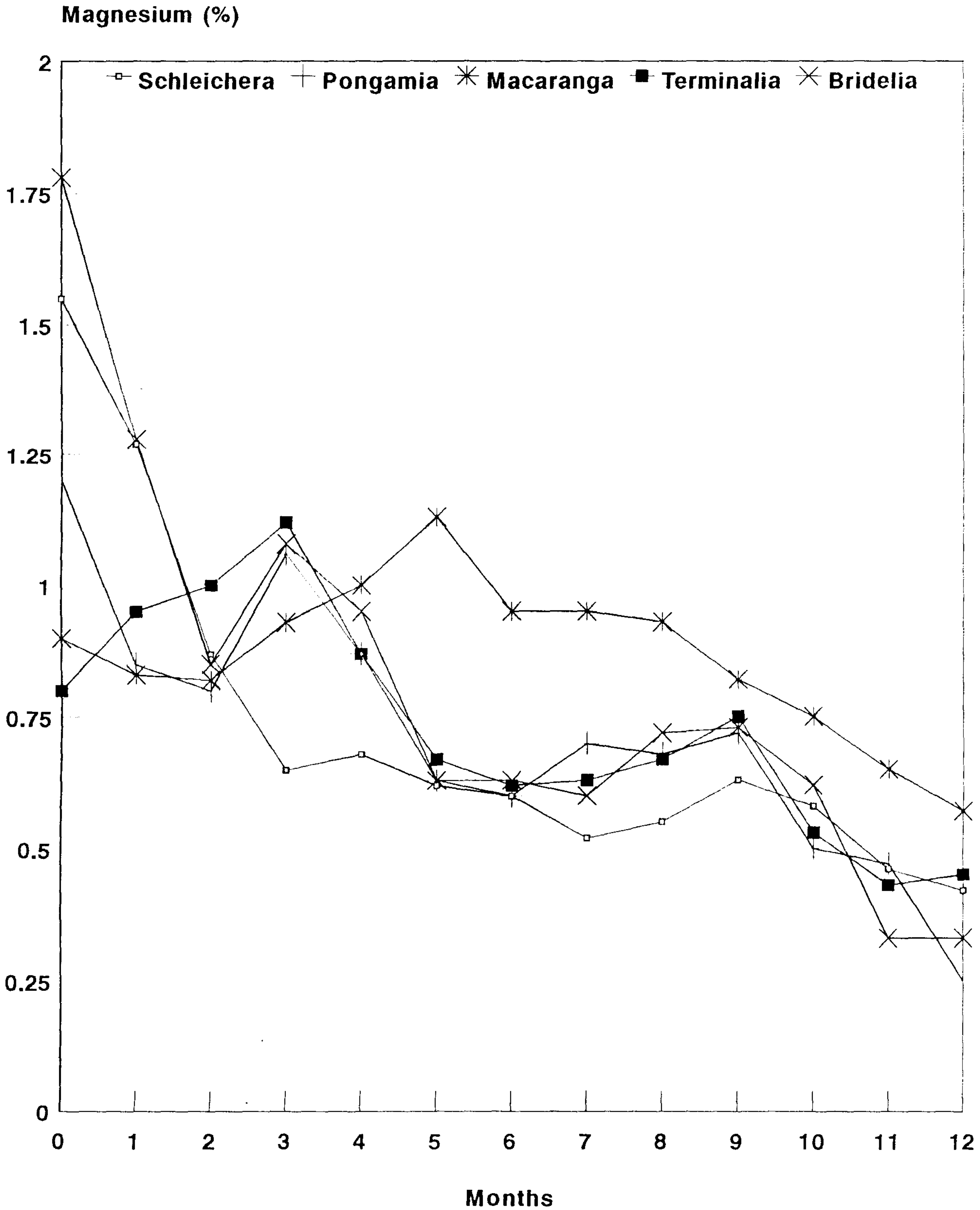

Fig. 12 Changes in the magnesium concentration in the leaf biomass

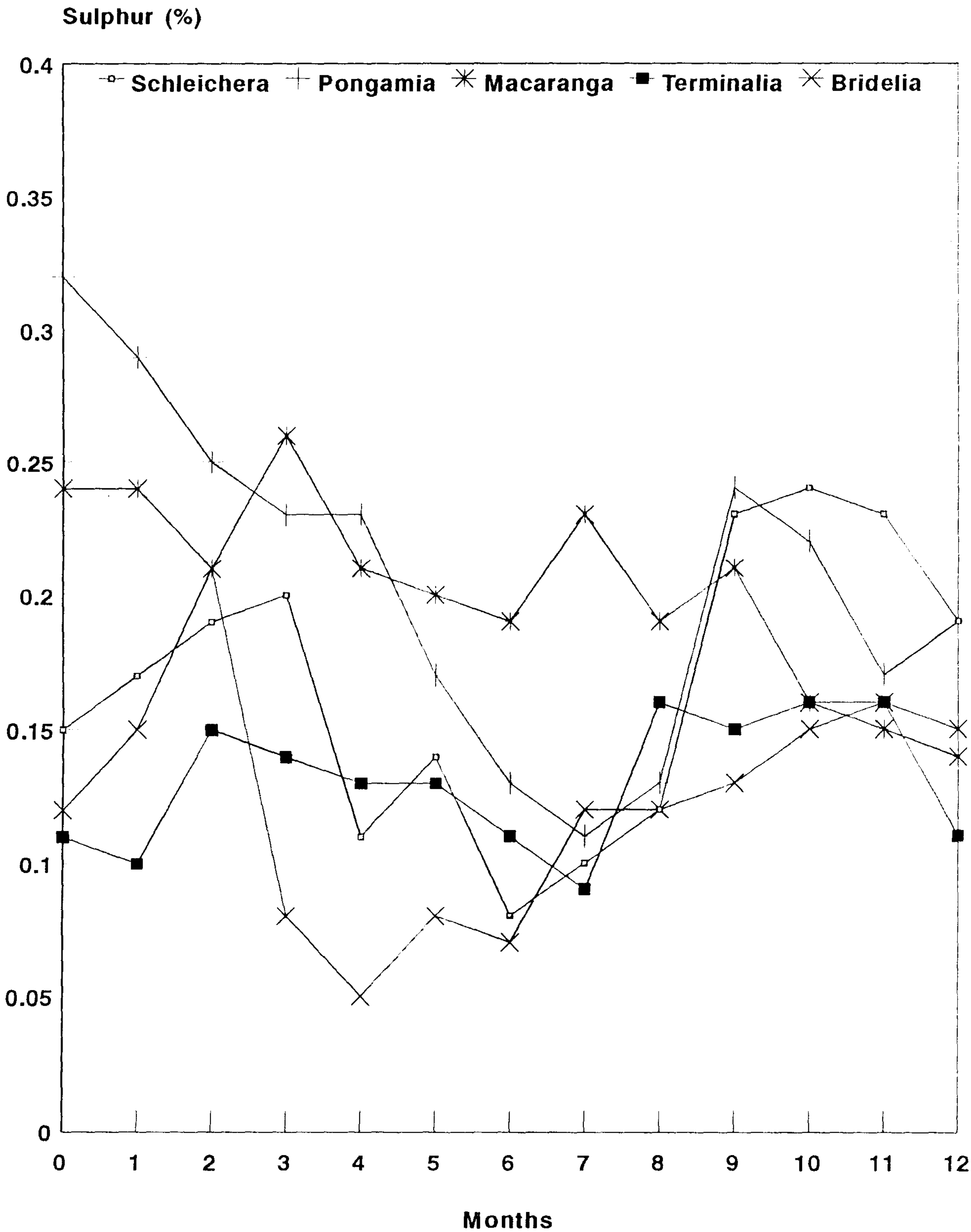

Fig. 13 Changes in the sulphur concentration in the leaf biomass

4.2.1.6 Sulphur

Figure 13 illustrates the changes in sulphur concentrations over time. Initial concentration was highest for *P. pinnata* (0.31%) and lowest for *T. paniculata* (0.11%). *P. pinnata* represented a steady decrease in sulphur concentration upto a period of 7 months followed by a rapid increase during the subsequent periods. Except *M. peltata*, all the other species showed an increase in concentration from 7th month onwards. Incidentally *M. peltata* showed lesser fluctuation in S concentration and retained higher concentration compare to many other species. At the end of the study, S concentration was found to be highest for *S. oleosa* and *P. pinnata* (0.19%) while lowest for *T. paniculata* (0.1%).

4.2.2 Relative changes in the nutrient concentrations

The relative changes in nutrient concentration of leaf biomass of various species are presented in table 7 and illustrated in figures 14 to 19.

4.2.2.1 Nitrogen

After two months of exposure to decomposition, relative concentrations of nitrogen in *T. paniculata* leaves was found to be 140.09 per cent of the initial concentration

Table 7. Relative changes in nutrient concentration in the decomposing leaf biomass of various tree species at monthly intervals

Species	Time (months)	Biomass remaining (g)	Relative nutrient concentration (% of initial concentration)					
			N	P	K	Ca	Mg	S
	0	38.36	100.00	100.00	100.00	100.00	100.00	100.00
	1	29.56	116.83	87.50	14.28	116.46	81.29	113.33
	2	19.76	128.16	100.00	13.38	96.45	54.48	126.66
	3	3.83	74.11	75.00	4.46	57.92	49.93	133.30
	4	3.03	76.69	62.50	12.50	63.71	43.87	73.33
	5	2.53	80.58	68.75	12.50	69.81	39.35	93.30
	6	1.62	54.04	50.00	9.82	60.06	38.70	53.30
Schleichera oleosa	7	1.05	64.07	75.00	11.61	55.74	32.90	66.67
	8	0.90	70.22	81.25	8.04	45.12	35.48	80.00
	9	0.77	104.53	87.50	16.07	63.41	40.64	153.33
	10	0.68	66.67	91.25	12.50	58.53	37.41	153.69
	11	0.59	66.01	100.00	9.80	44.20	29.67	153.33
	12	0.49	53.07	101.87	6.25	40.54	26.45	126.67

Contd.

Table 7 (Contd.)

Species	Time (months)	Biomass remaining (g)	Relative nutrient concentration (% of initial concentration)					
			N	P	K	Ca	Mg	S
	0	46.62	100.00	100.00	100.00	100.00	100.00	100.00
	1	30.18	70.80	68.42	25.00	87.73	70.83	90.62
	2	26.40	98.34	63.15	27.27	58.58	66.66	78.13
	3	17.25	62.11	52.63	36.36	117.98	88.33	71.87
	4	14.47	64.80	68.41	27.27	76.83	71.66	68.75
	5	12.25	72.04	63.15	18.18	113.89	52.50	53.12
	6	11.03	55.90	63.15	20.45	52.86	50.00	40.62
Pongamia pinnata	7	10.46	43.68	68.42	25.00	82.83	58.33	31.25
	8	6.93	52.58	63.15	31.81	86.64	56.67	37.50
	9	3.36	49.89	68.42	22.72	100.81	59.17	75.00
	10	3.01	37.68	73.65	9.09	34.05	41.66	68.75
	11	2.71	37.47	78.94	9.09	32.42	39.16	53.12
	12	2.64	38.09	78.94	6.81	34.69	20.83	56.25

Contd.

Table 7 (Contd.)

Species	Time (months)	Biomass remaining (g)	Relative nutrient concentration (% of initial concentration)					
			N	P	K	Ca	Mg	S
	0	34.71	100.00	100.00	100.00	100.00	100.00	100.00
	1	17.34	83.92	113.33	20.00	115.96	92.22	100.00
	2	10.33	108.99	113.33	18.88	96.48	90.00	87.80
	3	3.82	55.58	93.33	8.88	81.32	103.30	108.30
	4	3.57	79.29	90.66	5.56	57.22	111.11	87.50
	5	3.50	60.21	93.30	23.33	87.95	125.56	83.80
	6	3.12	73.29	90.66	20.00	78.31	105.55	79.17
	7	2.92	64.85	100.00	21.11	77.71	105.55	95.83
Macaranga peltata	8	1.42	50.68	117.33	23.33	59.63	103.33	79.16
	9	0.97	61.03	110.66	22.22	73.14	90.00	87.50
	10	0.84	49.86	106.66	15.56	59.63	83.33	66.65
	11	0.90	41.14	165.33	13.33	74.34	72.22	62.50
	12	0.70	40.05	106.66	10.00	52.40	62.22	58.33

Contd.

Table 7 (Contd.)

Species	Time (months)	Biomass remaining (g)	Relative nutrient concentration (% of initial concentration)					
			N	P	K	Ca	Mg	S
Terminalia paniculata	0	34.12	100.00	100.00	100.00	100.00	100.00	100.00
	1	23.24	102.76	83.33	36.36	109.01	118.75	90.90
	2	14.32	140.09	83.33	38.63	160.78	125.00	136.36
	3	2.68	73.27	75.00	15.91	171.76	138.75	118.18
	4	1.34	76.95	71.66	25.00	108.23	108.75	118.18
	5	0.95	128.57	83.33	29.54	100.78	82.50	114.54
	6	0.59	100.92	71.66	15.91	92.54	76.25	96.36
	7	0.46	74.65	66.66	15.91	70.58	78.75	81.81
	8	0.38	76.49	83.33	25.00	74.90	82.50	136.30
	9	0.35	95.39	108.33	38.63	84.31	92.75	132.72
	10	0.33	88.94	105.00	18.18	66.27	66.25	145.46
	11	0.30	67.28	116.66	18.18	49.80	53.75	141.81
	12	0.21	87.56	100.00	11.36	49.01	52.25	97.00

Contd.

Table 7 (Contd.)

Species	Time (months)	Biomass remaining (g)	Relative nutrient concentration (% of initial concentration)					
			N	P	K	Ca	Mg	S
Bridelia retusa	0	44.50	100.00	100.00	100.00	100.00	100.00	100.00
	1	26.99	67.38	107.69	30.68	148.38	71.91	125.00
	2	8.11	85.17	107.69	17.04	141.29	47.75	175.00
	3	2.27	36.65	61.53	22.72	128.38	60.67	58.33
	4	1.34	36.36	46.15	14.77	130.00	53.39	38.30
	5	1.05	45.28	53.84	10.22	117.74	35.39	63.33
	6	0.97	37.46	46.15	5.68	81.29	35.39	55.00
	7	0.84	57.68	73.84	9.09	114.19	33.70	96.66
	8	0.80	57.68	92.30	14.77	94.51	39.88	102.50
	9	0.64	55.25	92.30	10.22	88.70	41.01	108.30
	10	0.64	57.68	96.92	12.50	87.09	34.83	125.00
	11	0.51	52.02	100.00	9.09	85.80	18.53	1333.33
	12	0.34	39.08	110.00	5.68	66.45	18.53	127.75

(Fig.14). During this period *B. retusa* registered a lower relative concentration for nitrogen (85.17%). *T. paniculata* registered higher concentration during the fifth and sixth month in relation to their initial content.

4.2.2.2 Phosphorus

The relative changes in phosphorus concentration with respect to initial content are depicted in figure 15. The relative fluctuations in P contents were found to be minimum for all the species. The relative concentration for most of the species from 8th month onwards recorded high values compared to their initial concentrations, the values being 101.87 per cent for *S. oleosa*, 106.60 per cent for *M. peltata*, 110.0 per cent for *B. retusa* and 100.0 per cent for *T. paniculata*. However, *P. pinnata* retained 78.94 per cent of the initial P concentration at the end of one year.

4.2.2.3 Potassium

The relative concentration of potassium was found to have a sharp drop in the first month for all the species (Fig.16). During the first month, the corresponding relative values were 14.28 per cent for *S. oleosa*, 25 per cent for *P. pinnata*, 20 per cent for *M. peltata*, 36.36 per cent for *T. paniculata* and 30.68 per cent for *B. retusa*. There onwards the variations were within a narrow range for all the species.

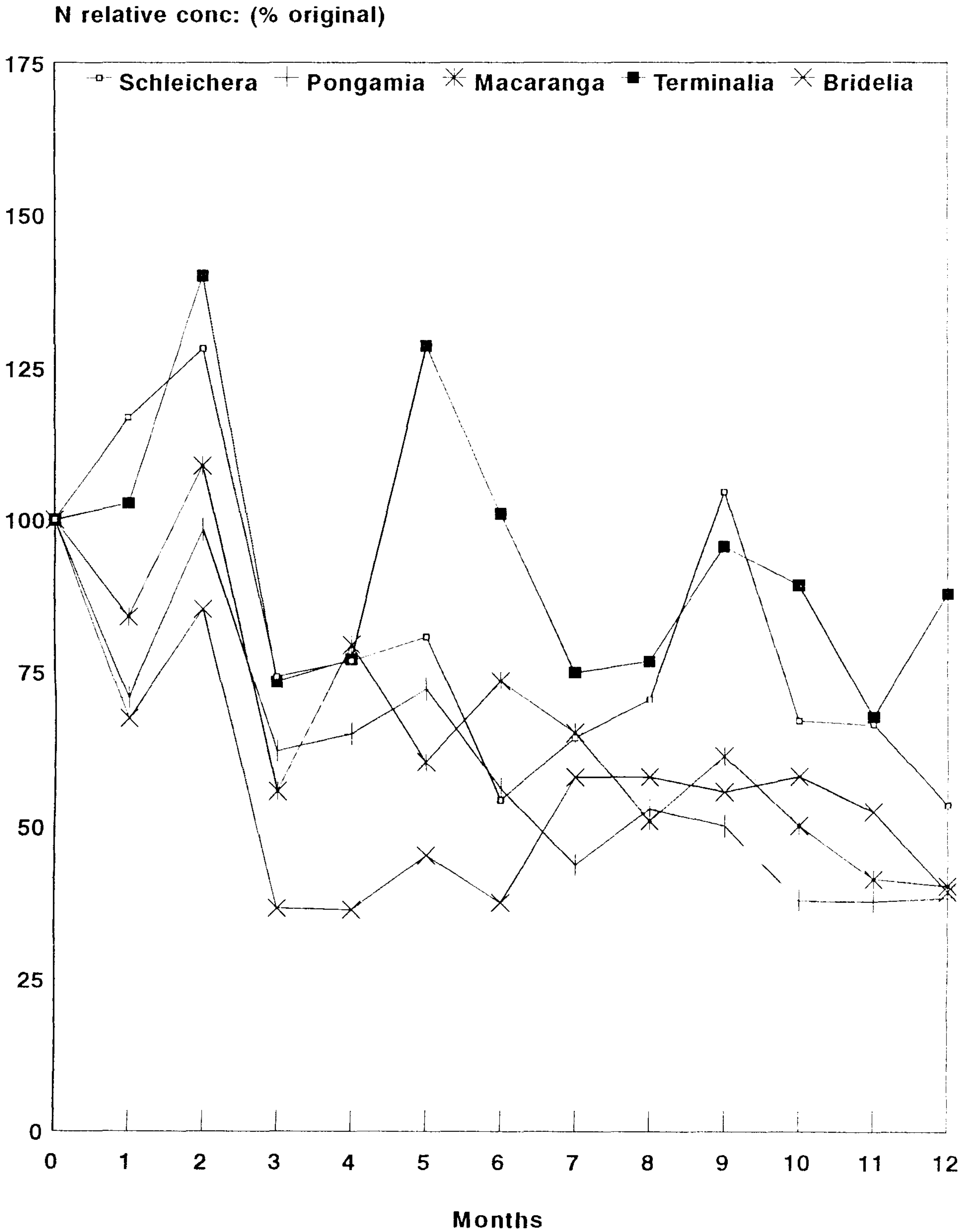

Fig. 14 Relative changes in nitrogen concentration in leaf biomass

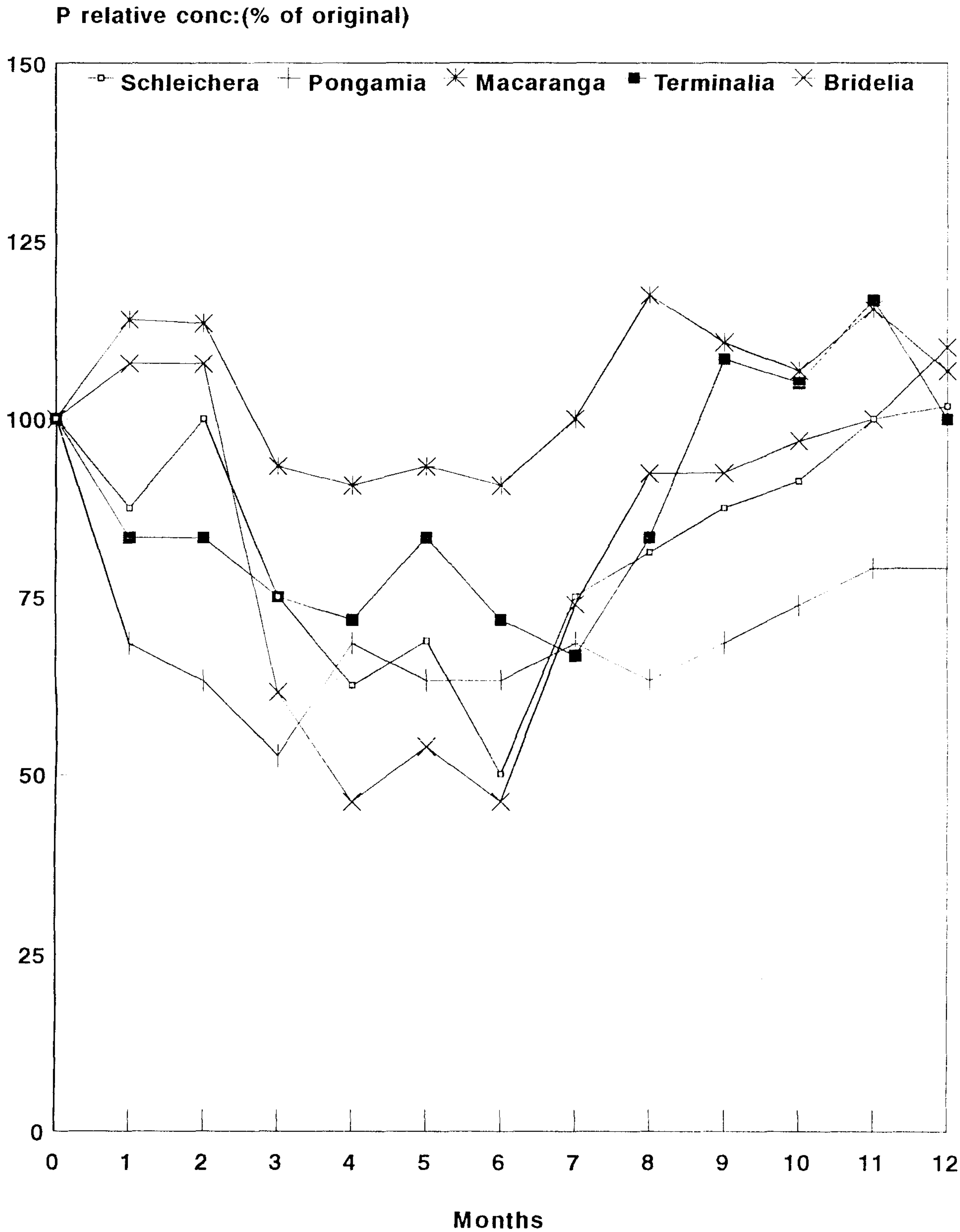

Fig. 15 Relative changes in phosphorus concentration in leaf biomass

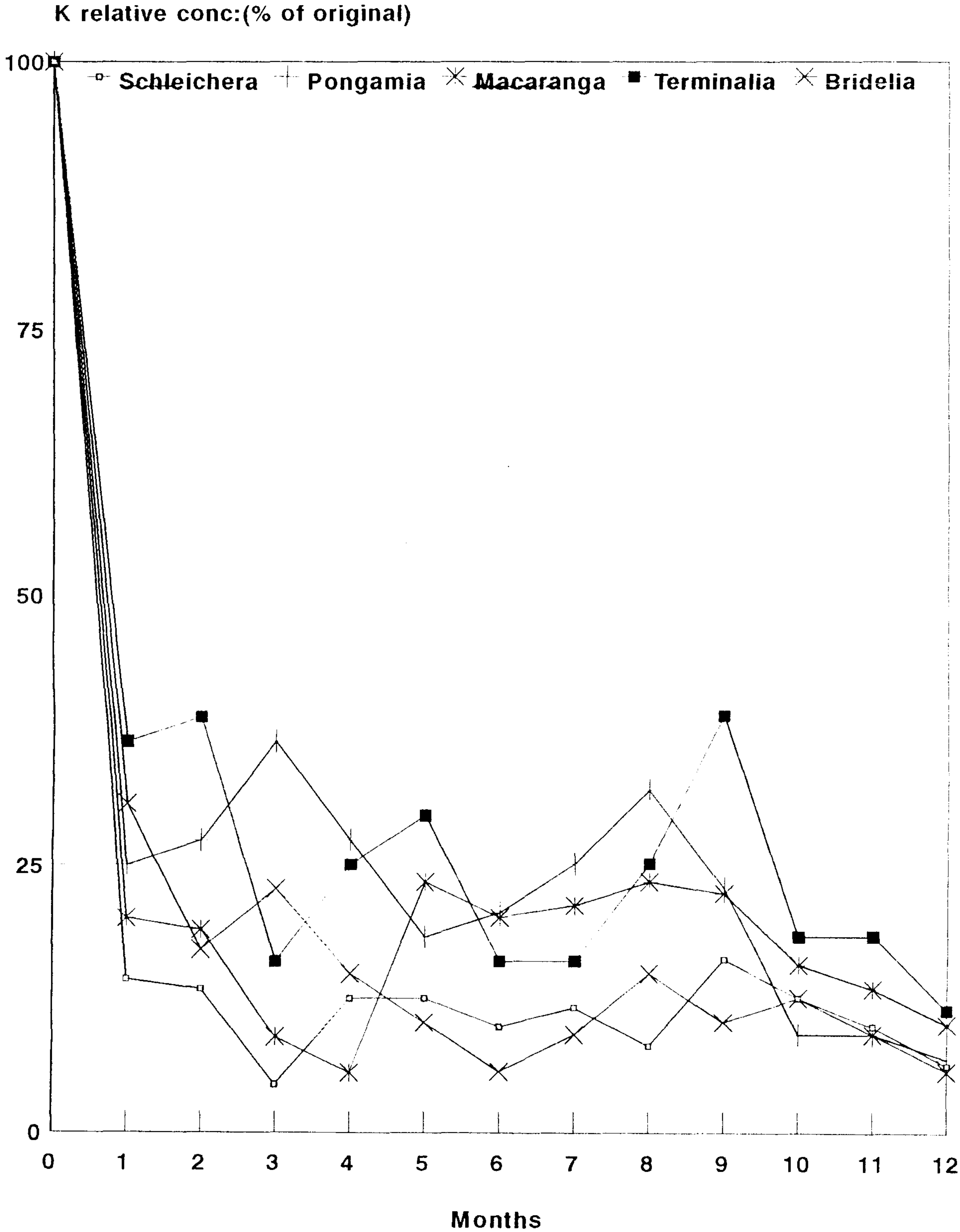

Fig. 16 Relative changes in potassium concentration in leaf biomass

At the end of one year the percentage of initial K concentration remaining in the litter bags were in the order of T. paniculata (11.36%), M. peltata (10%), P. pinnata (6.81%), S. oleosa (6.25%) and B. retusa (5.68%).

4.2.2.4 Calcium

Figure 17 illustrates the relative calcium concentration changes for different species. It follows a similar trend with the monthly changes in calcium content for different species. T. paniculata showed an increase over the initial concentration for the first three months. During the third month, the relative increase in concentration was as high as 171.80 per cent of initial Ca content. More or less a similar hike on relative concentrations was noted for B. retusa also. Generally for most of the species the relative calcium concentrations was found to be decreased during the end of the study.

4.2.2.5 Magnesium

The relative concentration of Mg also showed an initial decrease over the first two months for all the species except T. paniculata which incidentally showed an increasing trend upto third month (Fig.18). However, all the species showed a slow decline in relative concentration over time. At the end of study, the proportion of initial Mg concentration

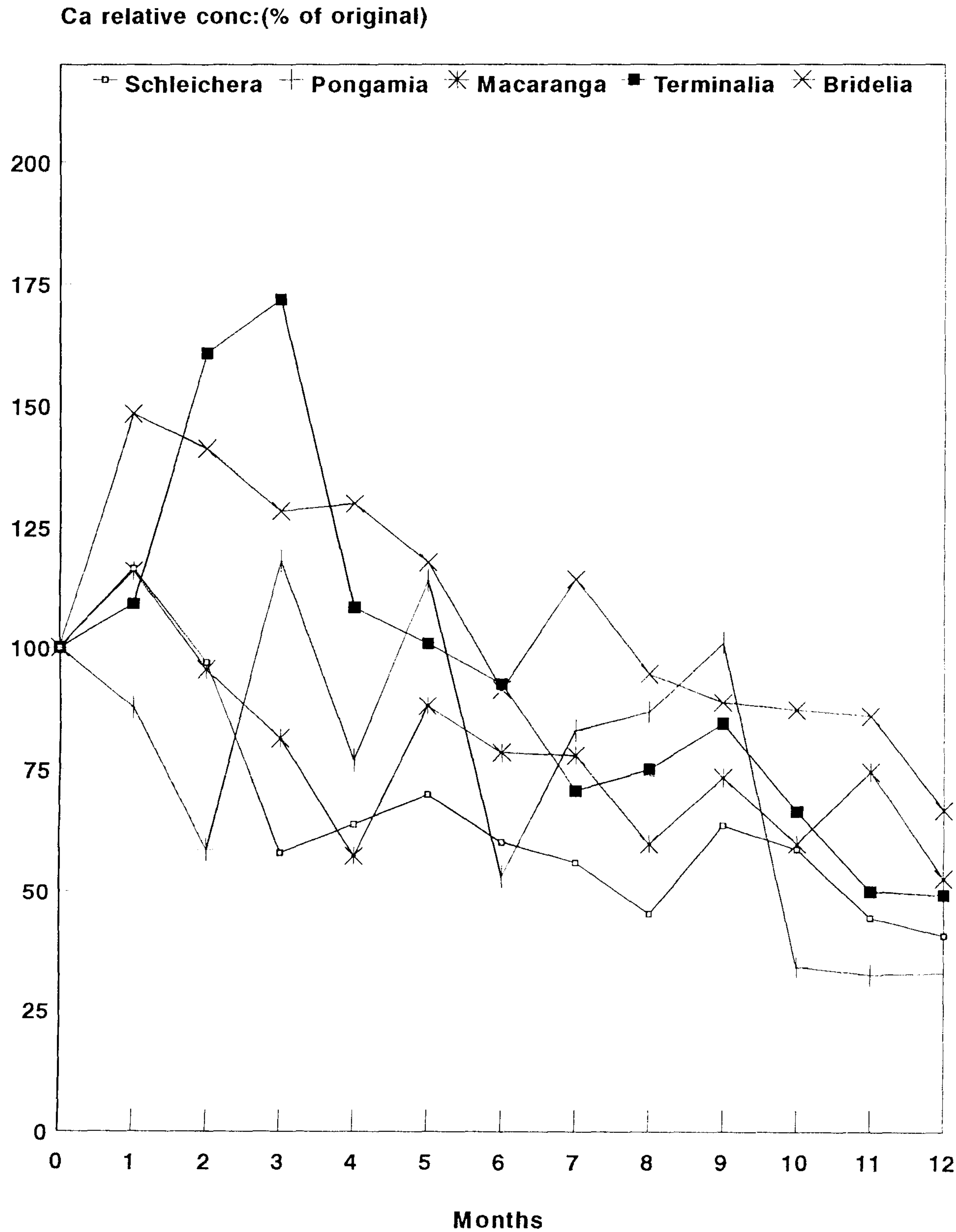

Fig. 17 Relative changes in calcium concentration in leaf biomass

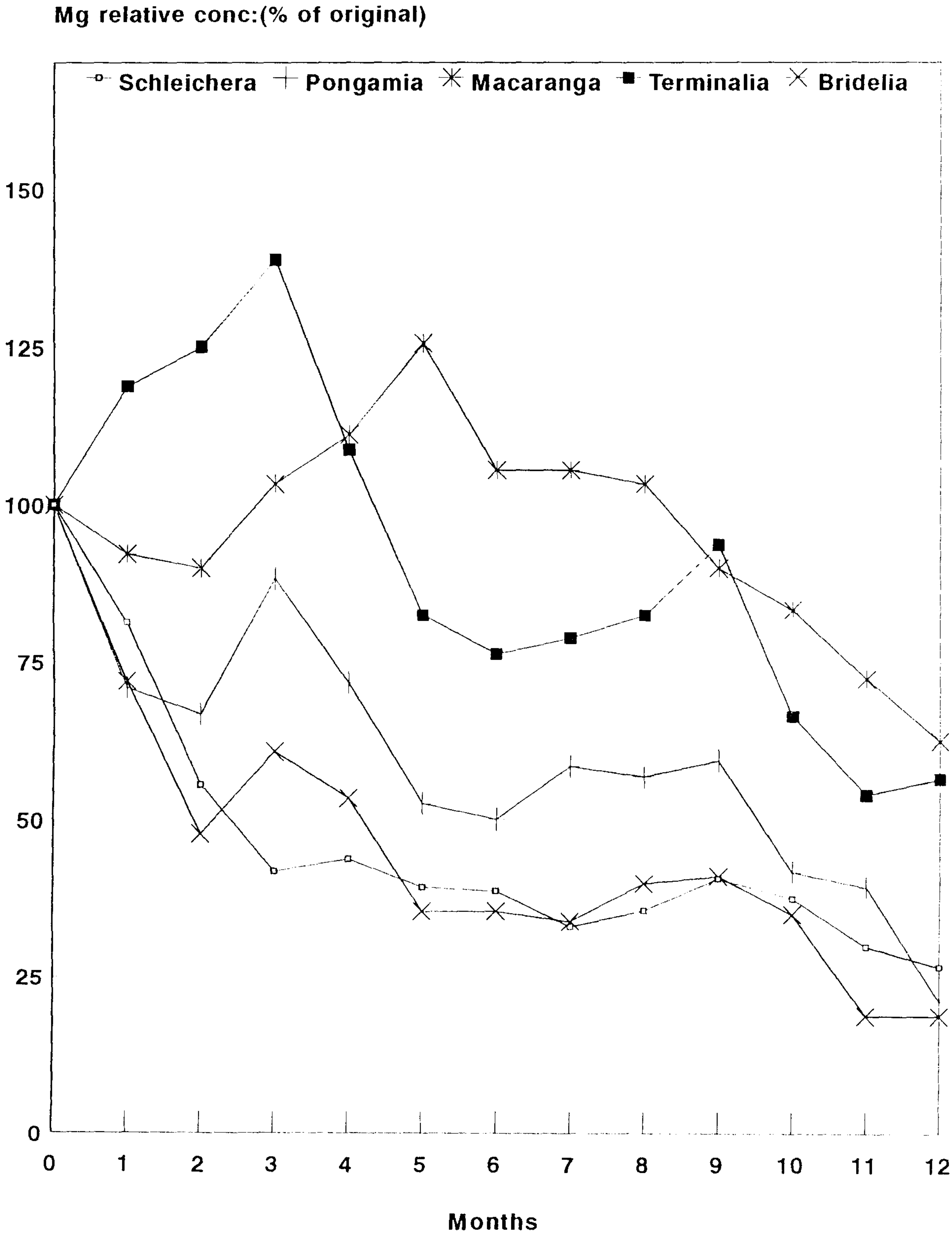

Fig. 18 Relative changes in magnesium concentration in leaf biomass

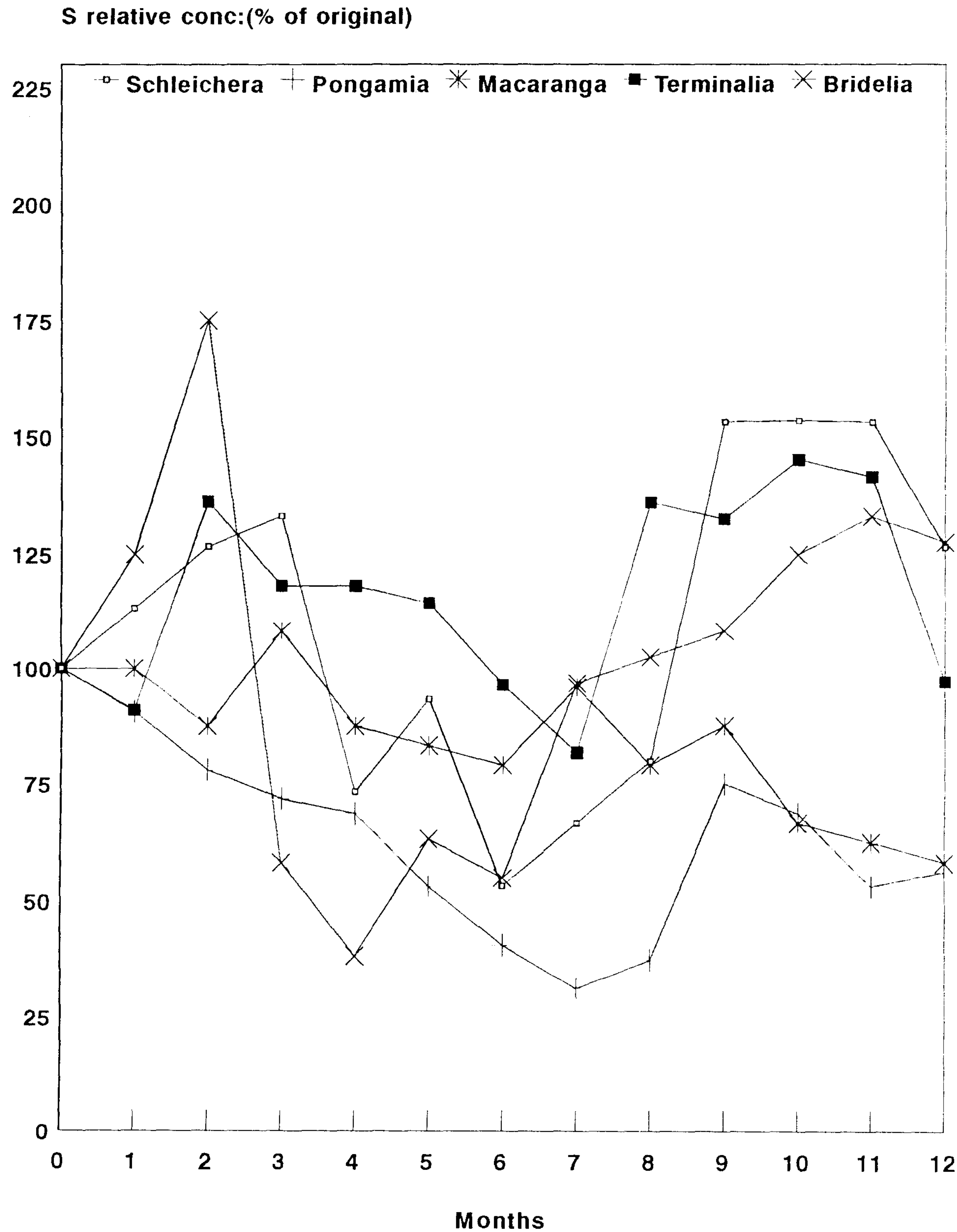

Fig. 19 Relative changes in sulphur concentration in leaf biomass

in the litter bags were maximum for M. peltata (62.2%) followed by T. paniculata (56.3%), S. oleosa (26.5%), P. pinnata (20.8%) and B. retusa (18.5%).

4.2.2.6 Sulphur

Bridelia retusa showed a high degree of inconsistency with respect to relative concentrations of sulphur (Fig.19). During the second month concentration increase was to the tune of 175 per cent of initial content for B. retusa. All the species exhibited a drop in relative sulphur content during mid periods of the year. During the end of study, relative concentrations was found to be increased for S. oleosa, T. paniculata and B. retusa. At the end of 12 months, S. oleosa and B. retusa were found to retain 126.67 per cent and 127.75 per cent of initial S respectively. However, P. pinnata and M. peltata showed lower proportions to the extent of 56.25 per cent and 58.33 per cent respectively at the end of one year.

4.2.3 Changes in absolute nutrient contents

Data corresponding to the absolute amounts of nutrients of various tree species represented in table 8 and illustrated in figures 20 to 25. The mathematical models relating the absolute amounts of different nutrients and time elapsed are furnished in appendix III.

Table 8. Changes in the absolute amounts of nutrients in the decomposing leaf biomass of various tree species at monthly intervals

Species	Time (months)	Biomass remaining (g)	Absolute amount of nutrient (%)					
			N	P	K	Ca	Mg	S
	0	38.36	100.00	100.00	100.00	100.00	100.00	100.00
	1	29.56	89.67	68.97	11.00	89.38	63.12	83.75
	2	19.76	65.76	52.69	7.35	49.87	29.13	62.57
	3	3.83	7.37	7.66	0.53	5.77	4.22	12.76
	4	3.03	6.03	5.05	0.98	5.00	3.49	5.55
	5	2.53	5.29	4.63	0.82	4.59	2.61	5.90
	6	1.62	2.27	2.16	0.41	2.53	1.64	2.16
Schleichera oleosa	7	1.05	1.74	2.10	0.31	1.52	0.90	1.75
	8	0.90	1.64	1.95	0.20	1.05	0.83	1.80
	9	0.77	2.08	1.79	0.32	1.26	0.82	2.95
	10	0.68	1.1	1.70	0.22	1.03	0.66	2.60
	11	0.59	1.01	1.57	0.15	0.67	0.47	2.26
	12	0.49	0.41	1.31	0.01	0.50	0.34	1.55

Contd.

Table 8 (Contd.)

Species	Time (months)	Biomass remaining (g)	Absolute amount of nutrient (%)					
			N	P	K	Ca	Mg	S
	0	46.62	100.00	100.00	100.00	100.00	100.00	100.00
	1	30.18	70.80	43.59	17.24	56.65	45.80	58.34
	2	26.40	98.34	35.20	15.05	33.19	37.71	44.00
	3	17.25	62.11	19.17	13.14	43.67	32.65	26.45
	4	14.47	64.80	20.90	8.26	23.77	22.48	22.13
	5	12.25	72.04	13.61	4.66	29.37	13.78	13.88
Pongamia pinnata	6	11.03	55.90	12.25	4.72	12.44	11.81	9.55
	7	10.46	43.68	15.10	5.47	18.59	13.07	7.61
	8	6.93	52.58	9.24	4.62	12.88	8.41	6.00
	9	3.36	49.89	4.85	1.60	7.27	4.26	5.60
	10	3.01	37.68	4.68	0.71	2.20	2.68	4.41
	11	2.71	37.47	4.51	0.52	1.88	2.27	3.07
	12	2.64	38.09	4.46	0.37	1.85	1.17	3.16

Contd.

Table 8 (Contd.)

Species	Time (months)	Biomass remaining (g)	Absolute amount of nutrient (%)					
			N	P	K	Ca	Mg	S
Macaranga peltata	0	14.71	100.00	100.00	100.00	100.00	100.00	100.00
	1	17.34	42.05	58.96	10.06	58.05	46.42	52.02
	2	10.33	32.53	35.12	5.66	28.38	26.99	27.11
	3	3.82	6.10	10.69	0.98	8.96	11.46	12.41
	4	3.57	8.18	9.28	0.57	5.89	11.51	9.37
	5	3.50	0.09	9.80	2.25	8.85	12.75	8.75
	6	3.12	6.60	8.11	1.81	7.05	9.56	7.41
	7	2.92	5.44	8.76	1.78	6.52	8.94	8.39
	8	1.42	2.07	4.82	0.96	2.44	4.26	3.37
	9	0.97	1.70	3.10	0.62	2.02	2.56	2.54
	10	0.89	1.28	2.84	0.40	1.53	2.15	1.78
	11	0.90	1.07	3.06	0.34	1.92	1.88	1.68
	12	0.70	0.81	2.24	0.20	1.05	1.26	1.22

Contd.

Table 8 (Contd.)

Species	Time (months)	Biomass remaining (g)	Absolute amount of nutrient (%)					
			N	P	K	Ca	Mg	S
Terminalia paniculata	0	34.12	100.00	100.00	100.00	100.00	100.00	100.00
	1	23.24	70.03	58.10	24.78	72.12	81.77	58.10
	2	14.32	58.82	35.80	16.22	67.48	53.03	50.12
	3	2.68	5.72	6.03	1.25	13.49	11.01	8.71
	4	1.34	3.00	2.68	0.89	4.25	4.26	4.35
	5	0.95	3.58	2.37	0.76	2.79	2.36	3.08
	6	0.59	1.74	1.32	0.23	0.60	1.33	1.47
	7	0.46	1.00	0.92	0.18	0.95	1.47	1.03
	8	0.36	0.85	0.95	0.27	0.83	0.92	1.42
	9	0.35	0.98	1.13	0.37	0.86	0.97	1.22
	10	0.33	0.86	0.99	0.18	0.64	0.64	1.32
	11	0.30	0.59	1.05	0.14	0.43	0.47	1.12
	12	0.21	0.58	0.63	0.05	0.30	0.35	0.52

Contd.

Table 8 (Contd.)

Species	Time (months)	Biomass remaining (g)	Absolute amount of nutrient (%)					
			N	P	K	Ca	Mg	S
Bridelia retusa	0	44.50	100.00	100.00	100.00	100.00	100.00	100.00
	1	26.99	40.89	62.97	18.68	89.96	43.73	80.97
	2	8.11	15.53	18.92	3.11	25.74	8.72	34.06
	3	2.27	1.87	3.02	1.16	6.54	3.10	3.45
	4	1.34	1.10	1.34	0.44	3.91	1.91	1.23
	5	1.05	1.06	1.40	0.24	2.77	0.83	1.47
	6	0.97	0.81	0.97	0.12	1.98	0.77	1.16
	7	1.84	1.08	1.26	0.17	2.15	0.63	1.84
	8	0.80	1.03	1.46	0.26	1.69	0.71	1.92
	9	0.64	0.79	1.28	0.14	1.26	0.59	1.06
	10	0.64	0.83	1.28	0.18	1.25	0.49	1.92
	11	0.51	0.59	1.10	0.10	0.98	0.21	1.63
	12	0.34	0.29	0.79	0.04	0.50	0.14	1.02

4.2.3.1 Nitrogen

All the species showed a rapid reduction in absolute amounts of N during the initial three months of decomposition period (Fig.20). At the end of three months, all the species, except P. pinnata released 90 per cent of their original quantity. Interestingly for P. pinnata, N mineralisation was comparatively gradual. From the third month onwards N mineralisation was found to be at a very slower rate. However, by the end of 12 months about 98 per cent of N was mineralised for all the species.

Among the various models suggested for N mineralisation, for S. oleosa, hoerl function model gave a good fit with high r^2 value (0.94). On the other hand, for P. pinnata, exponential model gave a suitable fitting ($r^2 = 0.97$). Second order hyperbola showed a good fit for N release for M. peltata and B. retusa with r^2 values of 0.97 and 0.98 respectively. For T. paniculata cauchy model was the best.

4.2.3.2 Phosphorus

Though P concentrations showed no appreciable change in decomposing leaf material over time, their absolute amounts were found to follow an initial rapid release followed by a slower release pattern as is evidenced from figure 21. It could be seen from the table and figure that during the rapid

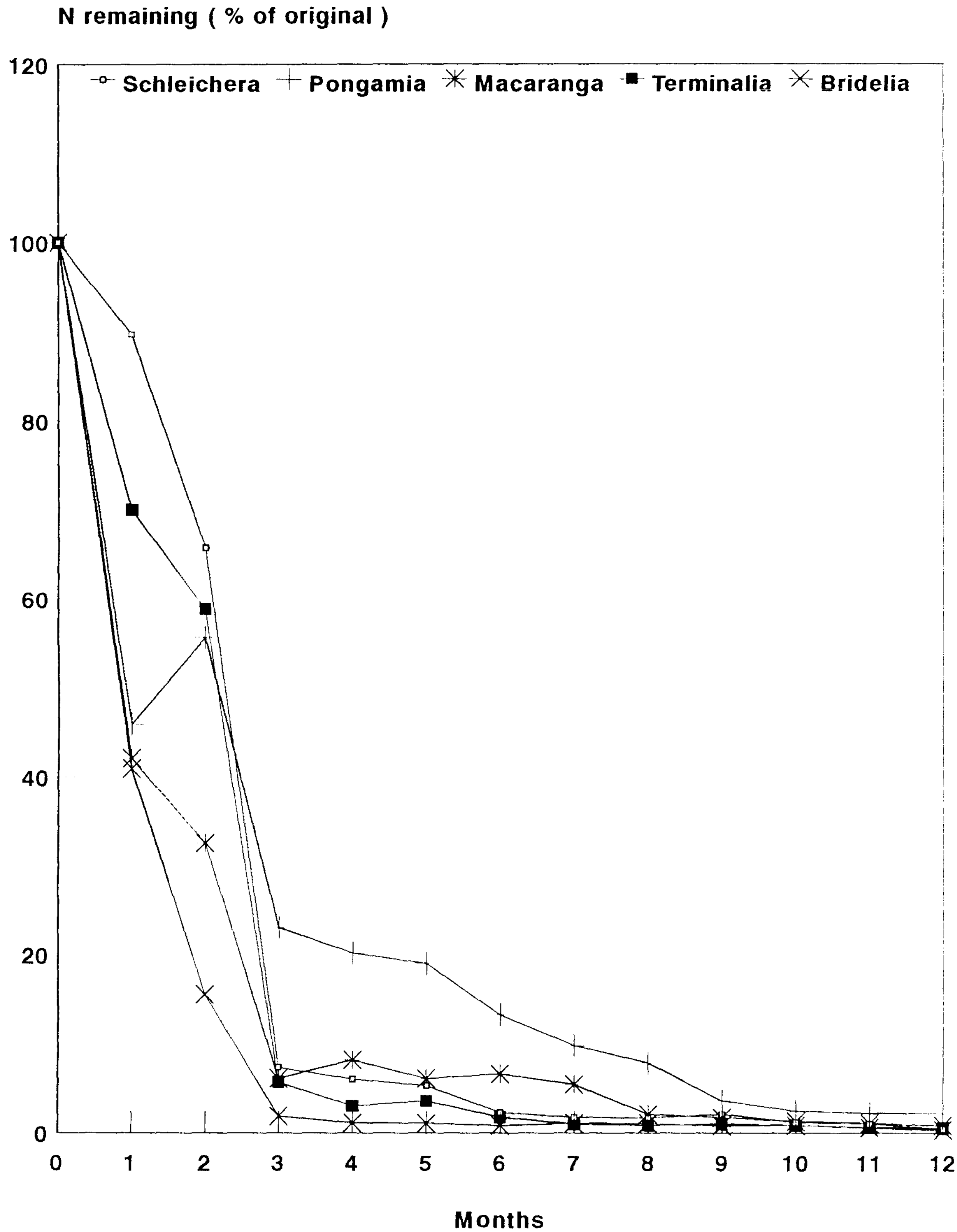

Fig. 20 Changes in absolute amounts of nitrogen in the leaf biomass

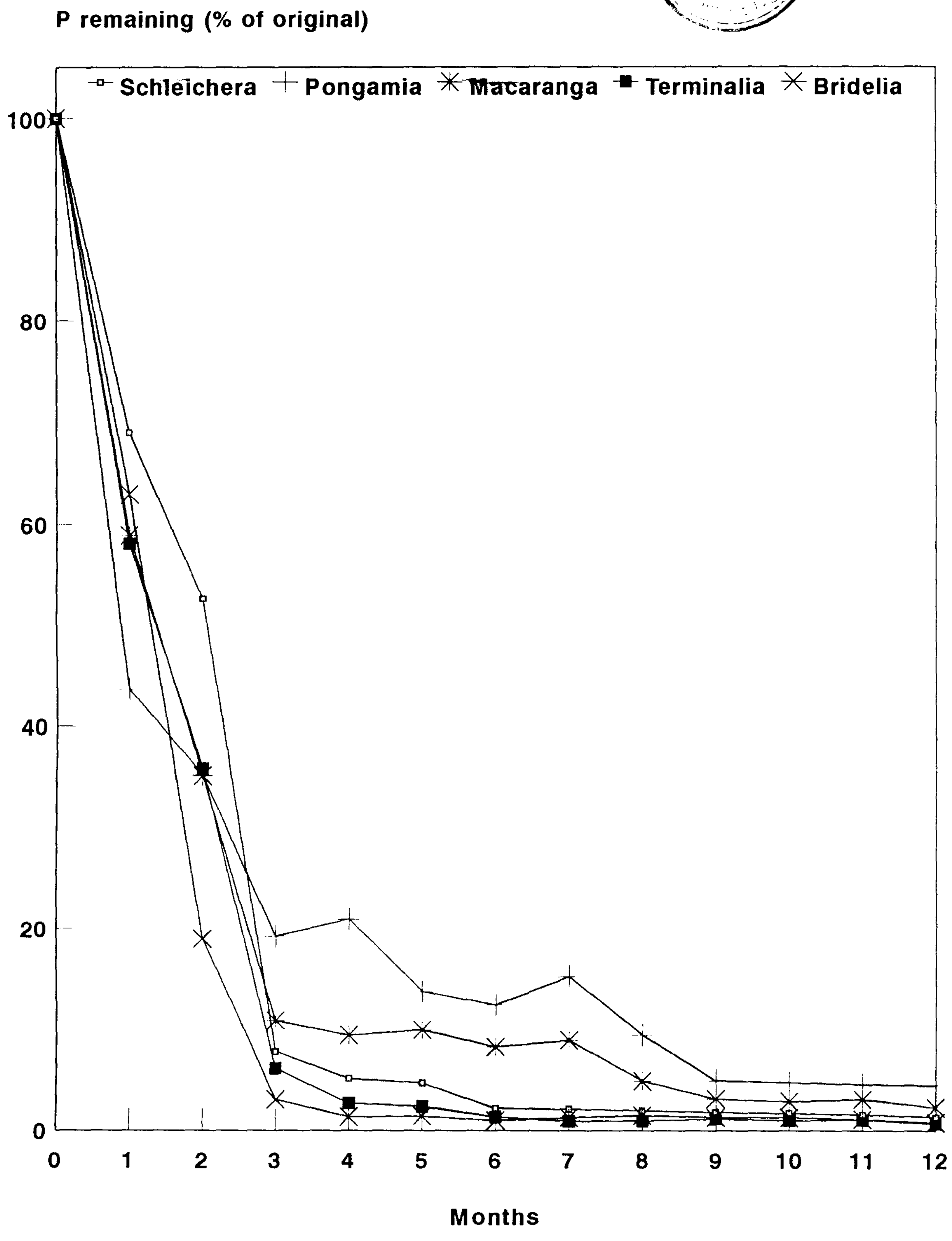

Fig. 21 Changes in absolute amounts of phosphorus in leaf biomass

P mineralisation phase (first three months), all the species lost around 80 to 95 per cent of their initial P content. At the end of one year, for all the species, more than 95 per cent of initial P was found to be released.

Reciprocal straight line model showed a good fit to depict P release pattern of S. oleosa ($r^2 = 0.95$). For all the other species second order hyperbolic model was found to give the good fit with r^2 values ranging from 0.96 to 0.98.

4.2.3.3 Potassium

Among the nutrients tested, K showed fastest release in terms of absolute quantity with regard to all the species (Fig.22). Interestingly, initial absolute K content declined to as low as 10 per cent for M. peltata within one month of exposure to decomposition. During the initial three to four months of decomposition period the absolute amount of K was drastically reduced to less than three per cent for most of the species.

Potassium release pattern was best represented for P. pinnata using logarithmic model with a high r^2 value of 0.99. However, for the all remaining species second order hyperbolic model showed a good fit with r^2 values ranging more than 0.99.

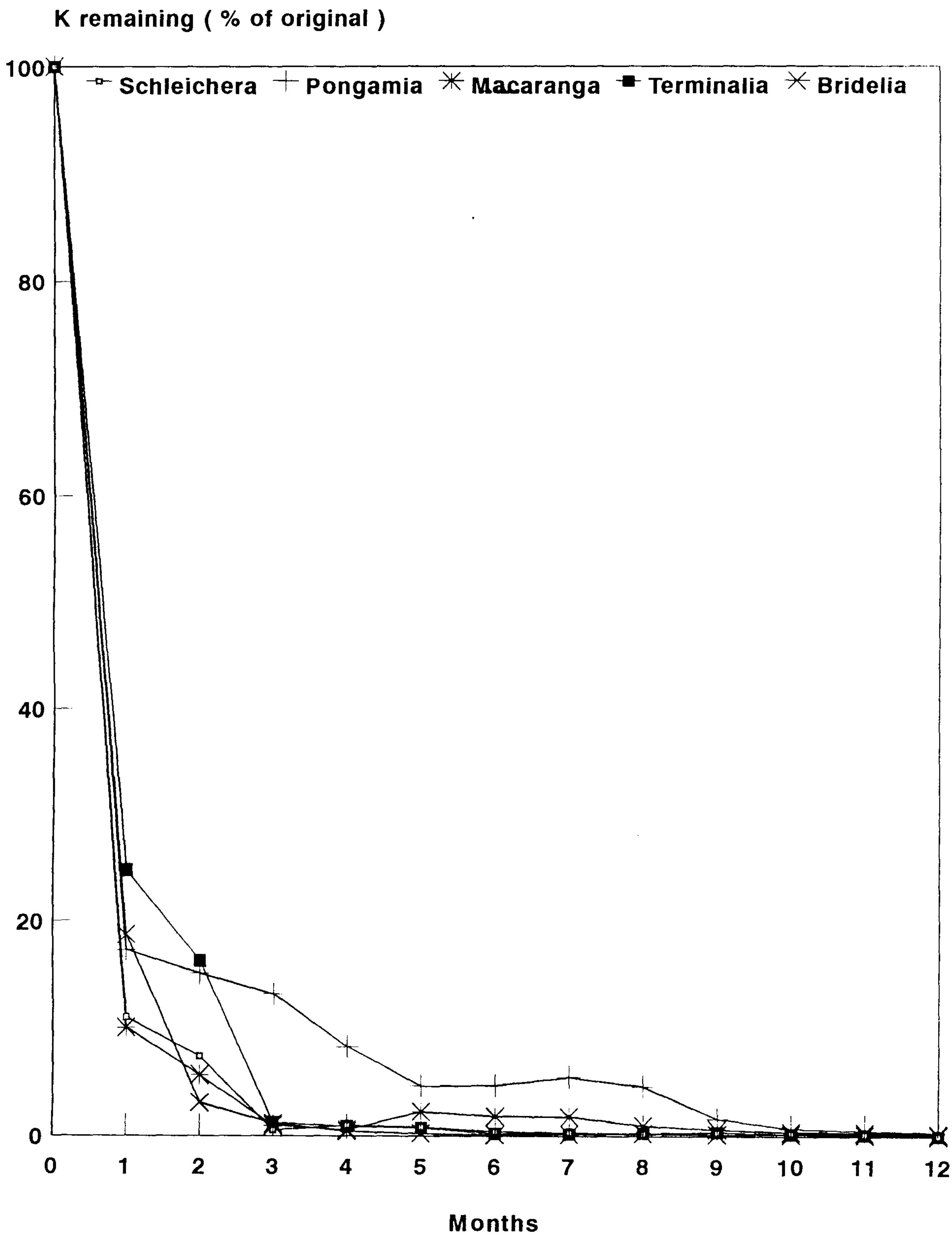

Fig. 22 Changes in absolute amounts of potassium in leaf biomass

4.2.3.4 Calcium

The illustration presented in figure 23 represents the changes in absolute Ca content over time for different species. Except *P. pinnata*, all the other species showed a rapid decrease in absolute amounts in the early three months of decomposition. *P. pinnata* exhibited a small trend for Ca immobilisation during the third, fifth and seventh month. However, after 12 months 97 per cent of original Ca was found to be mineralised for all the species.

To characterise the Ca release pattern for *S. oleosa* and *B. retusa*, modified hoerl model could be used as is evident from the data furnished in appendix III. *P. pinnata* followed a linear and reciprocal model ($r^2 = 0.03$) while the best for *M. peltata* was found to be second order hyperbolic model. A logarithmic normal model was best fitted for *T. paniculata*.

4.2.3.5 Magnesium

With respect to absolute amounts, Mg was characterised by a similar trend as that of calcium (Fig.24). After three months of decomposition, Mg marked a sharp decrease in initial mass. At the end of the decomposition study, for all the species, Mg registered a very low percentage of initial absolute mass.

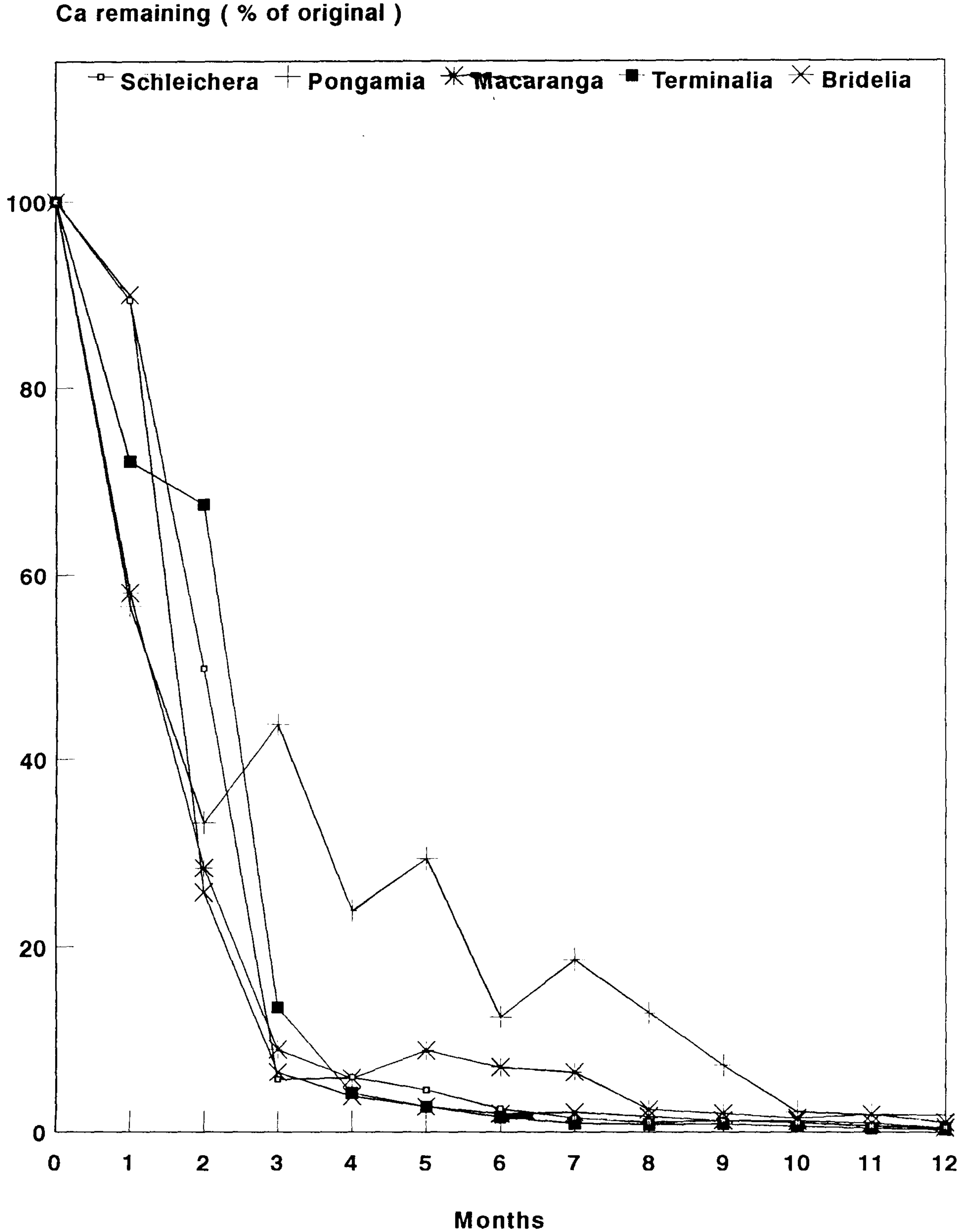

Fig. 23 Changes in absolute amounts of calcium in leaf biomass

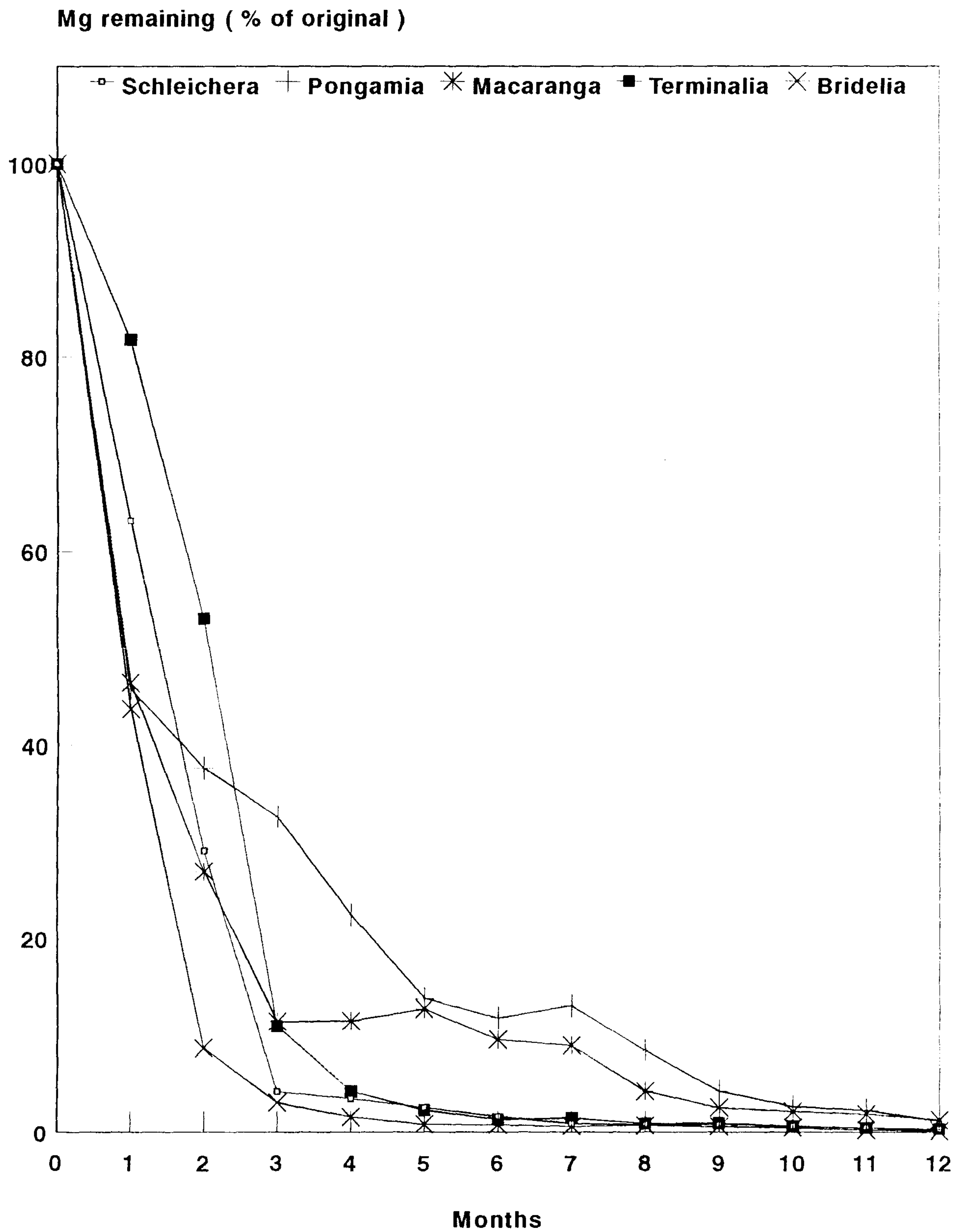

Fig. 24 Changes in absolute amounts of magnesium in leaf biomass

Second order hyperbolic equation was found to be good fitting for S. *oleosa* (r^2 = 0.98), M. *peltata* (r^2 = 0.99) and B. *retusa* (r^2 = 0.98) in characterising Mg mineralisation. Among the various prediction models attempted to represent Mg release over time, normal model was found to be the best for P. *pinnata* while log normal model (r^2 = 0.97) was best suited for T. *paniculata*.

4.2.3.6 Sulphur

Absolute mass of S decline linearly with time (Fig.25). A drastic release pattern was observed during the initial three months. At the end of 12 months percentage of initial sulphur remaining in the decaying material was maximum for P. *pinnata* (3.16%), followed by S. *oleosa* (1.55%), M. *peltata* (1.22%), B. *retusa* (1.02%) and T. *paniculata* (0.52%).

For species such as S. *oleosa*, M. *peltata* and B. *retusa*, second order hyperbolic model suitably explained the changes in the absolute content of sulphur over time. A normal equation was best fitted for P. *pinnata* (r^2 = 0.99) while log normal model was the best for T. *paniculata* (r^2 = 0.94).

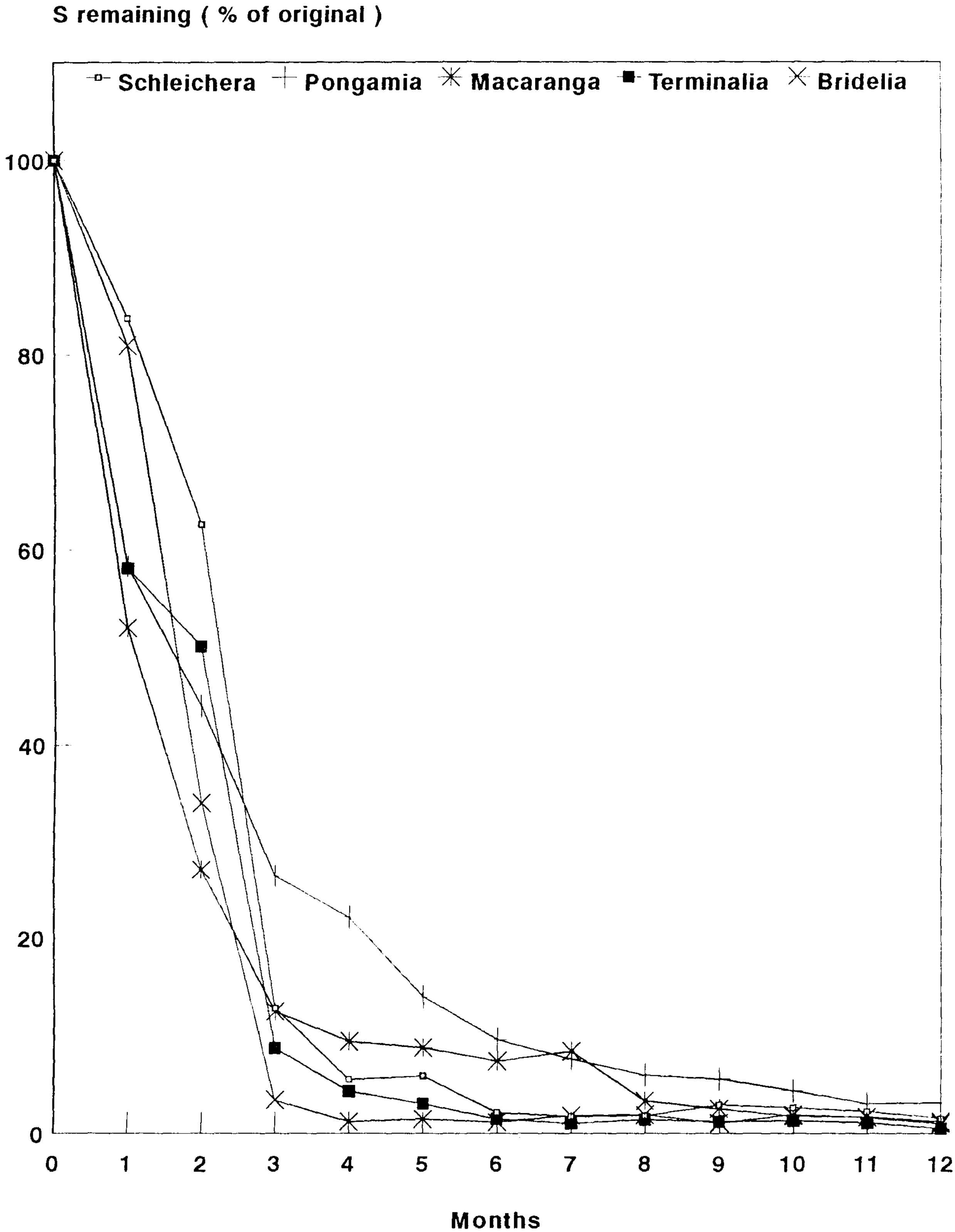

Fig. 25 Changes in absolute amounts of sulphur in leaf biomass

4.2.4 Relative mineralisation efficiency of nutrients for different species

The observations furnished in table 9 shows the absolute amounts of nutrients remaining (percentage of original) in the litter bags after a period of three months for different species. In general, for all the species fastest rate of mineralisation was observed for potassium. The corresponding absolute amounts of K remaining in the litter bags after three months were found to be of the order 13.14 per cent for _P. pinnata_, 1.25 per cent for _T. paniculata_, 1.16 per cent for _B. retusa_, 0.98 for _M. peltata_ and 0.53 per cent for _S. oleosa_. An efficient N mineralisation trend was observed for _M. peltata_, _T. paniculata_ and _B. retusa_. The percentage of absolute amount of N remaining at the end of third months in the biomass of the above species was found to be 6.1 per cent, 5.72 per cent and 1.87 per cent respectively. However, for _S. oleosa_ and _P. pinnata_, N showed a moderate rate of release. Immediately following K, _P. pinnata_ represented the lowest value for absolute amount of P (19.17%) indicating the better P mineralisation tendency of _P. pinnata_.

Generally for all the species, Ca, Mg and S recorded lower rates of mineralisation excepting _S. oleosa_ which

Table 9. Nutrients remaining in the litter bags at the end of 3 months of biomass decomposition

Species	Absolute amount of nutrient remaining (% of original)						Order of mineralisation
	N	P	K	Ca	Mg	S	
Schleichera oleosa	7.37	7.66	0.53	5.77	4.27	12.76	K > Mg > Ca > N > P > S
Pongamia pinnata	23.00	19.17	13.14	43.67	32.65	26.45	K > P > N > S > Mg > Ca
Macaranga peltata	6.10	10.69	0.98	8.96	11.46	12.41	K > N > Ca > P > Mg > S
Terminalia paniculata	5.72	6.03	1.25	13.49	11.01	8.71	K > N > P > S > Mg > Ca
Bridelia retusa	1.87	3.02	1.16	6.54	3.00	3.45	K > N > P > Mg > S > Ca
CD(0.05)	0.018	0.018	0.018	0.018	0.018	0.026	
SEM ±	0.006	0.005	0.005	0.005	0.005	0.008	

incidentally recorded higher efficiency with regard to Mg and Ca mineralisation.

Nutrient release was found to be statistically different between different species. At the end of three months, fastest N mineralisation was observed for *B. retusa* and slowest for *P. pinnata*. A similar trend was observed for phosphorus, magnesium and sulphur. For potassium, *S. oleosa* recorded maximum release followed by *M. peltata*, *B. retusa* and *T. paniculata*. *P. pinnata* registered lowest rate of K. Calcium also followed more or less a similar pattern. However, *B. retusa* showed a faster release of Ca than *M. peltata*.

Discussion

DISCUSSION

The tropical forest trees are reported to retain considerable portion of nutrients in their leaf biomass. So long as these nutrients contained in the plant biomass are held up as organic molecules, they are protected from leaching and hence not available to the plants. The incorporation of tree leaf biomass into the soil and their further decomposition offer a potential source of most of available nutrients to the plants in many agroforestry systems. A sound knowledge of the rates of decomposition and nutrient release patterns of the biomass of different tree species will help to regulate the timing of leaf litter incorporation into the soil, which will finally improve the soil nutrient status.

The present study was carried out to find out the rate of decomposition and nutrient release functions of leaf biomass of five selected tree species under Vellanikkara condition. The salient findings are discussed here under.

5.1 Leaf biomass decomposition

5.1.1 Rates of biomass decomposition

Species difference with regard to rate of biomass decomposition are evident from the present study. In general, all the species showed a high degree of decomposition during the 12 month period of study. Except Pongamia pinnata, all the species lost more than 97 per cent of their original biomass during a period of one year. Comparatively P. pinnata retained a higher per cent (5.68%) of initial leaf biomass as undecomposed. Kumar and Deepu (1992) also observed a very fast rate of litter decomposition for tropical deciduous tree species. They reported that all the species tested lost the mass completely within a period ranging from five to eight months. Decomposition studies in tropical agroforestry systems by Bardwaj at al. (1992) also revealed a very high mass loss for Leucaena leucocephala, Populus deltoids, Eucalyptus sp. and Prosopis juliflora during 274 days of exposure to decomposition. Favourable temperature and moisture conditions characteristic of tropics and physico-chemical quality of the plant materials could be some of the major factors for the fast rate of decomposition of the five species tested in the present study.

5.1.2 Decay rate coefficients

Analysis of the decomposition rates in the form of their calculated decay rate coefficients suggest higher values for Terminalia paniculata (0.25) and Bridelia retusa (0.24). It is worth to note that Schleichera oleosa and Macaranga peltata registered intermediate values (0.21 and 0.19

respectively), while the lowest decay rate coefficient was noticed for *P. pinnata* (0.12). The K values observed in the present study were found to be higher than those reported for temperate tree species by Melillo *et al.* (1982). Incidentally, the K values reported by them ranged from 0.08 to 0.47. However, a close perusal of the results show that the present K values were lower when compared to those reported by Kumar and Deepu (1992) in moist deciduous forest ecosystem. It is a well known fact that forest ecosystems provide better conditions for leaf biomass decomposition since it represents the only means of nutrient replenishment in natural forests.

The half life values observed for various species are also very interesting to discuss. The predicted half life values were of shorter duration for all the species studied when compared to values reported from elsewhere. Singh *et al.* (1993) observed a long half life value for *Shorea robusta* (8 fortnights); *Tectona grandis* (14 fortnights); *Eucalyptus hybrid* (23.6 fortnights) and *Populus deltoides* (15.8 fortnights).

5.1.3 Pattern of biomass decomposition

The pattern of biomass decomposition for different species are different as is evident from the data furnished earlier. It generally followed a biphasic pattern with an initial rapid decomposition phase followed by a prolonged slow decomposition phase. Similar trend has been reported by Singh et al. (1993) in their studies on the decomposition of sal, teak, eucalyptus and poplar. The possible reason for the initial high decomposition for the different species could be the prevailing favourable environmental condition and better soil aeration and soil moisture. This might have triggered the microbial activity on the decomposition of leaf materials. Moreover, heavy leaching losses of water soluble carbon fractions from the decomposing leaf biomass during the rainy periods might have accounted for the heavy mass loss during initial phase. Similar two phase mass loss pattern has also been reported by Berg and Staaf (1981) in the decomposing scot pine needle litter in which the heavy mass loss phase was regulated by the labile carbon components and the later slow decomposition phase by biodecay resistant refractory fractions.

5.1.4 Factors affecting biomass decomposition

Significant differences in the rates of decomposition have been observed between species. The difference is more obvious during the initial four months of decomposition. Strong interplay of an array of plant as well as soil factors was found to influence rate of decomposition.

5.1.4.1 Nitrogen content and C:N ratio

The positive influence of initial nitrogen content and C:N ratio of the leaf biomass on the rate of decomposition need not be over emphasised. The studies by Aber and Melillo (1980); Fog (1988) and Barry et al (1989) have clearly revealed the above fact. Tropical tree leaf biomass in general, contain a higher content of N compared to temperate species. This is more true in the case of tropical deciduous tree species and hence, they in general showed a faster rate of decomposition compared to temperate tree species. In the present study, all the species were found to retain higher amounts of nitrogen in their fresh samples and hence, a consequent heavy mass loss was registered by them. Studies by Kumar and Deepu (1992) revealed faster decomposition rates for *Pterocarpus marsupeum*, *Grewia tiliaefolia* and *Xylia xylocarpa* owing to their high initial nitrogen content. However, this was not absolutely true in the present study. Here N content or C:N ratio was not influencing the rate of decomposition significantly. Similar reports were also made by Barry et al. (1989) based on their studies using pine needles. In the present study, the slowest decomposing *P. pinnata* leaves showed high concentration of N in their fresh samples and also marked low C:N ratio (9.3). This strongly suggest the fact that in *P. pinnata* leaves, inspite of the higher N concentration, there may be other compounds which might have influenced the rate of decomposition. Such slow decomposition pattern of leaf material with high nitrogen contents due to the presence of poly phenols and volatile terpenes on the leaf biomass has been reported by De Moral and Muller (1969). However, the slowly decomposing species like P. pinnata and M. peltata recorded higher C:N ratios (4.8 and 6.8 respectively) in the decomposing leaf samples at 10th month, indicating the lower availability of nitrogen for the microbial decomposition. The general decline in C:N ratio in the subsequent sampling dates suggest the fact that there is a reduction in microbial activity due to the limitation of carbon during the later phase of decomposition (Aber and Melillo, 1980 and Berg and Staaf, 1981).

5.1.4.2 Lignin content

Lignin content of the biomass strongly influenced the rate of biomass decomposition of the species. The slowly decomposing P. pinnata was found to possess a higher lignin content in the initial samples. Such negative linear relationship between lignin concentration and rate of mass loss was also reported by Melillo et al. (1982) and Berndse et al. (1987). Initial lignin content exert more control over rate of decomposition than does nitrogen (Fogel and Cormack, 1977). Tree leaves with high lignin content is said to have poor correlation for initial N and C:N ratio with rate of decomposition (Barry *et al.*, 1989). In the present study, lignin content was found to increase during the subsequent sampling months for all the species which clearly indicated the pronounced effect of lignin on rate of decomposition during the later stages. Barry *et al.* (1989) stated that the regression of lignin content on mass remaining improved considerably during the later sampling period indicating the fact that the slow phase of decomposition is lignin controlled while the initial rapid mass loss phase is controlled by N present in soluble carbon compounds.

It could be seen that during the final sampling date also *P. pinnata* retained maximum lignin content in the litter resulting in slower decay rates. On the other hand, *T. paniculata* and *B. retusa* retained lower lignin content during the entire sampling periods, indicating the presence of more biodegradable carbon sources which finally enhanced faster biomass decomposition.

5.1.5 Environmental factors on decomposition

Among the climatic variables, the influence of temperature and moisture on the rate of decomposition is well established (Madge, 1965, Gupta and Singh, 1977 and Singh *et al.*, 1980). Witkamp and Van der Drift (1961) reported that microbial activities are favoured during summer due to high moisture and temperature resulting increased rate of decomposition. In the present investigations, the decomposition studies were started in July, a period with abundant rain fall and RH, which totally might have helped in the microbial proliferation and subsequent rapid mass loss (more than 90 per cent) during the initial three months of decomposition. Luizao and Schubart (1987) studied the leaf litter decomposition in Central Amazon with repetitions for dry and wet periods. They observed that one half of the litter disappeared in about 218 days under dry season as against 32 days in wet season.

It may also be stated that in the present study no direct statistical correlation could be established between the climatic variables with decay rates when considered for the entire study period. With regard to all the species, after three months of rapid mass loss, the mass remaining in the litter bags was substantially low to relate with the corresponding variation in the weather parameters. Had the study been started during the dry periods, relationship of environmental factors on decomposition rate could have been more precisely explained and discussed. Under favourable environmental condition more emphasis has to be given to the fact that the dominant factor controlling microbial activity of the decomposing leaf materials and subsequent rate of mass loss is the physical and chemical properties of the leaves as reported by Witkamp (1966).

5.1.6 Soil factors

It has already been discussed that bulk of the mass loss for the different species occurred during the earlier three months which incidentally was the period with high soil moisture. As discussed earlier, the mass remaining in the litter bags was relatively very small to establish a positive relationship with soil moisture content. However, S. oleosa and B. retusa recorded a positive correlation between mass loss and soil moisture content. The significant difference in the decay rates particularly during the initial three months periods when the soil moisture was maximum, could be related to the differential chemical quality of the leaf biomass. No relationship could be established between pH and rate of decomposition.

5.2 Nutrient release patterns

Leaf biomass decomposition is the primary mechanism by which various organically bound nutrients are released to the soil for the subsequent absorption by the plants. Tropical tree leaves are found to contain higher levels of most of the plant nutrients and hence, their incorporation into the soil offer a substantial contribution to the labile soil nutrient pool. However, different types of nutrient release patterns have been exhibited mostly due to the variation in the chemical quality of different leaf biomass. Chemical composition is an intrinsic property of the litter which determines the rate of turn over of organically bound nutrients (Meentemayer, 1978).

5.2.1 Nitrogen

Nitrogen present in the plant biomass serves as a potential source of nitrogen to enrich the labile soil nitrogen pool. In the present study, N concentration in the fresh leaf samples was higher than that reported for the litters of many temperate as well as tropical tree species. Leaf litters 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). The samples used in the present study were freshly collected from the trees and hence, the possibilities of nutrient retranslocation could be completely ruled out.

The nitrogen concentration of all the species varied significantly. *P. pinnata* registered the highest value for initial N concentration while the lowest was recorded by *T. paniculata*. A close perusal of the data shows that in all the species there was a faster decline in the concentration of N at the end of one month of decomposition. This could be attributed to the intense microbial activity in the initial stages of decomposition and thus a higher demand for nitrogen. Moreover, the leaching of water soluble nitrogenous substances might have accounted for the rapid decrease in N concentration (Nykvist, 1963). It is also evident from the results that there was an increase in nitrogen concentration in all the species during the second month. This apparent increase could be a result of faster oxidation and leaching of soluble carbon compounds resulting in an increase in nitrogen concentration. Similar results were also reported by Lousier and Parkinson (1976) based on their studies on nitrogen dynamics in temperate deciduous forests. The variation in N concentration for different species is also obvious in the present study. The preferential biological oxidation of various compounds present in the leaf biomass at various stages of decomposition perhaps would have resulted in the apparent fluctuation in concentration of nitrogen with regard to various species.

Despite the variation in the N concentration, there appeared a uniformity with regard to the changes in absolute amounts of the nitrogen present in different leaf samples. As the leaf samples decay, the absolute amount of N was found to be decreased as the rate of mass loss was far greater than the concentration increase (Coldwell and DeLong, 1950). George (1993) also noted a similar steady reduction in absolute amounts of N in leaf litters of acacia, ailanthus, casuarina and leucaena. An increase in the absolute amount of nitrogen during the first month highlights the possibility of accumulation of nitrogen in the *P. pinnata* leaf biomass. This absolute increase in the N mass during decomposition could be due to various factors like high rainfall, insect frass, fungal translocation etc. (Bocok, 1964 and Gosz *et al.*, 1973). Retention of higher absolute amount of N by *P. pinnata* leaves at the end of three months might be due to the retention of higher biomass in the litter bags on one hand and also its intrinsic nature to retain higher concentration of N owing to their structural complexity as is reported by Staff and Berg (1977).

5.2.2 Phosphorus

Phosphorus has been shown to be a limiting factor for vegetative growth and sometimes becomes a bottle neck for productivity of trees in natural ecosystems. The general decline in P concentration for different species in the initial few months could be associated with faster loss of P along with decaying biomass in the early rapid mass loss phase of decomposition. However, in the later phase, increase in P content in the decomposing leaf biomass for most of the species suggest better retention of P compared to other leachable compounds, resulting in an apparent increase in P concentration. This clearly portrays the immobile nature of P (Upadhyay, 1987).

The absolute amounts of P showed a steady decline over the 12 months decomposition period. The concentration changes were not substantially enough to make greater changes in the absolute amounts owing to the faster mass loss for all the species during initial rapid decomposition phase.

5.2.3 Potassium

Potassium is highly mobile, both in plant as well as in soil system. Unlike N or P, it is not structurally bound in the organic compounds. Potassium being a monovalent ion, is weakly bound to adsorption sites and is highly water soluble (Bocock, 1964; Attiwill, 1968 and Gosz et al., 1973). In the present study, K concentration was found to decline drastically during the first month itself after exposure to decomposition. Heavy rainfall and associated microbial activities during this period might have caused considerable leaching of K from the litter bags. In most of the species, absolute amounts of K followed a rapid declining trend comparable with their respective mass loss.

5.2.4 Calcium

It is a well established fact that calcium is absolutely essential for cell division and cell elongation in plants. Except _P. pinnata_, all the species showed a hike in Ca concentration during the initial decomposition periods. The apparent increase in Ca concentration might be due to the rapid leaching of water soluble substances during the initial phase. In the subsequent periods, Ca showed a gradual declining trend for _S. oleosa_, _T. paniculata_, _M. peltata_ and _B. retusa_. The faster decomposition process might be responsible for most of the Ca loss as reported by Thomas (1970) and Gosz _et al_. (1973). This is more evident if we consider the Ca loss in terms of absolute amounts. Upadhyay (1987) in his study also observed a similar heavy minerali- sation of Ca (more than 85 per cent) for the broad leaved tree species. Nutrient release studies using _Shorea robusta_ also revealed a faster declining trend in Ca content through out the study period (Shukla and Singh, 1984).

5.2.5 Magnesium

Magnesium is the only nutrient element which forms a constituent of chlorophyll and is also essential for protein synthesis. In the present study, Mg generally showed more or less similar release pattern with regard to all the species tested. The structural similarity of Mg present in the leaf biomass of these species might be the probable season for such a trend. However, the initial rapid decrease in Mg content, similar to mass loss pattern, as shown by B. retusa, S. oleosa and P. pinnata suggest the fact that Mg forms a part of more recalcitrant soluble portions of the litters. Similar faster release of Mg comparable to mass loss pattern was reported for Scot pine needles by Staaf and Berg (1982). The faster reduction in absolute quantity of Mg when compared to Ca, could be due to the higher mobility and leachability of Mg (Attiwill, 1967).

5.2.6 Sulphur

Sulphur forms an important plant nutrient involved in the synthesis of some of the amino acids and various metabolites in the plant systems. The concentration of sulphur in the leaf biomass is found to vary between different species. Higher concentration of sulphur noticed in the litters of P. pinnata, M. peltata and S. oleosa during the initial and final periods of the study could be partly due to the contribution of SO_4^- sulphur by way of stemflow and throughfall (Blair, 1988). Similar increase in sulphur concentration was reported by Bockheim et al. (1991) for trembling aspen and northern pine oak. Nevertheless, these concentration increase was not sufficiently enough to mark an increase in their absolute amounts of sulphur, primarily due to the heavy mass loss from the litter bags.

5.2.7 Relative mineralisation efficiency of nutrients

Present study shows that in all the species, potassium stands first in terms of mineralisation efficiency. Such faster mineralisation for K has also been reported for various tree species by other workers (Staaf and Berg, 1982 and Bargali _et al_. 1993). Slower N mineralisation was noticed for _S. oleosa_ which is also in agreement with the reports made by Bahuguna _et al_. (1990). However, species such as _M. peltata_, _T. paniculata_ and _B. retusa_ exhibited faster N release patterns. The faster leaching of nitrogenous substances could be the possible reason for the rapid mineralisation of N in these species. Several field studies of leaf biomass decomposition have clearly illustrated the faster leaching of water soluble nitrogenous substance in plant tissues (Howard and Howard, 1974 and Staaf and Berg, 1977).

Relative lower rates of mineralisation was exhibited by Ca, Mg and S which may perhaps be due to their lower mobility and structural complexity.

Present study also revealed significant differences among species with regard to nutrient release patterns. In general, nutrient release was found to be fast for species like *B. retusa* and *T. paniculata* and these also recorded higher rates of biomass decomposition. Inspite of the higher initial nutrient content, surprisingly, *P. pinnata* registered lower rates of mineralisation with regard to most of the nutrients studied. The possible reasons could be the presence of higher amounts of biodecay resistant materials like lignin, hemicellulose etc. in the litter which may reduce the microbial activity and thereby helping in maintaining higher amounts of nutrients locked in the leaf biomass.

Summary

SUMMARY

Tropical soils, in general, are facing the serious problems of degradation owing to unscientific management and intensive land use practices. This has become a great threat for sustainable production in agro - farm forestry systems. Recently, more emphasis is being given for the use of organic manures primarily in view of their potential to improve physico-chemical attributes and maintaining long term fertility of the soil. Trees in general, and tropical trees in particular, are found to retain a considerable portion of major and micro nutrients in their leaf biomass. Decomposition and release of these nutrients into the soil will help to improve the plant available nutrient pool in the soil. However, the efficiency of leaf biomass with regard to their rate of decomposition and nutrient release, is strongly dependent on the quality of the leaf biomass and to a small extent on prevailing weather conditions.

The present investigations were undertaken in College of Forestry, Vellanikkara, to find out the rate of decomposition and nutrient release patterns of the leaf biomass collected from five conventionally used forest tree species namely, <u>Schleichera oleosa</u> (Lour.) Oken, <u>Pongamia pinnata</u> (L.) Pierre, <u>Macaranga peltata</u> (Roxb), M.-A,

Terminalia paniculata Roth. and *Bridelia retusa* (L.) Spreng. The salient findings of the studies are summarised below:

1. The rate of leaf biomass decomposition was generally faster for all the species studied. During the 12 month period of study, all the species lost more than 94 per cent of the initial biomass.

2. Leaf biomass of *B. retusa* and *T. paniculata* showed faster rates of decomposition while *P. pinnata* recorded the lowest rate. *M. peltata* and *S. oleosa* showed a moderate trend with regard to rate of decomposition.

3. Characteristic biphasic pattern of biomass decomposition was exhibited by all the species. The first phase of heavy mass loss for a period of three months was followed by a gradual mass loss phase extending till the end of the study.

4. In the present study, the initial nitrogen or carbon:nitrogen ratio was not found to be directly related with decay rate. However, there was a general reduction in the C:N ratio as decomposition advanced.

5. Lignin content of the leaf biomass strongly influenced the rate of biomass decomposition. *P. pinnata* registered a high lignin content in their leaf biomass when

compared to other species. Also, faster decomposing species such as B. *retusa* and T. *paniculata* retained lower levels of lignin. Moreover, in all the species, lignin concentration increased as decomposition progressed.

6. The rate of decomposition of leaf biomass of P. *pinnata*, M. *peltata* and T. *paniculata* was found to have a poor correlation with soil moisture content while S. *oleosa* and B. *retusa* recorded a high positive relationship with soil moisture.

7. A high degree of variation in the nutrient content has been observed during the course of decomposition with regard to different species. P. *pinnata* registered the highest value for initial nitrogen content while the lowest was recorded by T. *paniculata*. At the end of the study, in all the species, N concentration was found to be lower when compared to initial value.

8. The phosphorus content was maximum in the leaf biomass of P. *pinnata* while T. *paniculata* recorded the lowest value. Generally, most of the species showed a reduction in P content during the initial stages while a pronounced increase in the P concentration was observed during the second half of the study.

9. For all the species under study, the potassium content showed a rapid declining trend during the initial three months comparable to the mass loss pattern. Thereafter, it followed more or less a steady trend.

10. Except P. pinnata, all the species showed an increase in Ca content during the initial period followed by a gradual decline over time. Further more, P. pinnata leaves recorded higher fluctuation in Ca concentrations.

11. Magnesium also recorded a similar trend. However, it followed a faster declining trend, particularly during the initial period.

12. Higher levels of sulphur concentration was observed in the leaf samples of P. pinnata, M. peltata and S. oleosa in both the fresh as well as decomposed samples.

13. Despite the fluctuations in nutrient concentrations, all the species exhibited a steady declining trend with regard to their absolute mass which was in accordance with the pattern of leaf mass loss.

14. For all the species, potassium could be considered as the fastest mineralising nutrient element. M. peltata, T. paniculata and B. retusa showed an efficient N mineralisation tendency also. Among the different

species, only *P. pinnata* showed a faster release of Phosphorus. Ca, Mg and S generally followed a slower rate of mineralisation. However, efficient release of Ca and Mg has been observed for *S. oleosa*.

15. The early and faster decomposing species like *B. retusa* and *T. paniculata* showed a rapid release of all the nutrients. The slow decomposing leaf biomass of *P. pinnata* registered lower rates of mineralisation with regard to most of the nutrients.

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Appendices

Appendix I

Decay rate coefficients and half life of decomposing leaf biomass

Species	K	r^2	S.E.E.	Half life (fortnights)
S. oleosa	-0.216830	0.99096	0.17709	3.20
P. pinnata	-0.129760	0.97205	0.52525	5.34
M. peltata	-0.190104	0.96632	0.50703	3.70
T. paniculata	-0.257054	0.95589	0.78872	2.70
B. retusa	-0.246907	0.93364	0.94013	2.80

Appendix II

Weather parameters for the experimental period (July 1993 to June 1994) recorded at nearby Agrometeorological station

Months	Weather parameters				
	Mean monthly rainfall (mm)	Maximum temper-ature °C	Minimum temper-ature °C	R.H. Mean %	No.of rainy days
June 93	700.3	30.1	23.9	86	22
July 93	661.6	28.5	22.9	87	29
Aug. 93	286.7	29.6	23.4	89	20
Sept.93	85.3	30.6	33.1	81	9
Oct. 93	519.0	30.7	23.4	83	16
Nov. 93	74.6	31.5	23.6	73	4
Dec. 93	18.0	31.6	23.1	66	2
Jan. 94	19.4	32.9	22.6	58	1
Feb. 94	1.7	34.8	23.1	59	0
Mar. 94	21.0	36.2	23.7	59	1
Apr. 94	165.2	34.9	24.4	74	10
May 94	124.2	33.6	24.7	75	7
June 94	955.1	28.9	22.9	90	27
July 94	1002.1	28.6	22.4	91	29
Aug. 94	509.2	30.0	22.8	85	20

Mean annual R.F. (from July 93 to June 94) = 2931.8 mm

Appendix III

Relationships between time elapsed and absolute nutrient contents of residual decomposing mass of various tree species

Species	Nutrient	Nutrient equation	Coef.A	Coef.B	Coef.C	R^2
		Y=A*B^X*X^C	121.2000	0.9981	-2.0790	0.9445
	N	Y=A*e^((lnX-B)^2/C)	4043.0000	-4.6100	-5.7250	0.9442
		Y=A*e^((X-B)/2)	0.7036	12.8900	31.7500	0.9230
		Y=1/(A+B*X)	0.0455	0.0663	0.0000	0.9566
	P	Y=1/(A*(X+B)^2+C)	-0.0003	-109.8000	3.8030	0.9525
		Y=A*e^((X-B)/2)	1.4050	9.9520	21.8900	0.9467
		Y=A+B/X+C/X*X	1.4330	12.7300	-0.0012	0.9983
	K	Y=A+B*X+C/X	6.2410	-0.6747	0.0090	0.9906
Schleichera oleosa		Y=A+B/X	1.8560	0.0098	0.0000	0.9836
		Y=A*B^(1/X)*X^C	107.3000	0.9980	-2.1140	0.9659
	Ca	Y=A*e^((lnX-B)^2/C)	3908.0000	-4.6510	-5.6800	0.9629
		Y=1/(A*(X+B)^2+C)	0.0147	-0.9685	0.0286	0.9497
		Y=A+B/X+C/X*X	-9.0360	69.8200	-0.0069	0.9810
	Mg	Y=A*B^(1/X)*X^C	70.6500	0.9981	-2.1100	0.9786
		Y=A*e^((lnX-B)^2/C)	2910.0000	-4.7840	-5.8230	0.9744
		Y=A+B/X+C/X*X	10.1800	99.1800	-0.0099	0.9339
	S	Y=A*e^((x-B)/2)	1.7660	9.6270	20.7400	0.9198
		Y=A*B^(1/x)*X^C	90.8900	0.9984	-1.7160	0.9050

Contd.

Appendix-III (Contd.)

Species	Nutrient	Nutrient equation	Coef.A	Coef.B	Coef.C	R^2
Pongamia pinnata	N	Y=Ae^(B*X)	82.2400	-0.3211	0.0000	0.9705
		Y=A*B^X	82.2400	0.7253	0.0000	0.9705
		Y=A*B^X*X^C	77.5700	0.7351	-0.0259	0.9704
	P	Y=A+B/X+C/x*X	4.0330	44.8300	-0.0044	0.9689
		Y=A*B^X*X^C	48.8700	0.8186	-0.0788	0.9534
		Y=A+B*X+C/X	36.0600	-3.1440	0.0063	0.9519
	K	Y=A+B*lnX	20.6600	-8.5510	0.0000	0.9964
		Y=A+B*X+C/X	16.2800	-1.5250	0.0083	0.9936
		Y=A*B^X*X^C	37.0900	0.7144	-0.1007	0.9310
	Ca	Y=A+B*X+C/X	49.8700	-4.5480	0.0050	0.9397
		Y=A*e^(X-B)/2)	109.0000	-5.3670	70.2700	0.9242
		Y=A*X^(B*X)	63.7000	-0.1233	0.0000	0.9197
	Mg	Y=A*e^(Cx-B)/2)	641.0000	-17.5800	-142.1000	0.9715
		Y=A*e^(B*X)	85.0000	-0.3320	0.0000	0.9688
		Y=A*B^X	85.0000	0.7175	0.0000	0.9688
	S	Y=A*e^((x-B)/2	2.3720	16.2500	71.0300	0.9943
		Y=A*B^x*X^C	63.5600	0.7699	-0.0527	0.9782
		Y=1/A*(x+B)^2C)	0.0020	0.5374	0.0099	0.9777

Contd.

Appendix-III (Contd.)

Species	Nutrient	Nutrient equation	Coef.A	Coef.B	Coef.C	R^2
		Y=A+B/X+C/X*X	-10.0200	88.9400	0.0088	
	N	Y=1/(A*(X+B)^2+C	0.0114	-1.9330	0.0236	0.9682
		Y=A*e^((ln X-B)^2+C)	1993.0000	-4.7020	-6.7890	0.9425
		Y=A+B/X+C/X*X	-3.2560	63.1100	0.0063	0.9859
	P	Y=A*e^((InX-B)^2/C)	689.0000	-4.8900	-9.6710	0.9531
		Y=A*B^(1/x)*X^C	65.3000	0.9989	-1.2850	0.9506
		Y=A+B/X+C/X*X	-0.5822	10.5100	-0.0010	0.9988
	K	Y=A+B*X+C/X	5.8580	-0.5730	0.0094	0.9938
Macaranga peltata		Y=A+B/X	2.1330	0.0097	0.0000	0.9887
		Y=A+B/X+C/X*X	-4.9590	61.9300	-0.0061	0.9898
	Ca	Y=A*e^((lnX-B)^2C)	1076.0000	-4.8330	-8.0570	0.9381
		Y=A*B^(1/x)*X^C	67.6500	0.9986	-1.5240	0.9319
		Y=A+B/X+C/X*X	-0.9736	48.8000	-0.0048	0.9904
	Mg	Y=1/(A*(X+B)^2+C)	0.0076	-2.3140	0.0173	0.9590
		Y=A*B^X*X^C	49.6500	0.7513	-0.0767	0.9585
		Y=A+B/X+C/X*X	-2.9730	55.3100	-0.0055	0.9959
	S	Y=1/(A*(X+B)^2+C)	0.0074	-1.8740	0.0224	0.9666
		Y=A*B^X*X^C	47.3900	0.7456	-0.8458	0.9610

Contd.

Appendix-III (Contd.)

Species	Nutrient	Nutrient equation	Coef.A	Coef.B	Coef.C	R^2
		Y=1/(A*(X+B)^2+C)	0.0085	3.4170	-0.1552	0.9490
	N	Y=A*B^(1/x)*X^C	91.4200	0.9980	-2.1360	0.9467
		Y=A*e^((X-B)/2)	0.6173	10.7600	21.3000	0.9412
		Y=A+B/X+C/X*X	-7.9810	66.9500	-0.0066	0.9773
	P	Y=A*e^((x-B)/2)	0.7493	9.6250	18.1100	0.9524
		Y=A*B^(1/x)*X^C	59.0200	0.9983	-1.8910	0.9418
		Y=A+B/X+C/X*X	-3.7310	29.0300	-0.0029	0.9914
	K	Y=A+B*Inx	18.5300	-8.8630	0.0000	0.9781
		Y=A+B*X+C/X	13.5100	-1.4970	0.0086	0.9497
<u>Terminalia paniculata</u>		Y=A*e^((Inx-B)^2/C)	8173.0000	-4.5730	-4.8820	0.9660
	Ca	Y=A*e^((x-B)/2)	0.3713	12.6300	26.3300	0.9617
		Y=A*B^(1/X)*X^C	141.1000	0.9977	-2.4130	0.9606
		Y=A*e^((Inx-B)^2/C)	6304.0000	-4.6090	-5.1130	0.9729
	Mg	Y=A*B^(1/X)*X^C	124.3000	0.9978	-2.3260	0.9726
		Y=1/(A*(X+B)^2+C)	0.0229	-1.3820	0.0267	0.9651
		Y=A*e^(X-B)/2)	0.8311	10.5500	22.0400	0.9402
	S	Y=A*B^(1/x)*X^C	78.7200	0.9982	-1.9490	0.9392
		Y=A+B/X+C/X*X	-7.4450	71.4800	-0.0071	0.9347

Contd.

Appendix-III (Contd.)

Species	Nutrient	Nutrient equation	Coef.A	Coef.B	Coef.C	R^2
		Y=A+B/X+C/X*X	-5.8380	43.8100	0.0043	0.9879
	N	Y=A+B*InX	20.1600	-8.9290	0.0000	0.9331
		Y=A*B^(l/x)*X^C	26.9500	0.9985	-1.730	0.9108
		Y=A+B/X+C/X*X	-9.0580	65.9000	-0.0065	0.9715
	P	Y=A*e^(X-B)/2	0.7747	8.6740	15.5600	0.8840
		Y=A*B^(l/x)*X^C	32.8300	0.9986	-1.6080	0.8746
		Y=A+B*X+C/X*X	-2.8750	19.0600	-0.0019	0.9957
	K	Y=A+B*InX	16.8900	-8.8140	0.0000	0.9769
		Y=A+B*X+C/X	7.5100	-0.8399	0.0092	0.9727
<u>Bridelia retusa</u>		Y=A*B^(l/X)*X^C	74.7100	0.9983	-1.9030	0.9758
	Ca	Y=A*e^((Inx-B)^2/C)	2068.0000	-4.7850	-6.4900	0.9649
		Y=A+B/X+C/X*X	-12.8300	94.3200	0.0094	0.9625
		Y=A+B/X+C/X*X	-6.4830	44.9000	-0.0044	0.9819
	Mg	Y=A*B^(l/X)*X^C	35.2600	0.9982	-2.0620	0.9765
		Y=A*e^((Inx-B)^2/C)	1675.0000	-5.0320	-6.2190	0.9676
		Y=A+B/X+C/X*X	11.6400	87.6700	-0.0087	0.9618
	S	Y=A+B*X+C*X*X	88.8100	-24.6700	1.5420	0.8312
		Y=A*e^((x-B)/2)	1.0130	8.4940	15.2300	0.8230

Appendix-IV

Details of the statistical models used to represent the absolute content of nutrients in the residual mass of various tree species

Sl.No.	Equation	Explanation
1.	Y=A+B*X	Straight line model
2.	Y=B*X	Line through origin
3.	Y-1/(A+B*X)	Reciprocal straight line model
4.	Y=A+B*X+C/X	Line and receiprocal model
5.	Y=A+B/X	Hyperbolic function
6.	Y=X/(A*X+B)	Reciprocal hyperbolic function
7.	Y=A+B/X+C/X*X	Second order hyperbolic function
8.	Y=A+B*X+C*X*X	Parabolic function
9.	Y=A*X+B*X*X	Par at origin function
10.	Y=A*X^B	Power function
11.	Y=A*B^X	Modified power function
12.	Y+B^(1/X)	Root function
13.	Y+A*X^(B*X)	Super Geometric function
14.	Y=A*X^(B/X)	Modified geometric function
15.	Y=A*e^(B*X)	Exponential model
16.	Y=A*e^(B/X)	Modified exponential model
17.	Y=A+B*ln(X)	Logarithmic model
18.	Y=1/(A+B*ln(X))	Reciprocal log function
19.	Y=A*B^X*X^C	Hoerl function

Contd.

Appendix IV (Contd.)

Sl.No.	Equation	Explanation
20.	Y=A*B^(1/X)*X^C	Modified hoerl function
21.	Y=A*e^((X-B)/2)	Normal function
22.	Y=A*e^((ln(X)-B)^2/C)	Log normal function
23.	Y=A*X^B*(1-X)^C	Beta function
24.	Y=A*(X/B)^C*e^(X/B)	Gamma function
25.	Y=1(A*(X+B)^2+C)	Cauchy function

APPENDIX-V

Abstracts of ANOVA tables for leaf biomass decomposition for five tree species

Source	d.f.	Mean square
Between species	4	0.331*
Within species	240	0.00026

* Significant at 5 per cent level

APPENDIX-VI

Abstracts of ANOVA tables for nutrient concentrations in the decomposing leaf biomass of five tree species

1. Nitrogen

Source	d.f.	Mean square
Between species	4	0.101*
Within species	10	0.0001

2. Phosphorus

Source	d.f.	Mean square
Between species	4	0.061*
Within species	10	0.0001

3. Potassium

Source	d.f.	Mean square
Between species	4	0.088*
Within species	10	0.0001

4. Calcium

Source	d.f.	Mean square
Between species	4	0.201*
Within species	10	0.0001

5. Magnessium

Source	d.f.	Mean square
Between species	4	0.166*
Within species	10	0.0001

6. Sulphur

Source	d.f.	Mean square
Between species	4	0.088*
Within species	10	0.0002

* - Significant at 5 per cent level

NUTRIENT CONTENT AND DECOMPOSITION OF LEAF BIOMASS OF SELECTED WOODY TREE SPECIES

By

KUNHAMU T. K.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Forestry

FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

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VELLANIKARA, THRISSUR

1994

ABSTRACT

A detailed study was conducted at the College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during 1992-94 to compare the rate of decomposition and nutrient release pattern of leaf biomass of five forest tree species namely, *Schleichera oleosa* (Lour.) Oken, *Pongamia pinnata* (L.)Pierre, *Macaranga peltata*, (Roxb) M.-A., *Terminalia paniculata* Roth and *Bridelia retusa* (L.) Spreng. The experiment was laid out in a typical home garden.

Generally, all the species under study showed a faster rate of leaf biomass decomposition. Among the various species tested, *B. retusa* and *T. paniculata* showed faster rates of leaf biomass decomposition while *P. pinnata* exhibited relatively a slower rate. The initial leaf nitrogen content and C:N ratio could not establish a direct relationship with rate of decomposition. However, in all the species, lignin content was found to exert a profound influence on mass loss patterns.

All the species showed a faster mineralisation of nutrients in accordance with the mass loss pattern. Among the nutrients, potassium followed a faster rate of mineralisation. A relatively good trend for N mineralisation

also has been reported for *M. peltata*, *T. paniculata* and *B. retusa* during the course of the study. Generally, Ca, Mg and S exhibited lower rates of mineralisation. *T. paniculata* and *B. retusa* followed an efficient release pattern for all the nutrients while *P. pinnata* showed slower rates of mineralisation with regard to most of the nutrients.