

**“LEAF LITTER DECOMPOSITION AND NUTRIENT
RELEASE PATTERN IN DIFFERENT TREE
SPECIES OF DRY DECIDUOUS FOREST”**

M.Sc. (Forestry) THESIS

by

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INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (C.G.)
2008**

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Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

KIRAN SHUKLA

**IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF**

Master of Science

In

FORESTRY

Roll No. 8573

ID No. 120106016

2008

CERTIFICATE – I

This is to certify that the thesis entitled **“LEAF LITTER DECOMPOSITION AND NUTRIENT RELEASE PATTERN IN DIFFERENT TREE SPECIES OF DRY DECIDUOUS FOREST”** submitted in partial fulfilment of the requirements for the degree of “Master of Science in Forestry of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **KIRAN SHUKLA** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

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This is to certify that the thesis entitled “**LEAF LITTER DECOMPOSITION AND NUTRIENT RELEASE PATTERN IN DIFFERENT TREE SPECIES OF DRY DECIDUOUS FOREST**” submitted by **KIRAN SHUKLA** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) in partial fulfilment of the requirements for the degree of “**M.Sc. (Forestry)**” in the **Department of Forestry** has been approved by the external examiner and Student's Advisory Committee after oral examination.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
%	Per cent
⁰ C	Degree Celsius
cm	Centimeter
Fig.	Figure
g	Gram
mg	Milligram
ha	Hectare
m ⁻²	Square metre
m	Metre
kg	Kilogram
RDR	Relative Decomposition Rate
<i>i.e.</i>	That is
<i>et al.,</i>	And co-workers
&	and

ACKNOWLEDGEMENT

“Work is Worship”

Words can hardly express emotions. My acknowledgment is much more than expressed here. It gives me immense pleasure to avail this unique opportunity in expressing my warmest appreciation with deep sense of gratitude to my guide, Dr. S.S. Bargali, Associate Professor, Department of Forestry and chairman of my advisory committee for his talented guidance, unique supervision, unfailing encouragement, fruitful criticism, scholarly advice which has given a touch of excellence to this thesis. It's my fortune to avail this opportunity of working under his guidance.

It is my devoir to express my heartfelt thanks to members of my Advisory Committee Dr. B.S. Thakur, Head, Department of Forestry, Dr. Lalji Singh, Associate Professor, Department of Forestry, Dr. M.L. Lakhera, Associate Professor, Department of Statistics, Mathematics and Computer Science, Dr. R.K. Bajpai Associate Professor, Department of Soil Science for their valuable and critical suggestion and regular encouragement during my study.

With profound respect I extend my gratitude to Dr. C.R. Hazra, Hon'ble Vice-Chancellor, Dr. A.S.R.A.S. Sastri, Director of Research Services, Dr. S.S. Kolhe, Director of Instructions, and Dr. B.S. Thakur, Dean, College of Agriculture, IGKV, Raipur for providing necessary facilities to conduct this research work.

I heartily obligate to Dr. M.N. Naugraiya (Forestry), Dr. R.K. Prajapati (Forestry), Dr. S.L. Swamy (Forestry), Dr. Nema (Forestry), Shri Pratap Toppo (Forestry), Miss Vijaylaxmi Kog..

Financial support from MOEn & F sponsored project entitled “Impact of land use on vegetation and soil carbon, net primary productivity and nitrogen budget in Tropical dry deciduous forest of Barnawapara sanctuary” is highly acknowledged.

I am very much thankful to Shri S.S. Porte (Soil Science) and Dr. Tapas Choudhary (Microbiology) for their kind help in chemical analysis of the samples.

I am expressing my sincere thanks to, Dr. Alka mam, Dr. Amita mam, Mrs, Shilpa mam and Rakesh bhaiya.

I wish to express my thanks to seniors Dr. Lekha mam, Jayant sir, Santosh sir, Bardani mam, Dheeraj sir, Sanjeevan sir, Shaliendra sir, Swati mam and Anjana mam. I extend

my thanks to my dearest friends and well wishers Shweta, Nidhi, Seema, Sarita, Anita mam, Bharti, Varsha, Dev sir, Ashutosh, Umakant, Manas, V.P Pandey, Abhishek,

I wish to express my heartiest gratitude to my Father-in-law Mr. P.K. Dwivedi, Mother-in-law Mrs. Premvati Dwivedi, Brothers-in-law Rajju and Avnish and Sister-in-law Rani whose selfless love caring nature and blessing always motivated me during the degree programme.

I have really run short of words to express my feelings for my Grand parents, my parents my Papa, Mr. K.P. Shukla, my Mummy, Mrs. Parvati Shukla, my Kaka, Mr. Arvind Shukla, my Kaki Mrs. Indravati Shukla and all family members who bore the weight of sacrifices with patience. Their continuous encouragement, support, love, advice and ever-showering blessings which have always been the source of inspiration in my life.

I express my feelings to my younger brother Devdutt, and Vinay and my sweet sister Nita, Kirti, Kukoo, Priya and my cute brother Shubham whose selfless love, support and tireless prayers have enabled me to come out with this priceless achievement.

Words run short to express thanks to my husband Mr. B.D. Dwivedi for their love, patience, support, sacrifices, pains, taking effort, constant encouragement and understanding me during the course of investigation.

My cordial thanks go to Bais bhaiya (Alfa-computers), for typing and printing.

I would like to convey my cordial thanks to all those who directly or indirectly helped me to fulfill my dreams come true.

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CHAPTER - I

INTRODUCTION

Decomposition leads with time to release of nutrients in a form available to plants. The importance of litter production in the forest ecosystems has long been recognized because the majority of organic matter produced by plants through photosynthesis is returned to the soil as litter. Litter fall may be seasonal or continuous process and represented one of most important pathway for the transfer of energy and material. The ways in which these two processes are accomplished, determine to a large extent the structural and functional features of the ecosystems. Litter decomposition plays a crucial role in the nutrient budget of forest ecosystem where vegetation depends mainly on the recycling of nutrients contained in the plant detritus. During this process plant nutrients become available for recycling within the ecosystem. Litter decomposition is influenced by environmental factor and also by physico-chemical properties of the plants and soil. Soil micro-organisms also play an important role in decomposition processes.

Singh *et al.* (1990) have stated that abundance of decomposing microbes depends partly on the native litter through its influence on the soil properties. Decomposition process plays an important role in soil fertility in terms of nutrient cycling and the formation of soil organic matter (Pandey and Singh 1982, Upadhyay 1988, Upadhyay and Singh 1989a&b, Bargali *et al.*1993 Usman *et al.*2000, Singh *et al.* 2007). The ways in which these two processes are accomplished determine to a large extent of structural and functional features of the ecosystems.

The decomposition of plant litter is one of the most crucial processes in the biogeochemical cycle of forest ecosystem (DeCatanzaro and Kimmins 1985). It is regulated by soil organism, environmental conditions and chemical nature of the litter. In many studies, litter N concentration or C: N ratio has been shown to be of critical importance in litter decay (e.g. Melin, 1930 Witkang 1966; Berg and staff 1980). A wealth of information on decomposition from above ground litter and on factors controlling these process in different

forests ecosystem of the world has been compiled by Singh & Gupta (1997), Swift *et al.* (1979), Vogt *et al.* (1991), Upadhyay and Singh (1985, 1989a&b), Upadhyay *et al.* 1989, Bargali *et al.* (1993&2006), Bargali (1995&1996).

The accepted pathway of decomposition of plant debris in the soil largely based on the work in temperate regions (Burgess, 1967) and can be summarized as follows:-

- (1) Development of phylloplane micro flora
- (2) Colonization of saprophytic micro-organisms,
- (3) Microbial colonization and utilization of feces and comminuted litter resulting in chemical degradation of tissues and production of complex phenolic polymers and
- (4) The formation of stable organo-mineral complexes (Wood, 1976). This is of course, a much over simplified picture and steps 2, 3 and 4 are concurrent rather than sequential. Nevertheless, several stages can be recognized in decomposition of plant debris.

However, Swift *et al.* (1979) explained decomposition as the result of processes, leaching and catabolism, which may be temporally separated or super imposed. Litter decomposition an important component of nutrient cycling process, is regulated by two groups of factors, the climatic factors & the substrate quality (swift *et al.* 1979). Mainly rainfall and temperature among climatic variables and primarily nitrogen and lignin concentrations, as litter quality measures have been used to explain and predict the decomposition rate (Meentemeyer and Berg 1986, McClaugherty and Berg 1987). Therefore, nutrient dynamics during decomposition are influenced by interactions among factors such as climate, litter quality and decomposing organisms. A significant and related aspect of these interactions is the release of nutrients in the soil in the forms available for the uptake. The rate of movement of essential nutrients through decomposition is an important regulator of primary production. The concentration of different nutrients in the senescing leaves also play a major role in decomposition dynamics. Nutrient rich litter and nutrient limited litters entering in the decomposer subsystem may have different rates of decay. The availability of nutrients influences the activity of decomposer organisms. However, climate and soil properties also are equally important in the decay dynamics whereas some nutrients control the initial stages

of decay, the other become important in the latter part of the decay phase. Several authors have reported the influence of initial concentrations of nitrogen, phosphorus, lignin actions, pH and some major nutrients on the decomposition rate (Daubenmire and Prussa 1963, Broadfoot and Pierre 1939, Swift 1978, Heal *et al.*, 1978, Fogel and Cronack 1977, Singh and Gupta 1977, Upadhyay and Singh 1985 and Usman *et al.* 2000).

Berg and staff, (1980), Mechaugherly and Berg (1987) have developed a model which showed that first phase of decomposition process (30% of initial mass loss) is regulated by nutrient content, while second phase is regulated by lignin and the hemi cellulose: lignin ratio. Melillo *et al.*, (1982) found a strong linear relationship between the initial lignin: nitrogen ratio and mass loss rates of leaf litter.

In terrestrial ecosystem, much of the energy fixed by photosynthesis finds its way to soil in the form of dead organic matter and during decomposition the litter acts as a host for soil organisms which are responsible for nutrient release. The rate of breakdown of forest litter influences the nutrients uptake and the standing state of nutrients which accumulated in the forest floor. Because of its role in nutrient cycling and in supporting the saprophagic component of the ecosystem, decomposition has received growing attention in recent years. According to Meentemeyer (1978), the two most important controls of litter decomposition rates are probably the prevailing climatic environment and substrate quality. Among climatic variables rainfall and temperature to be of major importance (Singh and Gupta, 1977) while in sub-polar to warm-temperate climates, actual evapo-transpiration was found to have a dominant effect on the rate of litter decay (Meentemeyer, 1978).

Proctor *et al.* (1983) pointed out that when leaf fall estimates are properly combined with other measurements of biomass, standing crop and fluxes, much information on production, decomposition and nutrient cycling can be gained. A substantial amount of organic matter produced by plants through photosynthesis is returned to the soil as litter. While a big portion of nutrient from the soil remains locked up in more permanent parts of the tree, a significant fraction is brought back to the soil surface and is released for reuse through a highly efficient decomposing system.

The dead organic matter plays a major role in determining the structure and function of an ecosystem by acting as an energy source for heterotrophic organisms and a nutrient reservoir for intro system cycling and by regulating to a large extent the hydrology of the system (Singh and Gupta 1977). Though much literature has been accumulated in recent years regarding decomposition pattern of plant litter of various forest ecosystems of tropical and temperate region but except the study on tree leaf litter decomposition in agro ecosystems of Pandey *et al.* (2006), Bargali *et al.* (2006) and Singh *et al.*(2007), no study involving quantitative data to describe the leaf litter decomposition of natural dry deciduous forests is known from Chhattisgarh/or Central part of India.

In view of this, the present study entitled “**Leaf litter decomposition and nutrient release pattern in different tree species of Dry Deciduous Forest**” was carried out with the following major objectives-

- 1) To observe the weight loss pattern of leaf litter in different species of dry deciduous forest.
- 2) To analyse the nutrient release pattern from the leaf litter of these species.

CHAPTER-II

REVIEW OF LITERATURE

Tree leaves are dropped periodically or continuously to the ground to form leaf litter, which decomposes in time to release the nutrients into the soil, from where they are recycled in the ecosystem. The chemical composition of litter as well as its environment affects the rate of decomposition and hence assumes great significance in controlling nutrient release pattern from the litter.

The pertinent literature on different aspects of the present study has been reviewed in this chapter covering the following objectives:

1. Weight loss pattern in leaf litter and
2. Nutrient release pattern from leaf litter.

The decomposition of ten important trees of tropical deciduous forests at Varanasi was studied and evaluated in terms of C/N ratio by Singh (1969). The rate of decomposition was found to be highest during the rainy season and slows down in winter mainly due to lack of moisture. Deka and Mishra (1982) found that the decomposition rate of bamboo was rapid during the first few months, from May to September, and then gradually slowed down and after one year, original dry weight remaining varied from 20-80 per cent.

Pandey and Singh (1982) have studied the decomposition in *Aesculus indica*, *Cedrus deodara*, *Cupressus torulosa*, *Daphne cannabina*, *Ilex dyprena*, *Quercus floribunda* and *Q. leucotrichophora*. They reported that in *A. indica* total disappearance was completed in 10 months. In *C. deodara*, *C. torulosa* and *Q. leucotrichophora* the actual weight loss was 82, 72 and 96 percent, respectively, after 17 months. *D. cannabina* showed rapid weight loss and it was completed in first six months.

Pande (1986) reported 81 and 69 per cent decomposition for sal and eucalyptus, respectively, after one year. Contrary to this, Bahuguna *et al.* (1990) reported 65 and 82 percent decomposition for sal and eucalyptus respectively, at the end of 12 months.

The effect of initial litter quality, climate and soil characteristics on decomposition rates of the tree leaf litter in different Himalayan Forest Ecosystems were studied

by Upadhyay (1993). Singh *et al.* (1993) found the maximum annual weight loss in sal (87%) followed by teak (72%), poplar (65%) and lowest in eucalyptus (50%). Singh *et al.* (1994) reported 73 and 81% annual weight loss in the leaf litter of *Dalbergia sissoo* and *Bombax ceiba* plantations respectively, in Uttar Pradesh.

Gilbert and Bocock (1960) reported that the content of water soluble organic material in *Fraxinus excelsa* leaves were 32 per cent while in *Quercus petraea*, it was only 18 per cent. After a month in *Fraxinus* this was reduced at 1.5 per cent but in *Quercus*, the decline was more gradual. Crossly and Hoglund (1962) found that the weight loss was initially rapid due loss of readily soluble material in pine, oak and dogwood leaves.

Nykvist (1961) and Kowal (1969) observed that the leaching of freshly fallen needles leads to accelerate litter breakdown through increased microbial decomposition and increased palatability to soil animals. Boyd (1970) has argued that the solubilization and leaching substances accounted for the initial rapid rate which is frequently observed during litter decomposition. In late autumn and early spring, the most important factor for weight loss in pine needles and birch leaf litter was found to be leaching. (Karenlampi, 1971).

In the Hubbard Brook forest, a marked difference was observed in the weight losses of litter of yellow birch, sugar maple, and beech leaves by the end of the first month. The weight losses in the case of yellow birch and sugar maple were higher as compared to beech which was attributed to the effect of leaching (Gosz *et al.* 1973). Anderson (1973) studied the effect of leaching and found that most of the losses from a beech litter and up to 75% of the losses from chestnut litter were due to leaching. This may be an over estimate as microbial decomposition must have contributed to weight loss even in aerial bags.

Singh (1969) studied the decomposition of leaf litter of important trees of tropical deciduous forests at Varanasi. He observed that species having higher amount of nitrogen content decomposed most rapidly and slowly decomposing species showed the lowest amount of nitrogen content.

According to van der Drift (1963) moisture is more important than temperature in litter decomposition. Edwards and Heath (1963) also observed that subsequent to heavy rains,

the leaf in the litter bags disappeared more rapidly than in dry periods. Wiegert and McGinnis (1975) found the highest rate of decomposition detritus in old fields during the spring and summer period and the lowest in fall and winter periods.

The combined effect of temperature and moisture is more prominent than the effect of temperature alone. Jenny *et al.* (1949) reported that the residues of *Alfalfa* leaves were smaller at high temperatures and moist conditions under the tropical climate in Columbia and Costa Rica and were longer at low temperature in the Sierra Nevada Mountains in California. The microbial activity is favoured during summer due to high moisture and temperature, thus affecting the rate of decomposition (Witkamp and van der Drift, 1961). Karenlampi (1971) reported that dry periods during summer were most retarding for weight loss.

Cornforth (1970) and Singh and Gupta (1977) found the decomposition rate being rapid during rainy period and low during dry period and under the low temperature results in slow decomposition rate. High seasonal climatic conditions help in decomposition. The higher decomposition rates during rainy season and significant relationship of relative decomposition rate with rainfall points to be favourable effect of the availability of suitable temperature and moisture condition on the activity of decomposers on one hand and stimulatory effect of frequent rain showers on leaching of water soluble substances on the other hand. In winter, unfavourable temperature and moisture condition exert a negative effect on the activity of decomposer resulting in lowest rate of decomposition.

Pandey and Singh (1982) studied the relative decomposition rate in *Aesculus indica*, *Cedrus deodara*, *Cupressus torulosa*, *Ilex dipyerna*, *Daphne cannabina* and *Quercus leucotrchophora*. The relative decomposition rate was higher in the rainy season for all the species except in *Quercus leucotrchophora* where the decomposition rate was highest in winter because it needs some initial period of weathering before the decomposition rate picks up. Bleak (1970) has reported a significant weight loss in litter even when it buried under snow. A linear combination of rainfall and temperature explained 53-82 per cent variability in weight loss in *A. indica*, *C. deodara* and *C. torulosa*. Higher decomposition rate in bamboo during rainy season has been reported when microbial population was high (Deka and Mishra 1982). Upayadhyay (1984)

reported that out of the climatic factor, rainfall is more important than temperature for increase in decomposition rate.

Tripathi and Singh (1992b) suggested that climatic seasonality, with wet and dry alternating periods, play an important role in controlling decomposition rates in dry tropical ecosystems. In winter season, the temperature is lower and moisture availability is decreased, causing unfavorable effects on the activity of decomposers, resulted in lower rate of decomposition. The summer followed by strong wetting in the second rainy season results in rapid mass loss of the remaining litter which may be due to heavy leaching of the more fragile (semi decomposed) materials.

Bargali *et.al* (1993) and Bargali (1995) have studied the decomposition of leaf litter in an age series (1-8yr) of eucalypt plantation, raised after the clear felling of natural mixed broad leaf forest, where 95 -98% weight loss occurred within 16 months and analysis of variance indicated significant differences in weight loss between age and time. The most rapid weight loss and nutrient release occurred in the young plantations and decreased with plantation age. The decomposition rate of eucalypt in their study was lower than that of surrounding natural mixed broad leaf forest and adjacent natural Sal (*Shorea robusta*) forest due to more favourable conditions for microbial activities in natural ecosystems.

Hartemink and O'Sullivan (2001) have studied the leaf litter decomposition *Piper aduncum*, *Gliricidia sepium* and *Imperata cylindrica* in the humid lowlands of New Guinea and concluded that *P. aduncum* leaf litter was significant and easily decomposable source of K where *G. sepium* leaf litter contained much N of which two third is mineralized in the initial period of decomposition. *I. cylindrica* leaf litter decomposes very slowly, releases relatively little nutrients and immobilizes N and it keeps the soil more moist.

Pandey *et al.* (2006) studied the decomposition pattern of leaf litter in *Leucaena leucocephala* where 88% weight loss was occurred within 30 days mainly due to the higher nitrogen concentration. Bargali *et al.* (2006) have reported that about 92% leaf mass loss with in 30 days in *Gliricidia sepium*. Both the species released all the nitrogen from its leaves within 201 days.

Devi and Yadav (2007) studied the decomposition of wood and leaf litter of a dominant tree species, *Dipterocarpus tuberculatus* in a tropical deciduous forest of Manipur Northeast India. The weight loss pattern and concentration of nitrogen (N) and lignin during decomposition were also evaluated. The monthly weight loss was significantly correlated ($P < 0.05$) with soil moisture and rainfall in both types of litter. The rate of weight loss was faster in wood litter than other litter probably due to termite feeding activities.

Nutrient changes and release during decomposition of leaf litter in Himalayan oak conifer forest was studied by Pandey and Singh (1983). They reported that the concentration of water soluble compounds and total available carbohydrates varied from species to species; both these constituents, however, continuously decreased with the progress of decomposition. Upadhyay (1993) while studying the effect of initial litter quality on decomposition rate of leaf litter in Himalayan Forest ecosystems found that initial water soluble compound did not show any significant relations with per cent mass remaining in rainy and winter seasons, respectively.

In a decomposition study, Pandey and Singh (1982) found that the slow decomposing species (*Cedrus deodara* and *Cupressus torulosa*) are comprised of low percentage of nitrogen. Species having higher N contents (*Daphne cannebina*) decomposed more rapidly. Among *Chenopodium*, *Desmostachya* and mixed grass sample, *Chenopodium* decomposed most rapidly due to high concentration of nitrogen, ash, acid detergent cell wall component and water soluble compound but lowest concentration of lignin cellulose and C:N ratio (Gupta and Singh 1981).

Patterns of nutrient immobilization and release in decomposing forest litter in Central Himalaya were studied by Upadhyay and Singh (1989a). They reported that most of the species had two phases in their nutrient dynamics, a net immobilization phase followed by a net release phase. Net immobilization of N and P occurred in all litter species except *Mallotus phillippensis*, *Lyonia ovalifolia* and *Quercus leucotrichophora*, while K exhibited only a release phase except in *Pinus roxburghii* and *Myrica esculenta*.

Palm and Sanchez (1990) studied the decomposition and nutrient release pattern in the leaves of three tropical legumes – *Inga*, *Cajanus* and *Erythrina*. They reported that the decomposition was accompanied by a decrease in the nitrogen concentration in the remaining

mass in all the three species. *Inga* and *Cajanus* showed a decrease until 20 week thereafter an increase in nitrogen concentration began. The faster loss of phosphorus than nitrogen in *Inga* and *Cajanus* resulted in an increase in nitrogen to phosphorus ratio from 15 to greater than 20, following an initial drop to 10. In *Erythrina*, nitrogen loss was faster than phosphorus and the nitrogen to phosphorus ratio decreased from 17 to less than 10, remaining fairly constant; despite significant changes in both nitrogen and phosphorus concentrations.

In a dry tropical bamboo Savanna, nutrient immobilization and release patterns during decomposition was studied by Tripathi and Singh (1992a). They found that nitrogen contents in bamboo leaves at the end of 127 days had increased by 18 per cent over the initial contents but this was followed by a net release of nitrogen between 127 and 227 days and then an absolute increase again, between 227 and 272 days.

Singh and Gupta (1977) have argued that the nitrogen rich broad leaf litter decomposes at a faster rate than nitrogen poor needled litter. In contrast, Daubenmire and Prusso (1963), Aber and Melillo (1980) and Upadhyay & Singh (1985, 1989a & b) did not find a significant correlation between initial nitrogen content and the rate of decomposition for several conifer and broad leaf species. Initial C/N ratio also did not show any significant relationship with per cent mass remaining.

Rawat *et al* (1995) reported a highly negative correlation ($r^2=0.861-0.940$) between nitrogen concentration and per cent weight remaining during decomposition in oak forest of central Himalayan region. Further, the absolute amount of nitrogen at various periods was calculated and was never more than 100 per cent of initial mass. Arunachalam *et al.* (1998) studied the nitrogen and phosphorus mineralization patterns of leaf litter of *Pinus kesiya*, *Quercus diletata*, *Rhododendron arboreum* and *Schima khasiana*. They found the initial lignin, nitrogen and lignin: nitrogen ratio to be negatively correlated with the decay rate, whereas soil properties such as pH, moisture and total nitrogen showed positive correlations.

Pande (1999) have studied the litter decomposition of four tree species viz. *Shorea robusta*, *Tectona grandis*, *Eucalyptus* spp. and *Pinus roxburghii* in relation to their chemical composition. They stated that lignin: nitrogen ratio showed negative correlation with decomposition rate. P and K did not show any significant relation with the decomposition rate.

Recently, Singh *et al.* 2007 have studied the nutrient release pattern during leaf litter decomposition of five multipurpose tree species i.e, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Eucalyptus teriticornis*, *Gmelina arborea* and *L. leucocephala*, where the rainfall and relative humidity influenced the decomposition rate significantly.

CHAPTER - III

MATERIALS AND METHODS

The study on “**Leaf litter decomposition and nutrient release pattern in different tree species of Dry Deciduous Forest**” was carried out at Barnawapara Wildlife sanctuary of North Raipur Forest Division in Raipur district (Chhattisgarh) during the year 2007–2008. The details of the study site, climate, geology, soils, forest flora, fauna and other features of land along with the methodologies adopted are described below:

3.1 Study Site

The study was conducted in Barnawapara wildlife Sanctuary (North Raipur Division) situated in North-Eastern corner of Raipur district. The geographical location and physiographic features of study area are given below:

3.1.1 Geographical location and physiography

The study area is located between 21°20'0" to 21°25'47" North latitudes and 82°21'17" to 82°26'27" East longitudes. It is situated about 17 km away from Patwara on Raipur-Sambalpur NH No. 6. The location of study area, important places and road network are depicted in Figs. 3.1 and 3.2.

The general topography of area is undulating due to formation of rock outcrops. The area adjoining Nawapara forest village has a number of hillocks scattered all over the area. The slopes of hillocks are moderate to steep. Tilsha pathar is the highest with an approximate altitude of 463 m above m.s.l. The stream and nalas flowing in the area have steep bank rich in alluvial soil and sustain a rich variety of vegetation.

Dry deciduous forest, grasslands, agriculture lands and human habitations surround the study area. Most of the villages in study area are categorized as forest villages and majorities of them are accessible through Kaccha roads, which is motorable only in dry season. Road network is absent in few hilly tracts, which are inaccessible due to steep slopes and dense forest.

3.1.2 Climate

The climate of study area is dry humid tropical consists of three seasons viz. rainy, winter and summer. The rainy season commences from about mid June to September. The winter season, which commences from the beginning of November, lasts till the end of February. The summer commences from the beginning of March. It is quite prolonged and severe and lasts till monsoon sets in.

3.1.3 Rainfall

The average annual rainfall in the study area ranges from 1200-1350 mm. About 80 percent of the annual rainfall in the study area is received from south west monsoon during June to August. The highest amount of rainfall occurs in July. Number of rainy days varies from 90-100 days.

3.1.4 Temperature

The mean monthly maximum temperature ranges from 27.3⁰C in January to 41.8⁰C in May and mean monthly minimum temperature ranges from 12.7⁰C in December to 27.3⁰C in May. The mean annual maximum and minimum temperature of study area are 33.1⁰C and 20.5⁰C, respectively.

3.1.5 Humidity

Relative humidity of study area increase with the onset of south-west monsoon and it generally becomes more than 80% in July. In the post monsoon and winter seasons the relative humidity lies between 50-65% in the morning (6:00 to 12:00 hrs.) and 30-40% in the afternoon (12:00 to 16:00 hrs.). Relative humidity is lowest during summer and drops below 30 percent in the afternoon in April and May.

3.1.6 Geology

The area is having three distinct geological formations viz. Chhattisgarh Super Group, Late Precambrian and Early Precambrians. Lithologically the area is divided into seven groups namely Raipur Shale and Limestone, Khairagarh Sandstone, Gunderdehi Shale, Cuddapahas Charmur Limestone, Chandrapur Sand Stone Grit, Dharwar Rocks, Granite and Genesis.

3.1.7 Soils

Physicochemical properties of study site are studied by Kumar and Singh (2008) which is summarized in Table 3.1. Soil of study was sandy loam in nature. Proportions of sand silt and clay in soil were 41 %, 30% and 34%, respectively. Bulk density was 0.93 g cm^{-3} . Water holding capacity of soil was 61.01%. Soil of the study area contained 0.94% organic carbon; 184.1 kg ha^{-1} available nitrogen where as total nitrogen in soil was 0.16%. Soil holds 16.34 kg ha^{-1} available phosphorus and 280.5 kg ha^{-1} available K. The nitrate and ammonium nitrogen in soil were 5.56 microgram per gram and 4.44 microgram per gram.

Table 3.1: Physico-chemical properties of soil (<20 cm depth)

Properties	
Physical properties	
Texture	Sandy loam
Mechanical composition	
Sand (%)	41.0
Silt (%)	30.0
Clay (%)	34.0
Bulk density (g cm^{-3})	0.93
Chemical properties	
% organic carbon	1.75
Available N (kg ha^{-1})	184.1
Total N (%)	0.16
Available P (kg ha^{-1})	16.34
Available K (kg ha^{-1})	280.5
$\text{NO}_3\text{-N}$ ($\mu\text{g g}^{-1}$)	5.56
$\text{NH}_4\text{-N}$ ($\mu\text{g g}^{-1}$)	4.44
Water holding capacity (%)	61.01

3.1.8 Forest types and flora

Different types of forest vegetation occur in the study area. Northern and eastern directions are covered with luxuriant forests, whereas Teak plantations occupy a major area in southern direction. In western direction, a large area is covered by degraded and mixed forest and also with bamboo brakes occasionally found as patches in this direction. According to Champion and Seth (1968), the forests of the study area are classified into four major forest types viz., (1) Southern Tropical Dry Deciduous Teak Forest (5A/C_{1b}), (2) Northern Tropical Dry Peninsular Deciduous Sal Forest (5B/C_{1c}), (3) Northern Tropical Mixed Deciduous Sal

Forest (5B/C₂) and (4) Dry Bamboo Brakes (5/E₉). Brief detail of the vegetation of the study area is summarized in table 3.2. Tree species composition other than these species of the study area is comprised of the following forest species: *Cleistanthus collinus*, *Pterocarpus marsapium*, *Cassia fistula*, *Lagerstroemia parviflora*, *Gentiana kurroo*, *Anogeissus latifolia*, *Adina cordifolia*, *Emblica officinalis*, *Madhuca indica* and *Terminalia tomentosa*. Total density and basal area of the study site were 920 stems ha⁻¹ and 25.16 m²/ha, respectively.

Table 3.2: Species Structure of tree layer of natural forest at Barnawapara Wildlife Sanctuary

S. No.	Species	D (stems/ha)	BA (m ² /ha)	IVI
1	<i>Cleistanthus collinus</i>	430	9.24	113.11
2	<i>Pterocarpus marsapium</i>	10	1.28	9.89
3	<i>Cassia fistula</i>	20	0.51	11.62
4	<i>Lagerstroemia parviflora</i>	70	1.10	23.10
5	<i>Gentiana kurroo</i>	280	3.95	60.96
6	<i>Anogeissus latifolia</i>	20	1.67	16.23
7	<i>Adina cordifolia</i>	20	1.23	14.49
8	<i>Emblica officinalis</i>	10	1.41	10.42
9	<i>Madhuca indica</i>	20	0.35	7.28
10	<i>Terminalia tomentosa</i>	40	4.30	32.87
Total		920	25.16	300

D = Density, BA = Basal area, IVI = Importance value index

3.2 Methodology

3.2.1 Experimental details

The studies on leaf litter decomposition and nutrient release pattern of four different species; Sal (*Shorea robusta*, Gaertn.F.), Mahua (*Madhuca indica*, J.F. Gmel.), Tendu (*Diospyros melanoxylon*, Roxb.) and Kusum (*Schleichera oleosa*, (Lour) Oken) of dry deciduous forest were

conducted after reconnaissance survey of Barnawapara Wild Life Sanctuary.

First of all mature, nearly senesced but attached leaves of the above four species were collected from the trees present in the forest. The collections were brought to the laboratory and air dried. The litter bag technique was used to quantify decomposition rates. Nylon litter bags were prepared having the size of 20 x 20 cm with 1mm mesh size in order to minimize artificial litter loss from the bags. 10 gm of air dried leaf samples were kept in each litter bag separately for each litter species. A mesh size of 1 mm was sufficient to permit movement of microarthropods which are the predominant litter feeders (Sharma *et al.*1984). Moisture content of the litter was determined by oven drying three sub-samples for each species at the time the bags were placed in the field. In the month of July 2007, 120 litter bags of each species were placed separately in the forest in such a manner that they were in contact with soil, care was taken not to disturb the floor vegetation as much as possible.

Five litter bags of each species were recovered randomly at monthly interval during August 2007 and June 2008. Immediately after recovery, the litter bags were placed individually in the polyethylene bags and transported to the laboratory. The recovered residual materials were carefully washed with water to remove the soil particles, then oven-dried at 60°C to constant weight and weighed.

3.2.2 Litter mass loss and decay rate coefficient

The rate of leaf material loss was expressed as the percentage remaining after a given time and was calculated as-

$$\% R = W(t_x)/W(t_i) \times 100$$

Where,

$W(t_x)$ is the dry weight (g) of the leaf material after time (t_x), and

$W(t_i)$ is the initial weight of the leaf material (Petersen and Cummins 1974).

In the present study % R was calculated monthly as well as for the entire period.

The mean relative decomposition rate (RDR) was computed by using the formula;

$$\text{RDR (gg}^{-1}\text{day}^{-1}) = \ln (w_1 - w_0) / (t_1 - t_0)$$

Where,

w_0 = mass of litter present at time t_0 ,

w_1 = mass of litter present at time t_1

$t_1 - t_0$ = sampling interval (days)

3.2.3 Chemical analysis

Three samples of dried materials for each species were ground in a Wiley Mill to pass a 1mm mesh screen. Samples of initial as well as incubated materials were analyzed for Nitrogen by microKjeldahl method (Jackson, 1958) by digestion (0.5g sample in 10 ml diacid containing conc. H_2SO_4 and perchloric acid in 5:1 ratio) followed by distillation and titration. Using the procedure outlined by Allen et al. (1974), 0.2g plant samples were digested in 10ml triacid mixture (nitric acid, perchloric acid and sulphuric acid in 5:1:1 ratio) and then digested, cooled and diluted to 100ml. Using 5ml aliquots total Phosphorus was determined calorimetrically by the spectrophotometer blue colour method, total Potassium by flame photometer (Jackson, 1958).

3.2.4 Nutrient release pattern

The monthly release pattern of nutrients (N, P and K) from the leaf litter was calculated by finding out the differences in nutrient quantities from initial month to the next month and the net release was calculated by sum up of nutrient release for the entire period.

3.2.5 Statistical analysis

Correlation and regression was calculated following Snedecor and Cochran (1969).

CHAPTER – IV

RESULTS AND DISCUSSION

The results obtained from the present study are described in this chapter under the following heads:

4.1 Decomposition pattern of different tree species

4.1.1 Weight loss pattern

4.1.2 Effect of substrate quality on cumulative weight loss

4.1.3 Effect of physical environment on weight loss

4.2 Nutrient changes during decomposition processes

4.2.1 Changes in nutrient concentration in decomposing litter

4.2.2 Changes in nutrient content in residual litter

4.2.3 Temporal changes in nutrient composition

4.2.4 Nutrient release pattern

4.1 Decomposition pattern of different tree species

4.1.1 Weight loss pattern

Decomposition of *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon* and *Schleichera oleosa* were studied for 332 days i.e. from July 2007-June 2008. Loss of dry matter (% of original mass) and actual weight loss per month (%), regarded as litter decomposition rate, are the two parameters which have been used to describe the results on weight loss pattern. Although weight loss continued throughout the study period relatively higher weight loss occurred within 129 days after the placement of litter bags. The weight loss in various species during decomposition is depicted in fig.4.1a - 4.1d.

4.1.1.1 *Shorea robusta*

Loss of dry matter in decomposing leaf litter of *Shorea robusta* was measured at monthly interval during 2007-08. It showed almost 95.7 per cent disappearance within a period of 332 days from July 2007 to June 2008. The maximum (30.3% of the

original litter mass) decomposition of leaf litter has been observed after the first month of the study period and the minimum decomposition rate was observed in the month of December (0.3%). The relationship between days elapsed and per cent weight loss for this species was positively significant as given in table 4.1. The monthly relative decomposition rate (RDR) for *S. robusta* ranged between 0.001-0.09g g⁻¹ d⁻¹ (Table 4.2). Seasonally, it was maximum during rainy and minimum during winter.

4.1.1.2 *Madhuca indica*

The weight loss pattern studied in the leaf litter of *Madhuca indica* showed 87.87% disappearance at the end of the study period (July 2007-June 2008). This species showed the maximum weight loss in the rainy season and minimum in the summer season. The relationship between days elapsed and per cent weight loss was significant and positively correlated (P<0.01).

Table 4.1: Relationship between percent weight loss of leaf litter (Y) and days elapsed (X). $\ln Y = a + bX$

Trees species	Intercept (a)	Slope (b)	Correlation coefficient (r)
<i>Shorea robusta</i>	31.75	0.231	0.871*
<i>Madhuca indica</i>	8.89	0.27	0.972*
<i>Diospyros melanoxylon</i>	30.49	0.21	0.866*
<i>Schleichera oleosa</i>	20.007	0.22	0.953*

* Significant at p < 0.01.

Table 4.2 : Relative decomposition rate (g g⁻¹ d⁻¹) for decomposing leaf litter of *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon*, and *Schleichera oleosa* tree species.

Days elapsed	<i>Shorea robusta</i>	<i>Madhuca indica</i>	<i>Diospyros melanoxylon</i>	<i>Schleichera oleosa</i>
31	0.09	0.05	0.10	0.10
62	0.08	0.014	0.054	0.02
89	0.05	0.058	0.061	0.05
129	0.02	0.016	0.017	0.02
151	0.001	0.009	0.001	0.001
182	0.002	0.001	0.008	0.002
212	0.003	0.033	0.001	0.003
241	0.021	0.014	0.004	0.021
272	0.020	0.005	0.003	0.020
302	0.001	0.021	0.033	0.001
332	0.006	0.006	0.013	0.006

The relative decomposition rate (RDR) for *Madhuca indica* ranged between 0.005 – 0.058 g g⁻¹ d⁻¹ across all the three seasons. It was maximum during rainy and minimum during summer season.

4.1.1.3 *Diospyros melanoxylon*

Within the period of 332 days (July 2007-2008), this species showed 93.7% disappearance of leaf litter. The maximum decomposition occurred during the month of August (32.4%) and minimum in December (0.3%). To show the temporal pattern of decomposition the days elapsed were regressed against the weight loss and found significantly (P<0.01) correlated (Table 4.1).

The relative decomposition rate (RDR) for *Diospyros melanoxylon* ranged between 0.001 – 0.10 g g⁻¹ d⁻¹ across the three seasons. It was maximum during rainy and minimum during winter season.

4.1.1.4 *Schleichera oleosa*

The weight loss pattern studied in the leaf litter of *Schleichera oleosa* during 332 days showed maximum decomposition rate (32.3%) after one month of placement of litter bags in the forest. The maximum decomposition was occurred during the rainy season and minimum in the winter. The day elapsed were regressed with per cent weight loss and showed significant positive correlation ($p < 0.01$).

The relative decomposition rate (RDR) for *Schleichera oleosa* ranged between $0.001\text{--}0.10\text{ g g}^{-1}\text{ d}^{-1}$ during the study period. It was again maximum during rainy and minimum during winter season.

4.1.2 Effect of substrate quality on cumulative weight loss

Cumulative weight loss was calculated for *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon* and *Schleichera oleosa*. The values were pooled to work out correlation with their respective initial quality.

The correlation coefficient between weight remaining and nitrogen concentration was significant ($p < 0.01$) but negative for all the four species i.e., *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon* and *Schleichera oleosa* and showed 90% to 98% variability (Fig. 4.2).

Correlation between weight remaining and phosphorus concentration was significant ($p < 0.01$) but negative for *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon* and *Schleichera oleosa* (Fig. 4.3).

The values of weight remaining and potassium concentration for all the four species were positively correlated and highly significant having 80 - 92% variability (Fig. 4.4).

4.1.3 Effect of physical environment on weight loss

The climatic conditions were markedly different during the various seasons of the year, therefore, the relationship between climatic variables (temperature, rainfall and

relative humidity) and litter decomposition rates and litter remaining verses time were worked out using simple correlation and regression analysis. The results so obtained have been tabulated in tables 4.3 and 4.4 and are described as under:

Correlation analysis

To assess the temporal pattern of weight loss, the per cent weight remaining was regressed against the time elapsed (Table 4.3) There existed a significant ($p < 0.01$) negative relationship between per cent weight remaining and time elapsed for all the species and showed 74.4 – 94.4% variability.

To find out the influence of abiotic factors on weight loss, the monthly weight loss values were regressed against the rainfall, temperature and relative humidity of respective periods (Table 4.4). The per cent weight loss was significantly correlated with the above climatic factors except for *M. indica*. In this species the per cent weight loss was non-significantly correlated with rainfall and relative humidity and showed only 8% and 11% variability.

Table 4.3 : Relationship between percent weight remaining of leaf litter (Y) and days elapsed (X). $\text{Ln } Y = a + bX$

Trees species	Intercept (a)	Slope (b)	Correlation coefficient (r)
<i>Shorea robusta</i>	90.824	-0.2738	-0.972*
<i>Madhuca indica</i>	90.89	-0.2738	-0.972*
<i>Diospyros melanoxylon</i>	69.073	-0.2100	-0.863*
<i>Schleichera oleosa</i>	79.73	-0.2210	-0.953*

* Significant at $p < 0.01$.

**Table 4.4: Allometric relationship between percent weight loss (WL)
and rainfall (R), temperature (T) and relative humidity (RH)**

X vs Y	Trees species	Intercept (a)	Slope (b)	Correlation coefficient (r)
R vs WL	<i>Shorea robusta</i>	2.933	0.078	0.699*
	<i>Madhuca indica</i>	8.381	-0.006	0.280 ^{NS}
	<i>Diospyros melanoxylon</i>	4.035	0.067	0.639*
	<i>Schleichera oleosa</i>	4.480	0.057	0.638*
T vs WL	<i>Shorea robusta</i>	18.483	2.182	0.675*
	<i>Madhuca indica</i>	12.620	1.763	0.513*
	<i>Diospyros melanoxylon</i>	16.928	2.029	0.663*
	<i>Schleichera oleosa</i>	10.261	1.966	0.695*
RH vs WL	<i>Shorea robusta</i>	-19.075	0.450	0.721*
	<i>Madhuca indica</i>	0.341	0.126	0.335 ^{NS}
	<i>Diospyros melanoxylon</i>	-12.068	0.340	0.579*
	<i>Schleichera oleosa</i>	-9.989	0.301	0.609*

*Significant at $p < 0.05$, NS - not significant

It has been shown that the labile fractions of litter provide a readily available source of energy for the decomposers; moreover the nutrients are easily leached. Nutrient decomposition should therefore be most influential in determining the rate of decomposition in the initial stage (Melin, 1930; Anderson, 1973; Singh and Gupta, 1977). The present study showed that the leaf litter decomposed very fast in the early periods of study. Though, in some species the decomposition rate was slower as compared to other species. Singh *et al.* (1990) have shown that the microbial populations are also related to site conditions and that could be influenced by native leaf litter and finally affect the decomposition process.

All the four species i.e. *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* showed 87.9-95.7% disappearance after 332 days of study period, in which *S. robusta* decomposed at faster rate and *M. indica* at the slower one. Among seasons the higher weight loss occurred during rainy and summer seasons as compared to winter season except in case of *M. indica*, where this species showed maximum decomposition during rainy, and minimum during summer season.

The usually greater decomposition during the rainy season is perhaps due to pronounced microbial activity under favorable temperature and moisture conditions and accentuated leaching due to rainfall (Pandey and Singh, 1982). Continuous decomposition of litter after the loss of soluble components is primarily a result of biotic processes (Vossbrink *et al.* 1979).

The rate of decomposition (% day⁻¹) at monthly intervals showed the different patterns (Table 4.5). In case of *S. robusta* it was 0.28% day⁻¹ and for *D. melanoxylon* and *S. oleosa* 0.27% day⁻¹ whereas, *M. indica* showed the minimum value (0.21% day⁻¹) of decomposition rate after 332 days.

Table 4.5: Rate of decomposition (% days⁻¹) of *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon*, *Schleichera oleosa* tree species.

Days elapsed	<i>Shorea robusta</i>	<i>Madhuca indica</i>	<i>Diospyros melanoxylon</i>	<i>Schleichera oleosa</i>
31	0.98	0.510	1.04	1.04
62	0.81	0.140	0.56	0.22
89	0.53	0.580	0.63	0.33
129	0.22	0.150	0.17	0.02
151	0.01	0.090	0.01	0.36
182	0.02	0.090	0.06	0.21
212	0.03	0.330	0.01	0.23
241	0.21	0.150	0.04	0.10
272	0.21	0.050	0.03	0.15
302	0.01	0.210	0.34	0.04
332	0.06	0.006	0.14	0.36

Differences in the rate of decomposition among species of different forest sits have been reported by several authors e.g., Crossly and Hoglund (1962), Edwards and Heath (1963), Wiegert and McGinnis (1975), Gupta and Singh (1977, 1981), Pandey and Singh (1982), Upadhyay and Singh (1989a), Upadhyay *et al.* (1989), Bargali *et al.* (1993). A comparison of rates of leaf litter decomposition from a variety of habitats is shown in (Table 4.6).

Gupta and Singh (1977) have shown highest disappearance rate, 36-53% during rainy season, while a weight loss of 15-26% was recorded in winter season. Higher weight loss in the summer season than in winter season is possibly related to favourable microbial activity and higher temperature (Witkamp and van der Drift 1961). Wiegert and McGinnis (1975) have found the highest rates of decomposition of detritus in old fields during the summer and spring periods and lowest in winter periods.

Singh and Gupta (1977), Upadhyay and Singh (1989a) have concluded that the rate of decomposition is markedly affected by the amount of water soluble compounds and leachable substances, nitrogen content of fresh litter. Wiegert and McGinnies (1975) have shown a highly significant effect of litter type (leaf litter), on the disappearance rate in Puerto

Rico rain forest. In the present study the regression equation relating nutrient concentration to weight loss indicated significant correlation ($P < 0.01$) for all the species (Fig.4.2, 4.3 and 4.4).

Several workers have suggested that the higher initial nitrogen content in leaf litter promotes decomposition (Witkamp 1966, Bocock 1964, Pandey *et al.* 2006, Bargali *et al.* 2007, Singh *et al.* 2007), Anderson (1973), Pandey and Singh (1982), Upadhyay *et al.* (1989) reported lower initial nitrogen for the slow decomposing litter and higher for the fast decomposing litter.

Table 4.6: Rate of decomposition of leaf litter in certain forest types of the world.

Vegetation	Rate (% day ⁻¹)	Author (s) with country
Oak forests	0.016-0.032	Jenny <i>et al.</i> (1949) USA
Oak forests	0.018	Reiners and Reiners (1970) USA
Oak forests	0.095	Rochow (1974) USA
Mixed oak forests	0.178	Lang (1974) USA
<i>Quercus patraea</i>	0.12-0.14	Bocock and Gilbert (1957) England
<i>Quercus alba</i>	0.107	Olson (1963) Eastern United States
<i>Quercus alba</i>	0.126	Witkamp (1966) Eastern United States
<i>Quercus alba</i>	0.150	Witkamp (1966) USA
Oak leaves	0.300	Edwards and Health (1963) Englad
Pine forests	0.0027-0.0082	Jenny <i>et al.</i> (1949) USA
Pine forests	0.070	Olson (1963) USA
Pine forests	0.017	Olson (1963) USA
<i>Pinus alba</i>	0.110	Witkamp (1966) USA
Pine needles	0.083	Karenlampi (1971) England
<i>Aesculus indica</i>	0.298	Pandey and Singh (1982) India
<i>Daphne cannabina</i>	0.365	ibid, India
<i>Ilex dipyrena</i>	0.329	Pandey & Singh (1982) India

<i>Quercus floribunda</i>	0.193	ibid, India
<i>Quercus leucotrichophora</i>	0.193	ibid, India
<i>Cedrus deodara</i>	0.158	ibid, India
<i>Cupressus torulosa</i>	0.139	ibid, India
<i>Shorea robusta</i>	0.253	Upadhyay & Singh (1989a), India
<i>Mallotus philippensis</i>	0.274	ibid, India
<i>Quercus leucotrichophora</i>	0.253	ibid, India
<i>Lyonia ovalifolia</i>	0.253	ibid, India
<i>Quercus glauca</i>	0.274	ibid, India
<i>Rhododendron arboretum</i>	0.165	ibid, India
<i>Pinus roxburghii</i>	0.126	ibid, India
<i>Myrica esculenta</i>	0.156	ibid, India
<i>Eucalyptus teriticornis</i> (1-8 years old plantation)	0.250	Bargali <i>et al.</i> (1993), India
<i>Shorea robusta</i>	0.281	Present study, Raipur, India
<i>Madhuca indica</i>	0.270	Present study, Raipur, India
<i>Dispyrous melanoxylon</i>	0.270	Present study, Raipur, India
<i>Schleichera oleosa</i>	0.210	Present study, Raipur, India

4.2 Nutrient changes during decomposition process

4.2.1 Changes in nutrient concentration in decomposing litter

Nitrogen

There was a continuous increase in the N concentration of the residual litter throughout the decomposition cycle in all the species (Fig.4.2). At the end of the study period (332 days) the N concentration was above 2 times higher than that of initial value for *Shorea robusta*, about two time higher for *Madhuca indica* and *Diospyros melanoxylon* and whereas for *Schleichera oleosa*, it was more than one and half times higher.

An increase in N concentration in decomposing litter is a generally occurring phenomenon (e.g. Bockock 1963; Gosz *et al.* 1983; Fehey, 1983; Vogt *et al.* 1983, Pandey and Singh, 1982, Upadhyay and Singh 1989, Bargali *et.al* 1993, 2006). Similar pattern was observed in the present study also. There existed significant ($P < 0.01$) inverse linear relationship between N concentration in residual material and per cent weight remaining for all tree species (Fig.4.2). Aber and Melillo (1980) and Melillo *et al.* (1983) have emphasized the significance of these relationships in the framework of immobilization and mineralization of N during decomposition. The weight loss in enclosed litter and increased N concentration in residual material reflect N immobilization by microorganisms.

The critical N level is also an important factor for the weight loss rates. The critical N level was higher for *S. robusta* (0.97%) and *D. melanoxylon* (0.99%) as compared to *M. indica* (0.67%) and *S. oleosa* (0.66%). The weight loss was higher in the former set of species as compared to later one. Berg and Staaf (1981), Staaf and Berg (1982), Pandey and Singh (1982), Upadhyay and Singh (1989a,b), Hartemink and O'Sullivan (2001); from a variety of litter types, concluded that there is a greater tendency towards a higher critical N levels for higher decomposition rates and vice – versa.

Aber and Melillo (1980) have generalized that this relationship is inversely linear in case where (i) physical removal of material from bags is minimized, (ii) nitrogen is sufficiently low in concentration in the litter material to be limiting to microbes; and (iii) a continuous external source of N is available.

Phosphorus

Phosphorus concentration was also increased continuously in the residual litter throughout the decomposition cycle for all the species (Fig.4.3). At the end of the study period, the P concentration was near about twice as much as the initial value in the leaf litter.

Phosphorus ranks next to N in importance for living plants, however, in comparison with other nutrients, the concentration of soil phosphorus in the soil solution is generally low (Stewart *et al.*1990). It has been suggested that the P is subject to same pattern

of immobilization and uptake by micro-organisms as is found for N in decomposing litter (Gosz *et al*, 1973).

Peterson and Rolfe (1980) found that P was retained and assimilated at least, temporarily, in decomposing leaf litter of bottom land hard wood forests. Gosz *et al*. (1973) also observed increase in P concentration for sugar maple and beech leaf litter.

There existed significant inverse relationship between per cent weight remaining and P concentration in residual material for all tree species ($P < 0.01$). The intercept, slope and values of regression coefficient are given in fig.4.3 and showed 57.6% to 94.4% variability.

Potassium

A continuous decrease in potassium concentration was observed in the residual litter of all the species during decomposition cycle (Fig.4.4). Pattern of changes in K concentration was distinctly different from that of N and P. The decrease in K concentration was observed for all the tree species. K is highly mobile, readily leached ion, usually occurring in amounts in excess of decomposer demand (Gosz *et.al* 1973, Upadhyay *et al* 1989). Nearly all published results also indicate that K is subject to extensive leaching from decomposing leaf litter (Staff and Berg 1982; Peterson and Rolfe 1982; Fahey 1983; Anderson *et al*. 1983; Vogt *et al*. 1983). K is not bound by cell wall and is highly water soluble (Bidewell 1974; Gosz *et al.*, 1975).

There existed significant positive relationship between per cent weight remaining and K concentration in residual material ($P < 0.01$). Fig. 4.4 showed the values of slope, intercept, and coefficient of determination having 79.2 to 92% variability.

4.2.2 Changes in nutrient content in residual litter

Nutrient changes in decomposing litter of *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon* and *Schleichera oleosa* are shown in (Fig. 4.5, 4.6, 4.7). In each case the nutrient mass were declined continuously with the progress of time except in case of phosphorus for *S. robusta* and *D. melanoxylon*.

4.2.3 Temporal changes in nutrient composition

The regression models (Fig.4.2, 4.3 and 4.4) have been developed to explain the temporal changes of nutrients. There was generally an increase in N and P concentration in the residual litter of all the species, but the magnitude of increase was different among nutrients as well as among the species. The concentration of N increased approximately linearly as a function of mass loss and showed 60 to 94% variability among the species. The K concentration in the residual litter of all the species are decreased with the progress of time. All the species had significant inverse relationships between N and P concentration in residual material and percent weight remaining. The N concentration in *S. robusta* increased more than two fold higher after 332 days. The pattern of relative change in K was distinctly different from those of N and P. Evidently K is actively leached hence the litter residue had a lower concentration than the original litter.

Several attempts have now been made to produce simple, general models of decomposition which include the dual effects of the abiotic and litter quality variables. (Meentemeyer 1978; Aber and Mellilo 1982; Meentemeyer and Berg 1986; Dyer 1986; Rogers 1986; Upadhyay *et.al* 1989; Bargali *et.al* 1993). The regression equations produced in this study are directly comparable with the several earlier attempts.

4.2.4 Nutrient release

Nitrogen

Nitrogen release in the first 129 days was fastest in *S. robusta* and *D. melanoxylon* (58.7 to 61%). In the same period *M. indica* released only 17% nitrogen whereas, *S. oleosa* showed about 40% release from the residual litter (Fig. 4.5). The later two species released about 41- 49% nitrogen after 151 days from the leaf litter. At the end of the study period the percent N release ranged from 75.2-89.4%. Nitrogen immobilization phase was not distinct among any species.

Phosphorus

The pattern of phosphorus release was fastest among *S. robusta* (70.6%) and *D. melanoxylon* (67.7%) after 129 days whereas during this period, in *M. indica* and *S. oleosa* it was only 32.1% and 33.5%, respectively. At the end of the study period (332 days) *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* released 88.9, 70.6 88.8 and 77.14% P, respectively. Phosphorus immobilization phase was found in *S. robusta* and *D. melanoxylon* (Fig.4.6).

Potassium

Absolute increase in K was not observed for any species (Fig. 4.7). The pattern of K release closely parallel to that of weight loss throughout the decomposition in all the tree species however, in the later periods weight loss was slower than that of K release. Decrease of K mass was more pronounced in *S. robusta* and *D. melanoxylon* within 89 days (72.3 and 71.1%, respectively).

Nutrient dynamics in decomposing litter may show three sequential phases; (i) the initial release phase in which leaching predominates; (ii) the net immobilization phase in which nutrients are imported into the residual material through the activity of microorganism; and (iii) the net release phase in which an absolute decrease in the nutrient mass of the decomposing litter occurs (Gosz *et al*, 1973; Swift *et al*, 1979; Staff and Berg, 1982; Upadhyay and Singh 1989a). However, in the present study, none of nutrient showed all the three phases across all the four tree species. N and P showed a similar pattern of release in all tree species. Potassium showed a continuous net release from the beginning in all the tree species. *S. robusta* and *D. melanoxylon* released all the nutrients in faster rates as compared to *M. indica* and *S. oleosa* in the present study. The species wise pattern of nutrient release for N and P was *S. robusta* > *D. melanoxylon* > *S. oleosa* > *M. indica*, and for K it was *D. melanoxylon* > *S. oleosa* > *S. robusta* > *M. indica*. *M. indica* released all the nutrients in a slower rate as compared to other species. *S. robusta*, the dominant species released the N and P in a faster rate would certainly affect the production capacity of the forest. Hunt *et al*. (1988) have observed that primary production showed a greater relative response to N fertilization than did decomposition and suggested that primary production is more N- limited process.

Two phases, net immobilization succeeded by the net release were generally present. According to Vitousek and Semford (1986), the general pattern of nutrient release from decomposing leaves involves an early immobilization of N and often P followed by net nutrient release. Exceptions to this generalization may occur, however, Gosz *et al.* (1973) in beech and sugar maple leaves and Schlesinger (1985) in Chaparral shrubs litter found an initial release phase followed by net accumulation for Nitrogen and Phosphorus.

Element mobility

Potassium was lost faster than that of other nutrients followed by N and P. The generalized element mobility series for three litter bag substrates is $K > N > P$. The trend in the present study showed similarity with several earlier attempts.

CHAPTER-V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

The investigation entitled “**Leaf litter decomposition and nutrient release pattern in different tree species of Dry Deciduous Forest**” was conducted at Barnawapara Wild Life Sanctuary, Raipur, Chhattisgarh, India, during July 2007 to June 2008. The summary of the results is given below under following heads:

5.1 Weight loss patterns in leaf litter of different tree species under decomposition.

5.2 Nutrient changes and release during decomposition processes.

5.1 Weight loss patterns in leaf litter of different tree species under decomposition

Leaf litter decomposition expressed as loss of dry matter at monthly intervals was studied for *Shorea robusta*, *Madhuca indica*, *Diospyros melanoxylon* and *Schleichera oleosa* during 2007-2008. The loss of dry matter from decomposing leaf litter was correlated with the substrate quality and climatic variables (rainfall, temperature and relative humidity). Residual litter at monthly intervals was also analyzed for the changes in nutrient concentration and their absolute amounts.

Loss of dry matter was fastest in *Shorea robusta*, where 95.7 per cent decomposition was achieved with in 332 days. The loss of dry matter was slowest in *Madhuca indica* where 87.87 per cent decomposition was achieved after 332 days. The correlation analysis revealed a significant correlation ($p < 0.01$) for nitrogen, phosphorus and potassium with cumulative weight loss.

To assess the temporal pattern of weight loss, the per cent weight remaining was regressed against the time elapsed. There existed a significant ($p < 0.01$) negative relationship between per cent weight remaining and time elapsed for all the four species.

To find out the influence of abiotic factors on weight loss, the monthly weight loss values were regressed against the rainfall, temperature and relative humidity of respective periods. The percent weight loss was significantly correlated with the above climatic factors except for *M. indica*. The percent weight loss pattern of this species showed the non-significant correlation with rainfall and relative humidity.

The above studies indicated the following order of leaf litter decomposition among the four species;

Shorea robusta > *Diospyros melanoxylon* > *Schleichera oleosa* > *Madhuca indica*.

5.2 Nutrient changes and release during decomposition

To access the change in nutrients, the regression models have been developed. Nutrient concentration in the residual litter varied significantly with the lapse of time. Nitrogen and phosphorus concentration increased in all the four species. The concentration of nitrogen and phosphorus increased approximately linearly related as a function of mass loss.

The pattern of relative change in potassium concentration showed the similar patterns of decrease in residual litter mass till the end of study period. The relationship showed significant relationship between potassium concentration in residual material and percent weight remaining.

Among the nutrient release pattern N and P showed a continuous net release in all the tree species. At the end of the study period the present N release ranged from 75.2% (*M. indica*) to 89.4% (*S. robusta*). The pattern of N release was *S. robusta* > *D. melanoxylon* > *S. oleosa* > *M. indica*. The P release pattern was fastest in *S. robusta* (88.9%) followed by *D. melanoxylon* (88.8%), *S. oleosa* (77.14%), and *M. indica* (70.6%). The K release was closely parallel to that of weight loss throughout the decomposition process in all the four species however, in the later periods weight loss was slower than K release. The highest K release within the study period was observed in *D. melanoxylon* (95.4%) followed by *S. oleosa* (91.6%), *S. robusta* (90.1%), and *M. indica* (85.3%).

CONCLUSION

1. The dry matter loss in individual leaf litter of *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* at monthly intervals was analysed to access the decomposition rate and revealed that the rate of decomposition was highest in *S. robusta* followed by *D. melanoxylon*, *S. oleosa* and *M. indica*. Although weight loss continued throughout the study period, relatively highest weight loss occurred with the initial 129 days (August to November) after the placement of litter bags. The relationship between present weight loss in leaf litter and time elapsed showed the significant positive correlation for all the above species.
2. The correlation coefficient between weight remaining and N and P concentration attributes a negatively significant ($p < 0.01$) relationship but it was positive for K.
3. The climatic factors (rainfall, temperature and relative humidity) influenced the decomposition process significantly ($p < 0.05$) except for *M. indica* where rainfall and relative humidity showed the non significant relationship.
4. The rate of decomposition ($\% \text{ day}^{-1}$) at monthly intervals showed the different patterns. In case of *S. robusta* it was $0.28\% \text{ day}^{-1}$ and for *D. melanoxylon* and *S. oleosa* $0.27\% \text{ day}^{-1}$ whereas, *M. indica* showed the minimum value ($0.21\% \text{ day}^{-1}$) of decomposition rate after 332 days.
5. Changes in nutrient concentrations of residual leaf litter studied at monthly intervals during decomposition for all the four species (i.e. *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa*) and exhibited a continuous increase in N and P and decreasing pattern in K concentration with the progress of time.
6. The changes in nutrient content in the residual litter showed continuously a decreasing pattern with the days elapsed for all the species except in case of P for *S. robusta* and *D. melanoxylon*.
7. The net release of nitrogen in *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* at the end of the study period (332 days) were 89.4, 75.2, 88.2 and 87.4 percent, respectively.
8. The *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* showed 88.9, 70.6, 88.8 and 77.14 percent net release of phosphorus, respectively.

9. The net release pattern of potassium was; *D. melanoxylon* > *S. oleosa* > *S. robusta* > *M. indica* and ranged between 85.3 to 95.4%.
10. Among element mobility series the potassium was lost faster than the other nutrients followed by N and P (i.e. K>N>P).
11. Based on the present study on decomposition for different tree species of Barnawapara Wild Life Sanctuary, it was concluded that the *S. robusta* decomposed with faster rate followed by *D. melanoxylon*, *S. oleosa* and *M. indica*. The former species also released the two important nutrients (N and P) at faster rate as compared to other species. *M. indica* showed the slowest decomposition rate and nutrient release pattern.

SUGGESTION FOR FUTURE RESEARCH WORK

As evident from the present study that 100% decomposition (weight loss) has not been completed in any of the species under investigation, hence the continuation of the study till complete decomposition is necessary for the validity of recommendations and suggestions for future research work.

Further, the natural forest ecosystems are rich in species as well as in litter diversity and litter of many species intermingled with each other on the ground in natural way, so a detailed study is also needed to observe the decomposition pattern of litter of different species in combinations. The cumulative effect of different litters of different species may enhance the decomposition processes.

**LEAF LITTER DECOMPOSITION AND NUTRIENT
RELEASE PATTERN IN DIFFERENT TREE SPECIES OF
DRY DECIDUOUS FOREST**

BY

KIRAN SHUKLA

ABSTRACT

The present study on “Leaf litter decomposition and nutrient release pattern in different tree species of Dry Deciduous Forest” was conducted at Barnawapara Wild Life Sanctuary, Raipur Chhattisgarh, India during 2007-2008.

For this study mature and senesced leaves of *Shorea robusta* (Gaertn.F.), *Madhuca indica* (J.F.Gmel.), *Diospyros melanoxylon* (Roxb.) and *Schleichera oleosa* (Lour.) Oken were collected and air dried. The litter bag technique was used to quantify the decomposition rates. The litter samples were subjected to chemical analysis for assessing the nutrient release pattern during decomposition processes. Nitrogen concentration was determined by microKjeldahl method (Jackson, 1958). Phosphorus content was determined calorimetrically by phosphomolybdic blue colour method and Potassium by Flame photometer.

Among the four species studied, weight loss was fastest in *S. robusta* and slowest in *M. indica*. The pattern of weight loss was biphasic. An initial rapid phase was followed by slower phase. Climatic factors (rainfall, temperature and relative humidity) influenced the decomposition processes significantly ($p < 0.05$) except for *M. indica*, where rainfall and relative humidity, showed the non significant relationship.

The correlation coefficient between weight remaining and N and P concentration attributes a negatively significant ($p < 0.01$) relationship but it was positive for K. The change in nutrient content in the residual litter showed a continuous decreasing pattern with the progress of time for all the species except in case of P for *S. robusta* and *D. melanoxylon*. The rate of decomposition ($\% \text{ day}^{-1}$) at monthly intervals ranged from $0.21 \text{ \% day}^{-1}$ (*M. indica*) to $0.28 \text{ \% day}^{-1}$ (*S. robusta* and *D. melanoxylon*) after 332 days.

The net release of nitrogen in *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* at the end of the study period (332 days) were 89.4, 75.2, 88.2 and 87.4 percent, respectively. The *S. robusta*, *M. indica*, *D. melanoxylon* and *S. oleosa* showed 88.9, 70.6, 88.8 and 77.14 percent net release of phosphorus, respectively within 332 days. The net release pattern of potassium was; *D. melanoxylon* > *S. oleosa* > *S. robusta* > *M. indica* and ranged between 85.3 to 95 percent, respectively. Among element mobility series the potassium was lost faster than the other nutrients followed by N and P (i.e. $K > N > P$).

Based on the present study on decomposition for different tree species of Barnawapara Wild Life Sanctuary, it was concluded that the *S. robusta* decomposed with faster rate followed by *D. melanoxylon*, *S. oleosa* and *M. indica*. The former species also

released the two important nutrients (N and P) at faster rate as compared to other species. *M. indica* showed the slowest decomposition rate and nutrient release pattern.

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Appendix - I
Monthly meteorological data for temperature (°C), rainfall (mm)
and relative humidity (%) during decomposing period

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	Relative humidity (%)	
				I	II
July 07	26.2	25.0	273.9	90	73
August	29.2	26.1	218.0	92	77
September	30.7	24.4	225.3	93	75
October	31.0	19.9	29.0	92	49
November	29.5	14.7	7.4	91	36
December	28.3	12.2	0.0	90	33
January 08	28.0	12.6	7.6	87	36
February	28.1	12.9	11.6	80	36
March	34.7	19.1	24.8	73	31
April	39.0	22.7	5.2	57	20
May	42.5	26.8	0.6	37	16
June	34.9	25.5	203.6	76	54

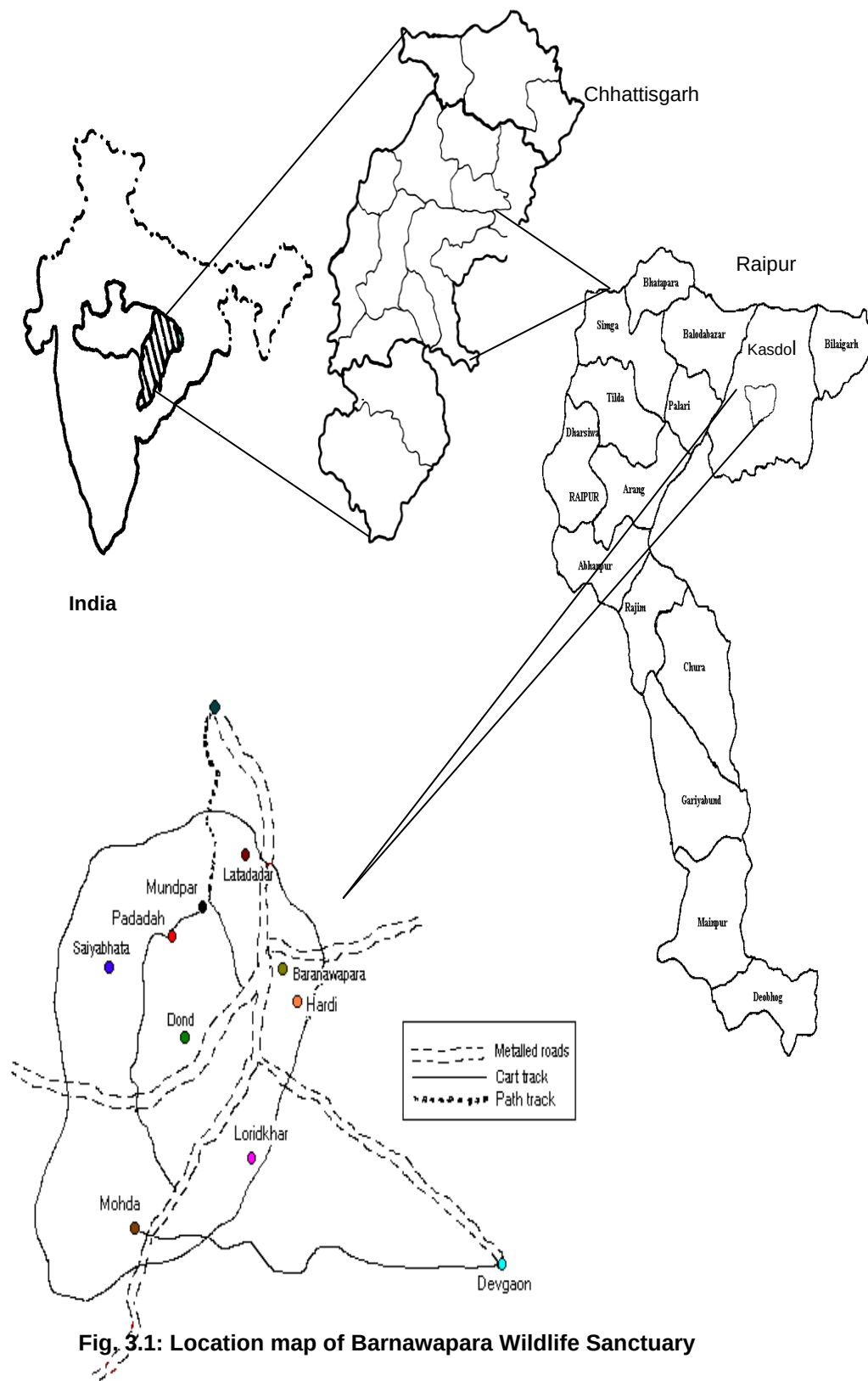


Fig. 3.1: Location map of Barnawapara Wildlife Sanctuary

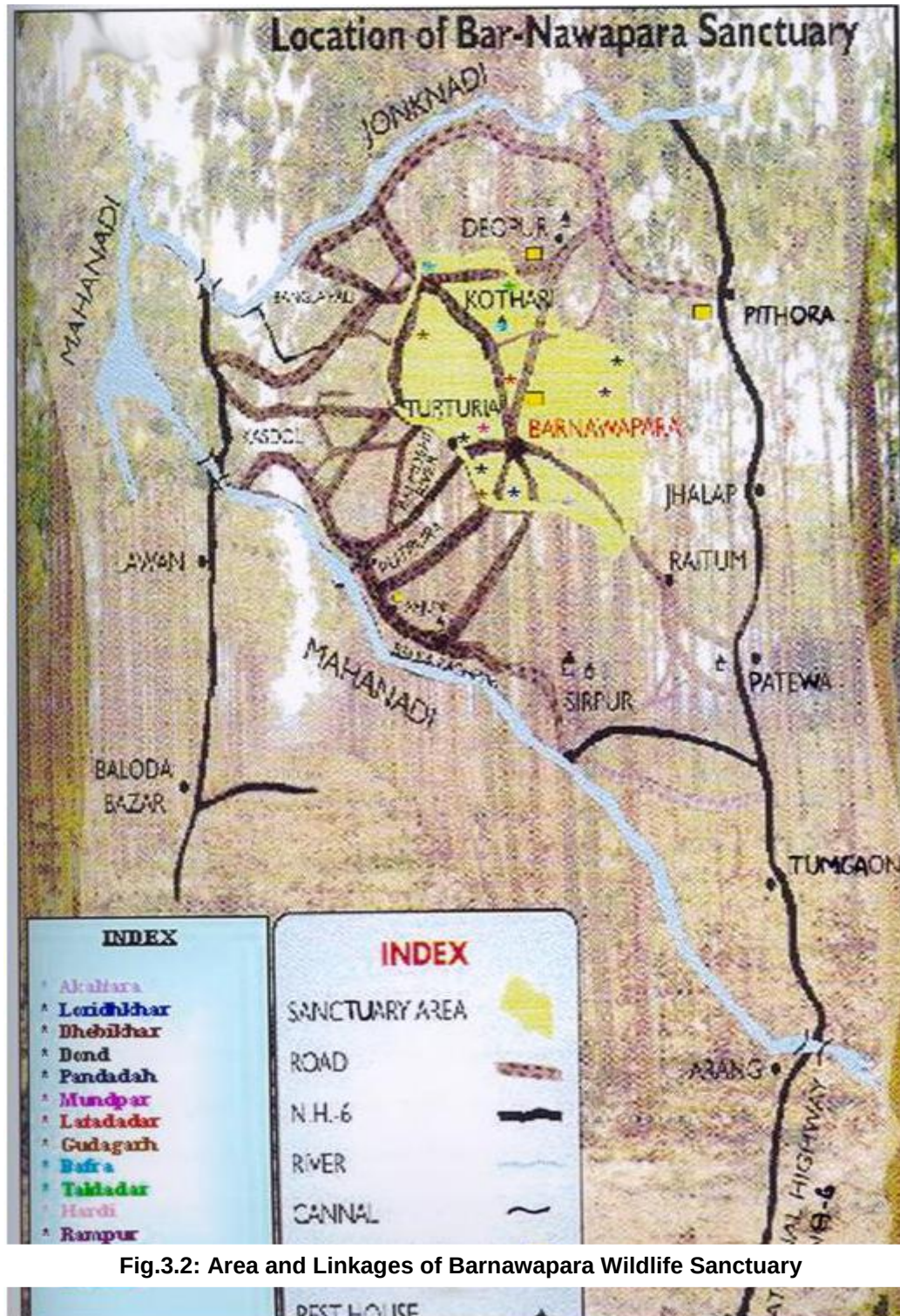


Fig.3.2: Area and Linkages of Barnawapara Wildlife Sanctuary

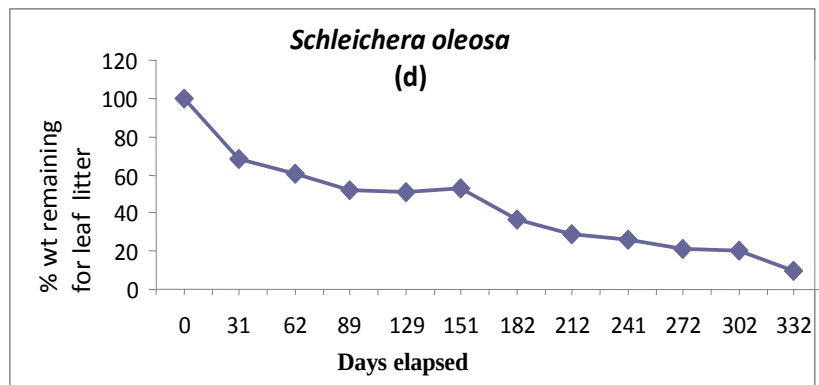
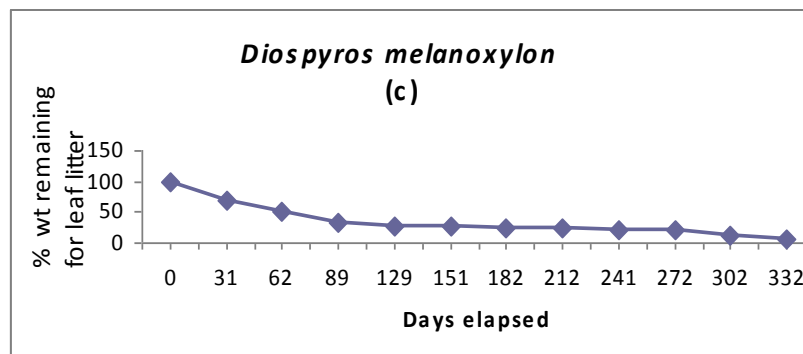
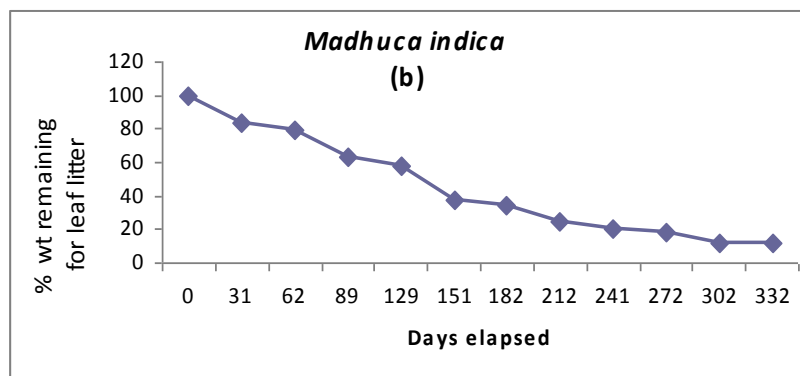
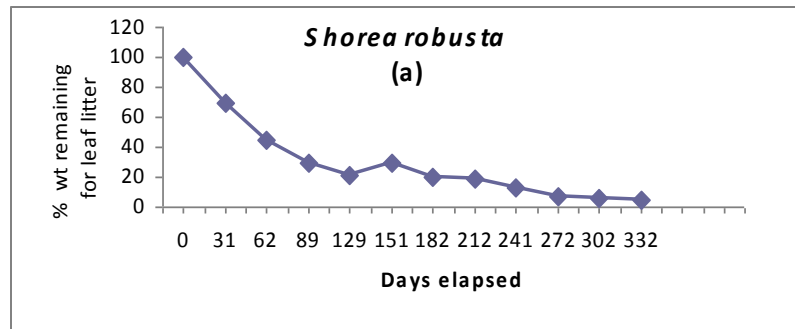


Fig. 4.1: Per cent leaf litter remaining of different tree species

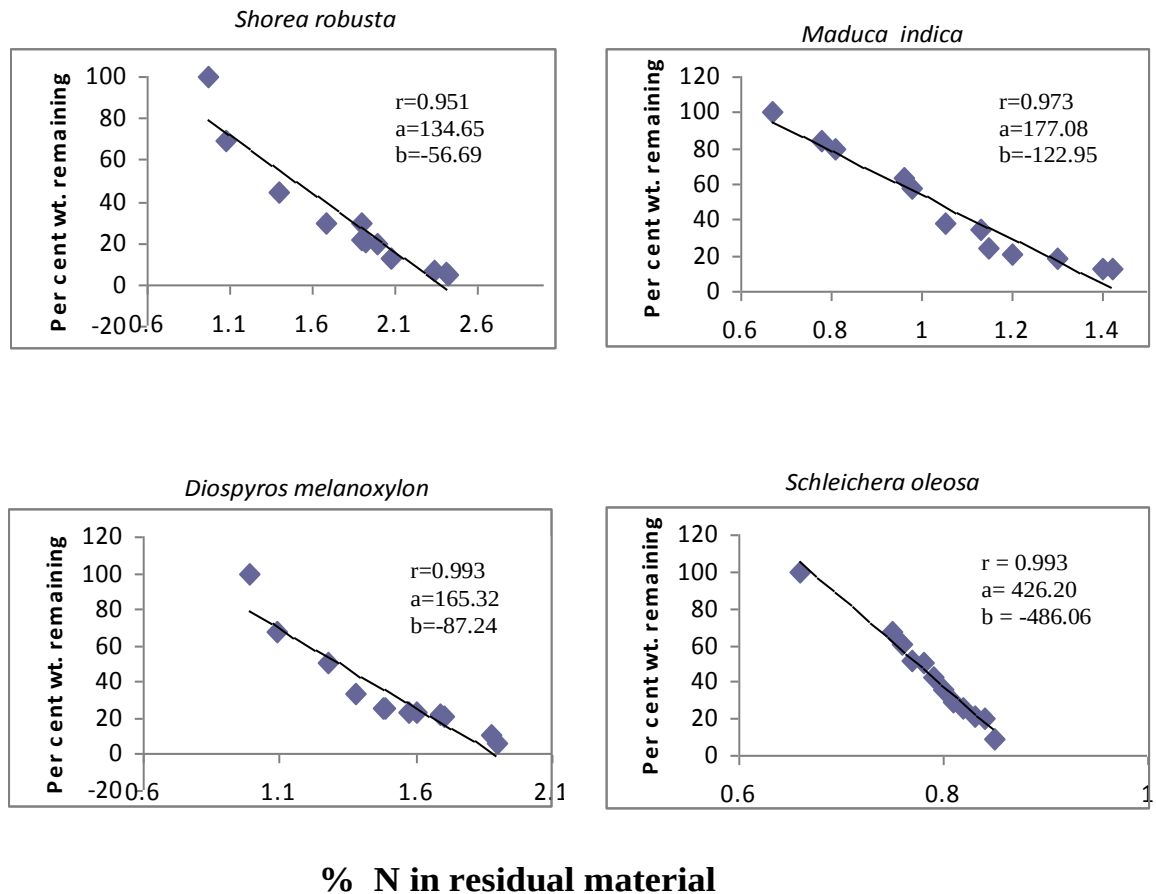


Fig. 4.2 : Percentage of original litter mass remaining (y) expressed as a function of N concentration in residual material (x) for four tree species of Barnawapara forest site Raipur, India. Correlation coefficient (r), intercept (a) and slope (b) values for regression , $y = a + bx$, are given for statistically significant relationships. ($p < 0.01$)

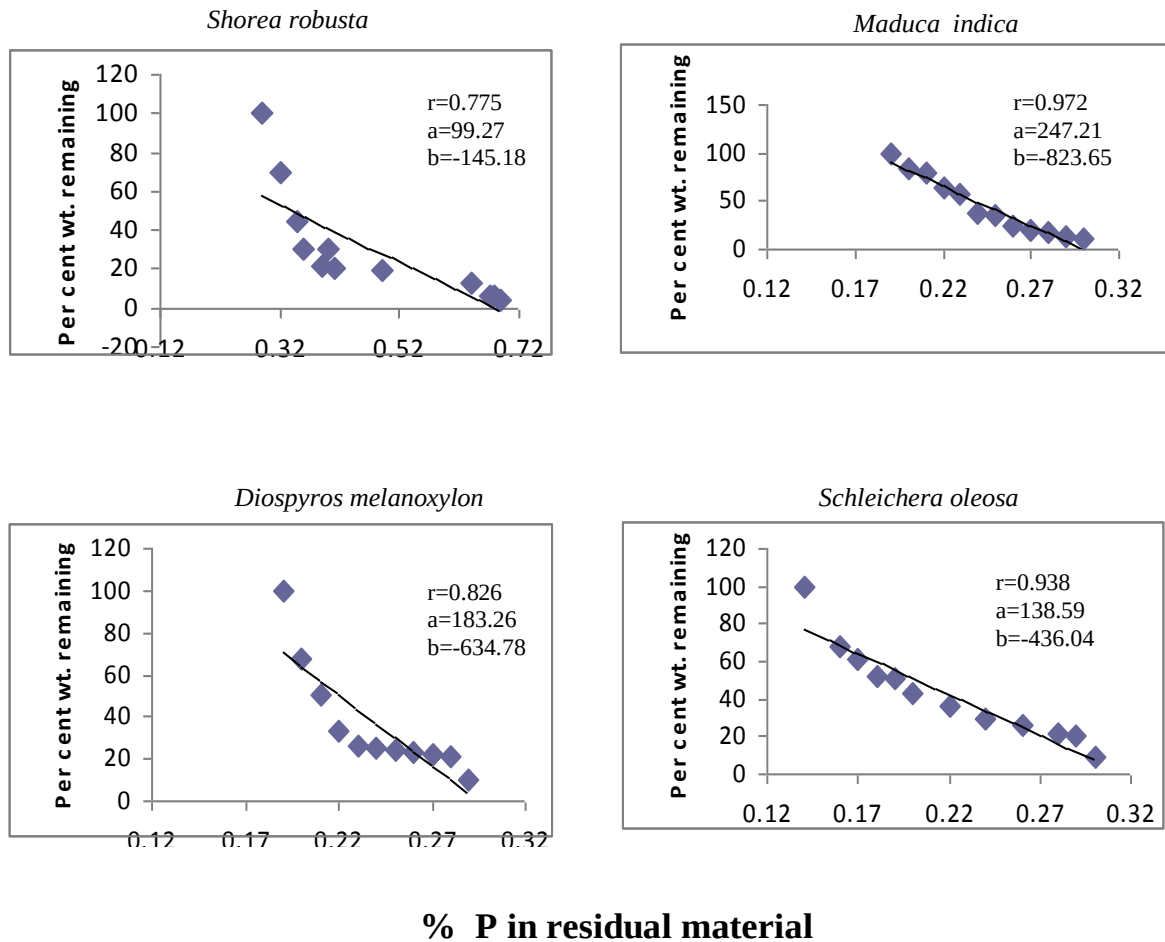


Fig. 4.3 : Percentage of original litter mass remaining (y) expressed as a function of P concentration in residual material (x) for four tree species of Barnawapara forest site Raipur, India. Correlation coefficient (r), intercept (a) and slope (b) values for regression , $y = a + bx$, are given for statistically significant relationships. ($p < 0.01$)

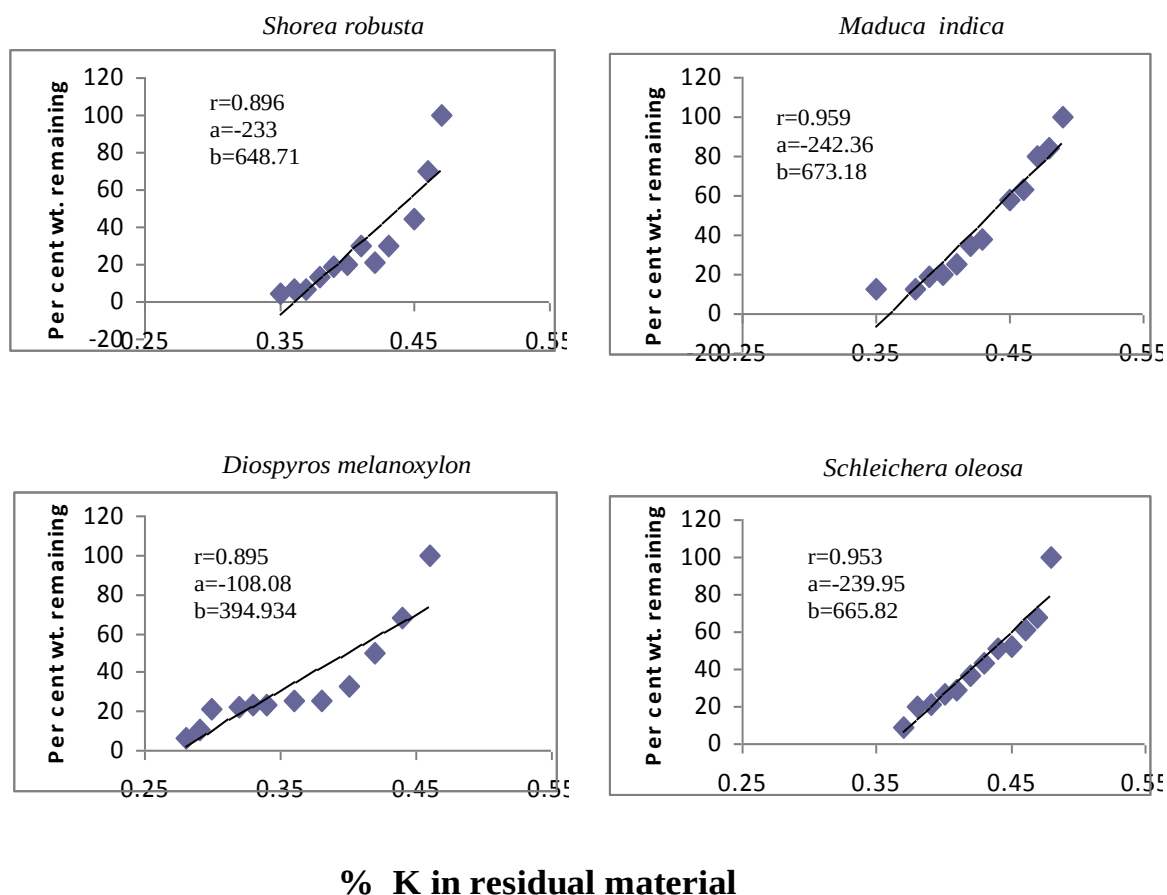
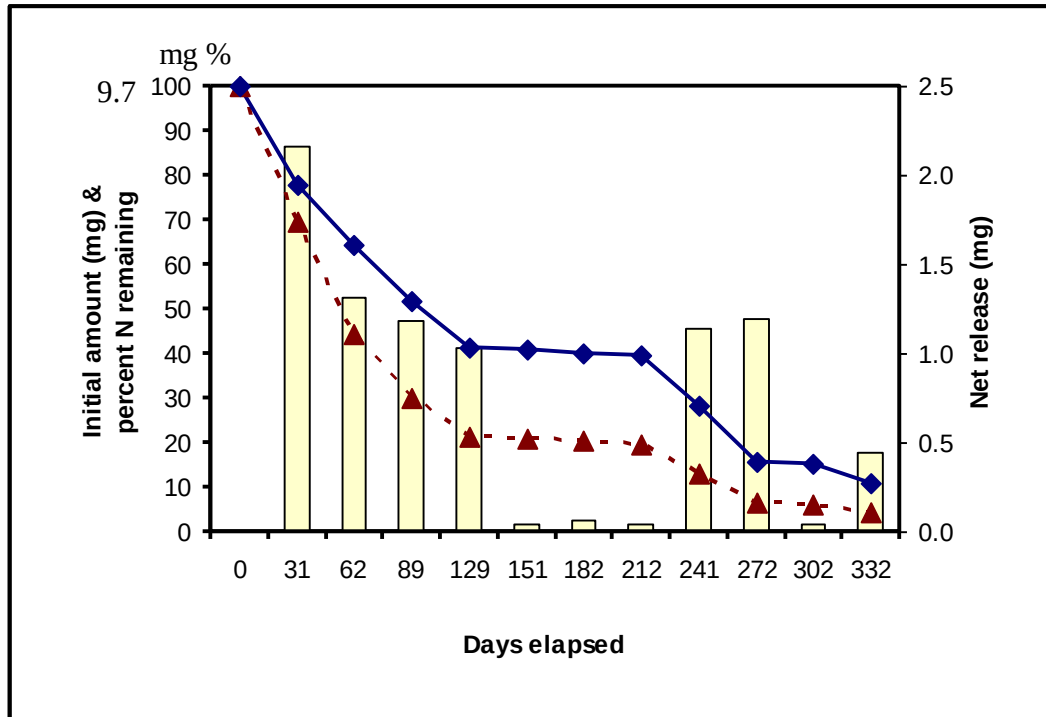
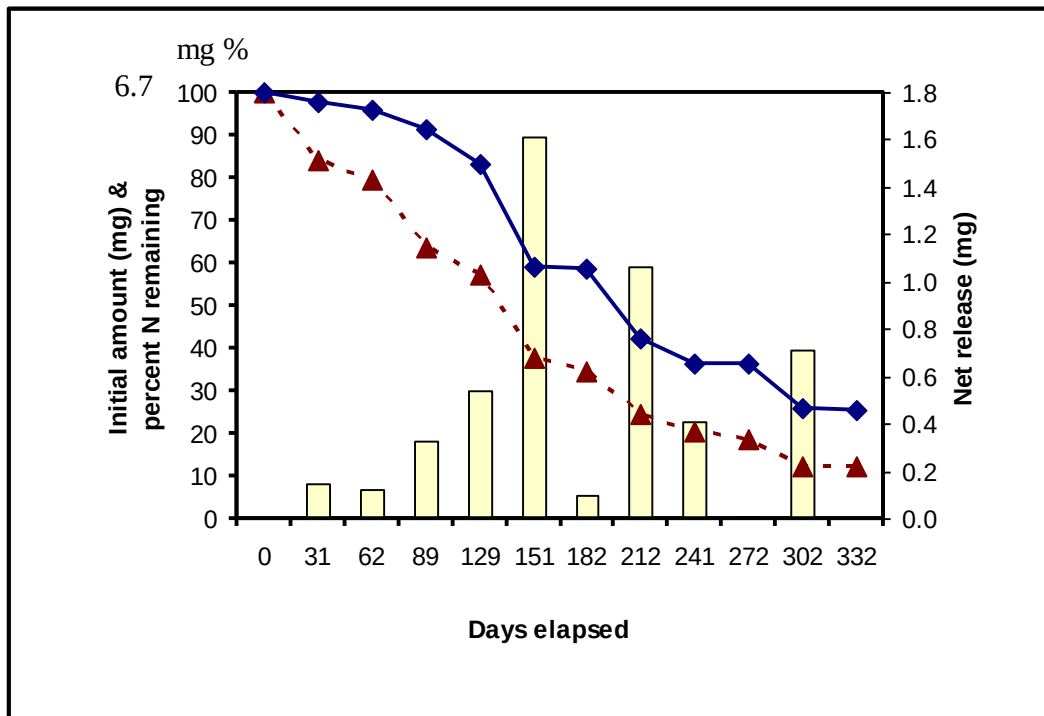


Fig. 4.4 : Percentage of original litter mass remaining (y) expressed as a function of K concentration in residual material (x) for four tree species of Barnawapara forest site Raipur, India. Correlation coefficient (r), intercept (a) and slope (b) values for regression , $y = a + bx$, are given for statistically significant relationships. ($p < 0.01$)

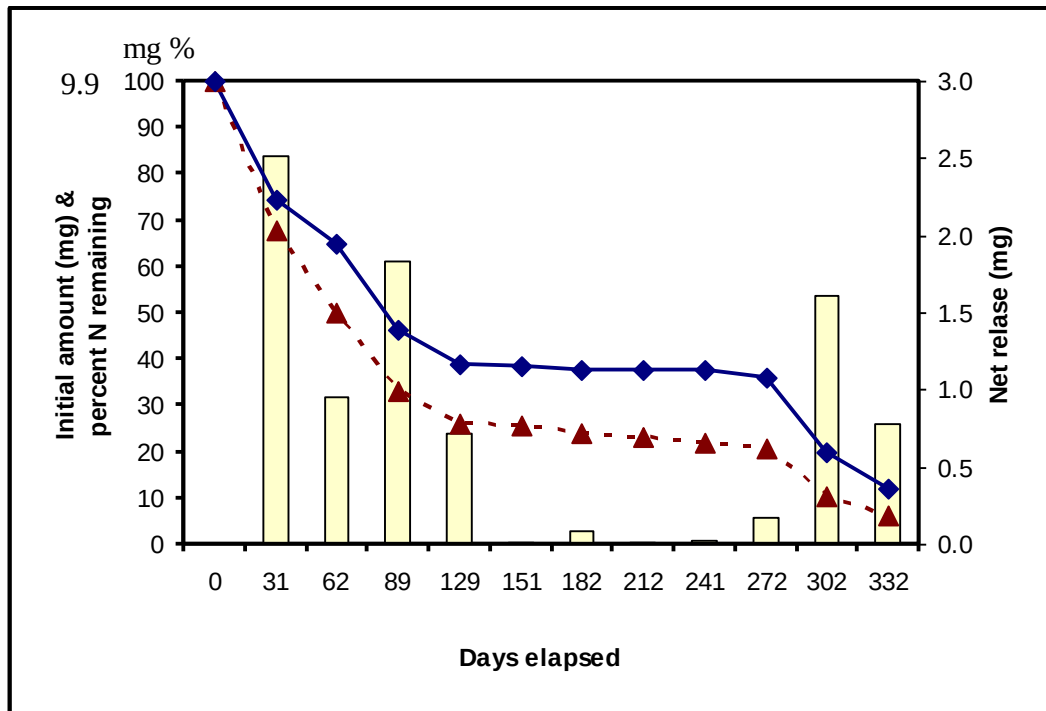


Shorea robusta

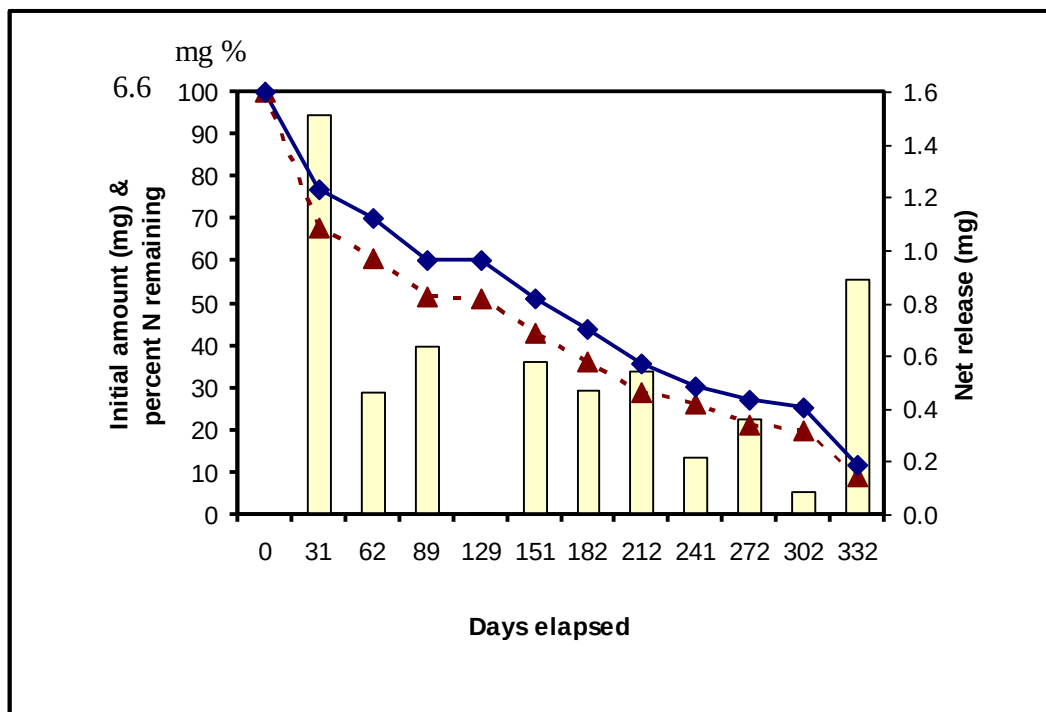


Madhuca indica

Fig. 4.5 : Change in absolute amount of Nitrogen (solid line ◆) in the litter mass enclosed in litter bags placed at Barnawapara forest site. The initial mass of Nitrogen in the bag is given on the left side of the left y-axis. The column indicates the net release between measurement (right y-axis). The broken line - ▲ - indicate the per cent weight remaining of the enclosed litter.

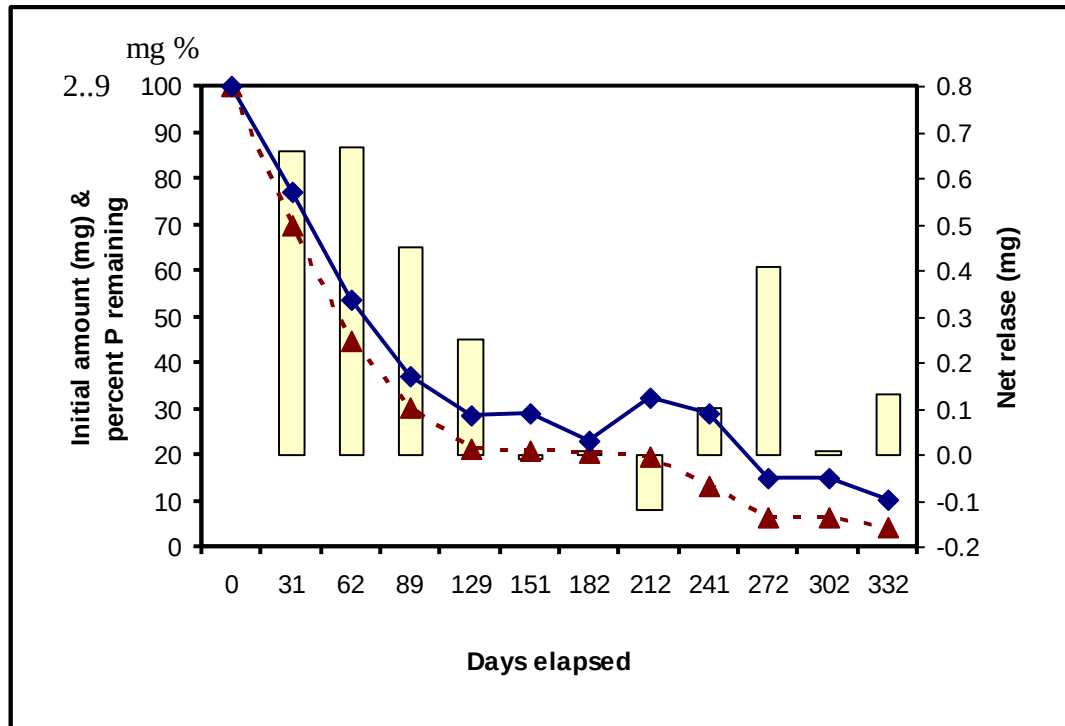


Diospyros melanoxylon

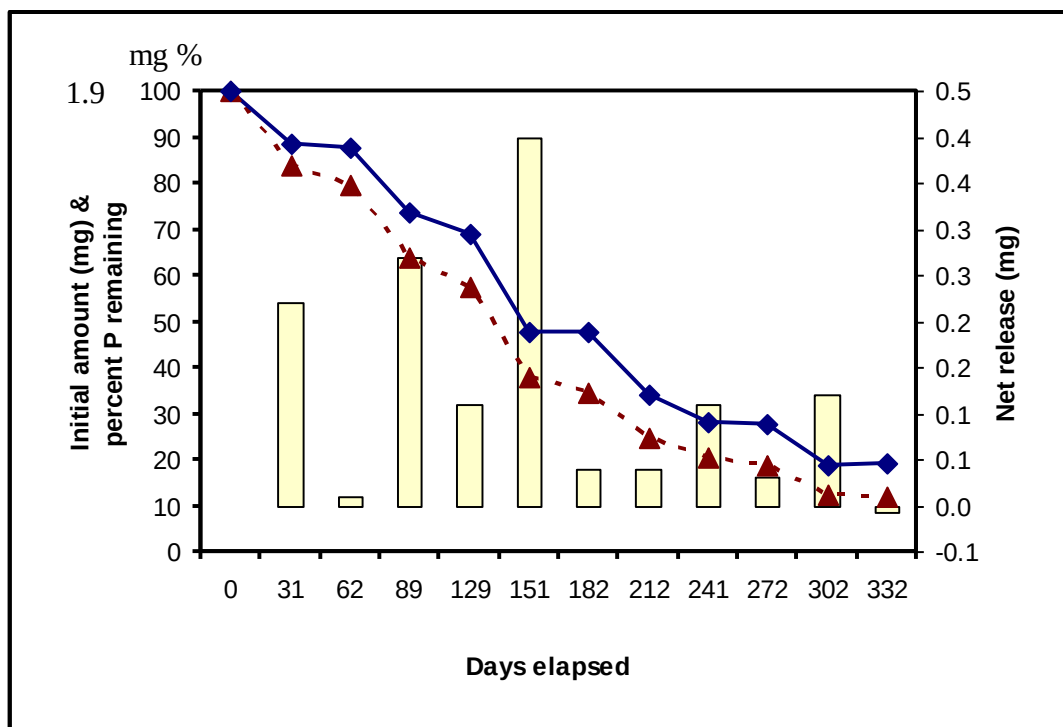


Schleicheria oleosa

Fig. 4.5 : Change in absolute amount of Nitrogen (solid line ◆) in the litter mass enclosed in litter bags placed at Barnawapara forest site. The initial mass of Nitrogen in the bag is given on the left side of the left y-axis. The column indicates the net release between measurement (right y-axis). The broken line - ▲ - indicate the per cent weight remaining of the enclosed litter.

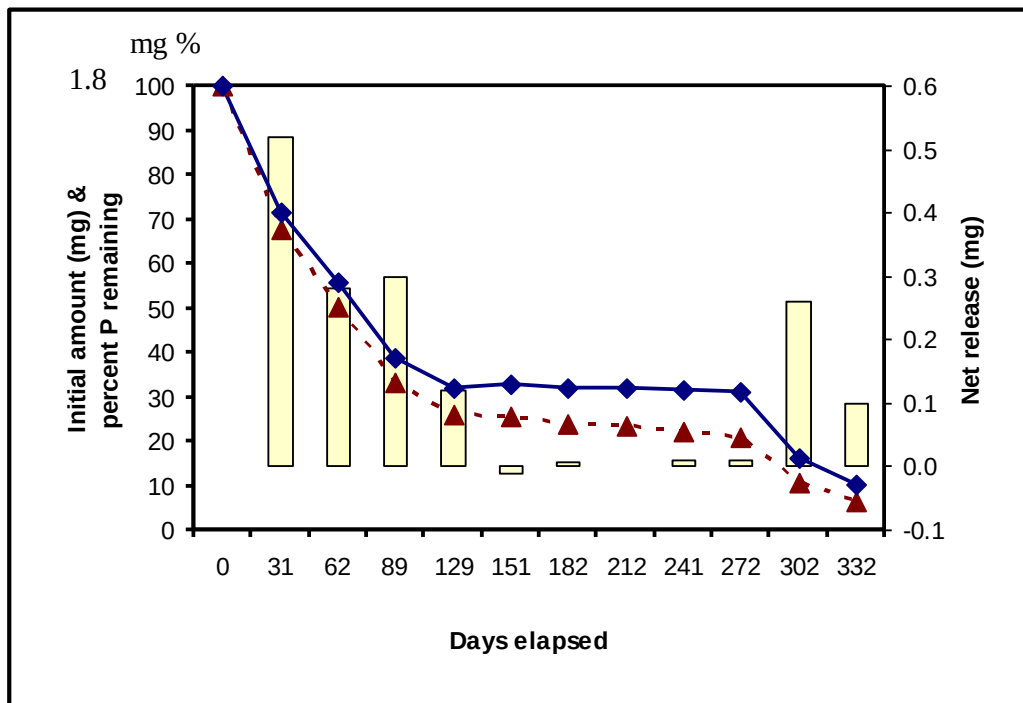


Shorea robusta

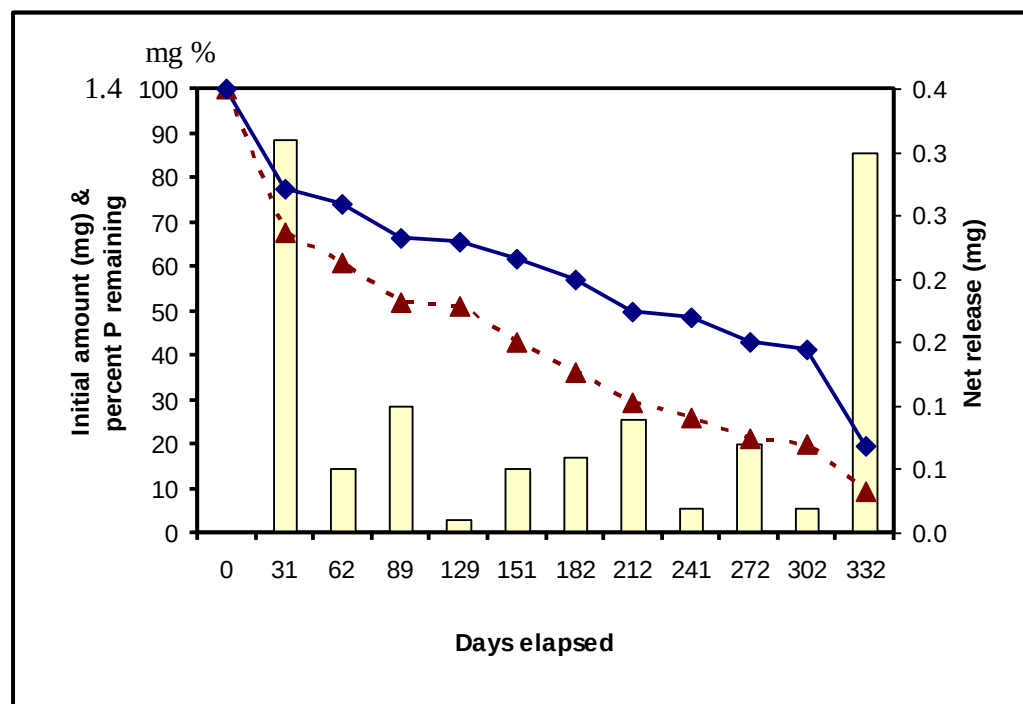


Madhuca indica

Fig. 4.6 : Change in absolute amount of Phosphorus (solid line —◆—) in the litter mass enclosed in litter bags placed at Barnawapara forest site. The initial mass of Phosphorus in the bag is given on the left side of the left y-axis. The column indicates the net release between measurement (right y-axis). The broken line -▲- indicate the per cent weight remaining of the enclosed litter.

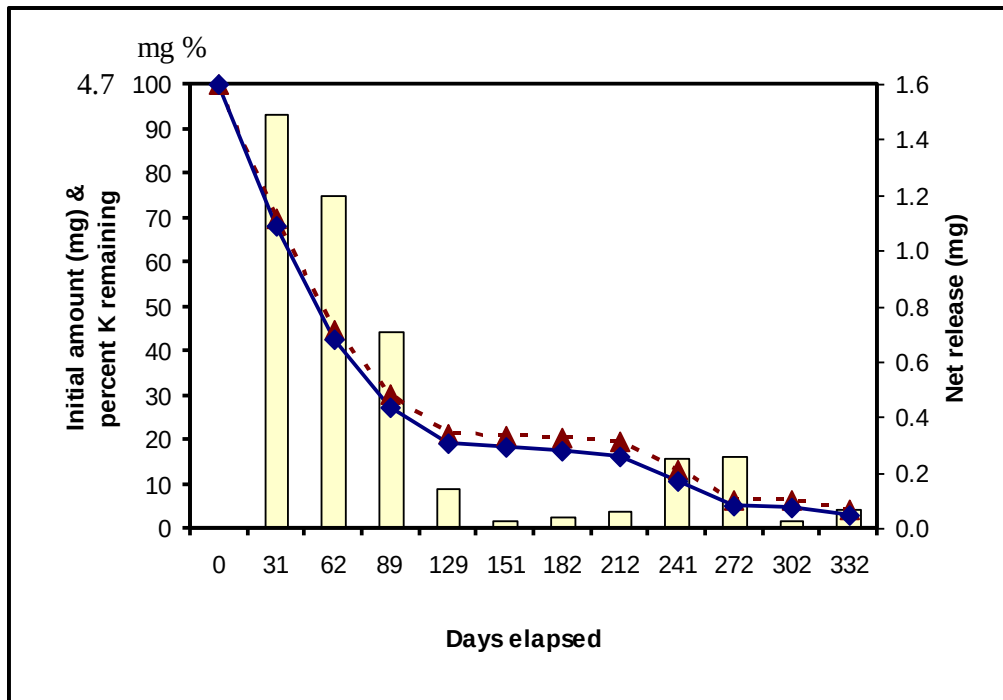


Diospyros melanoxylon

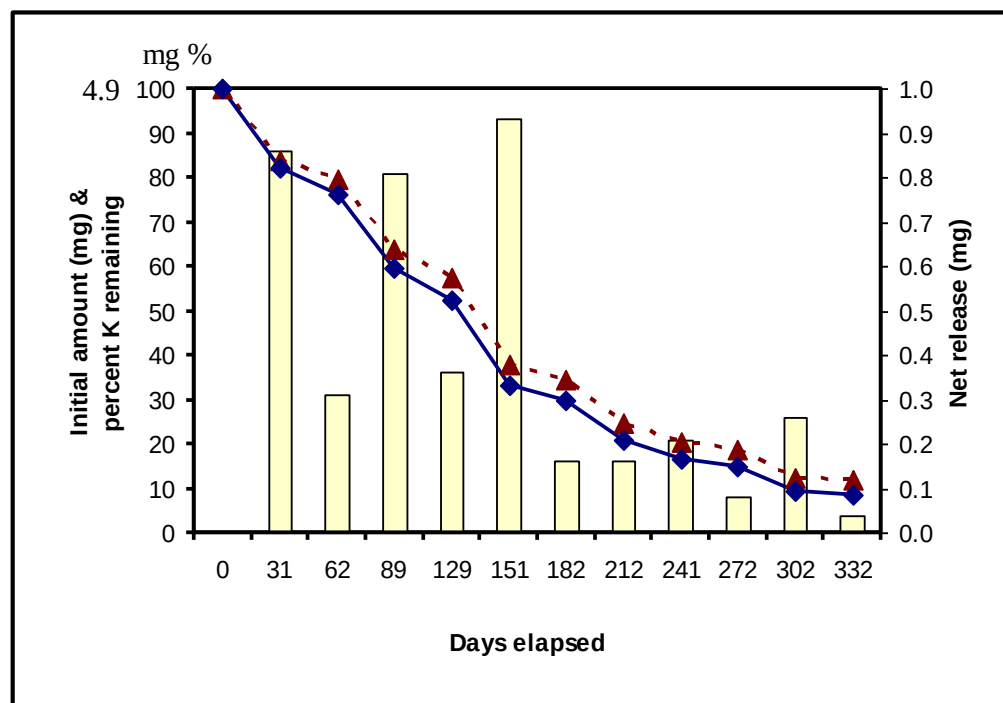


Schleicheria oleosa

Fig. 4.6 : Change in absolute amount of Phosphorus (solid line —◆—) in the litter mass enclosed in litter bags placed at Barnawapara forest site. The initial mass of Phosphorus in the bag is given on the left side of the left y-axis. The column indicates the net release between measurement (right y-axis). The broken line -▲- indicate the per cent weight remaining of the enclosed litter.

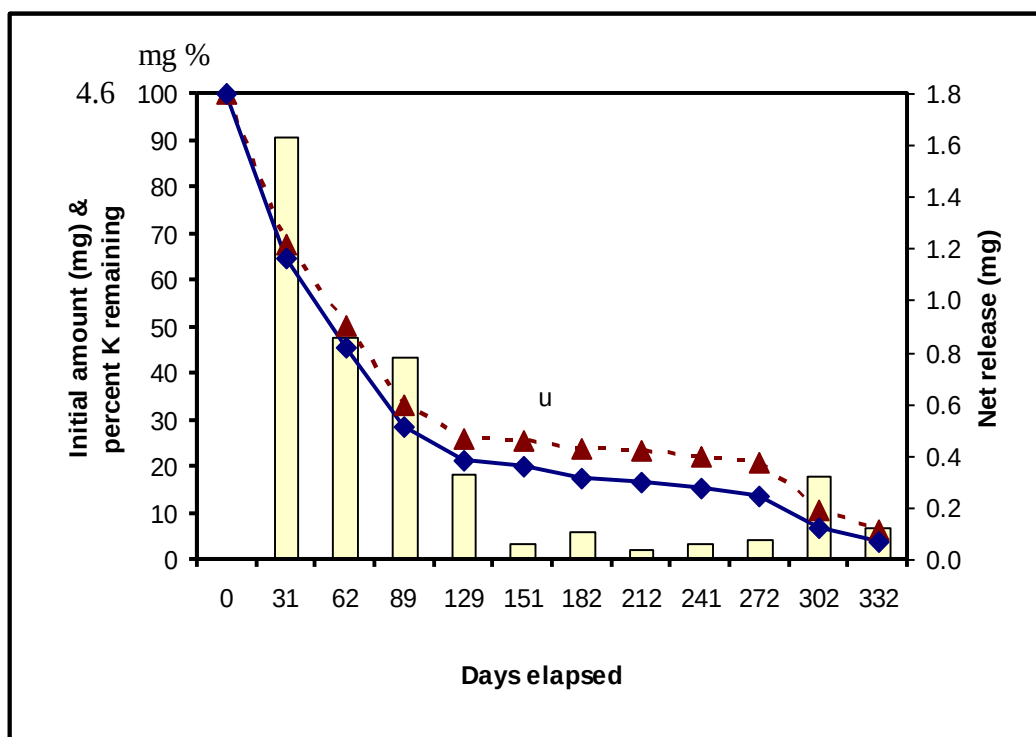


Shorea robusta

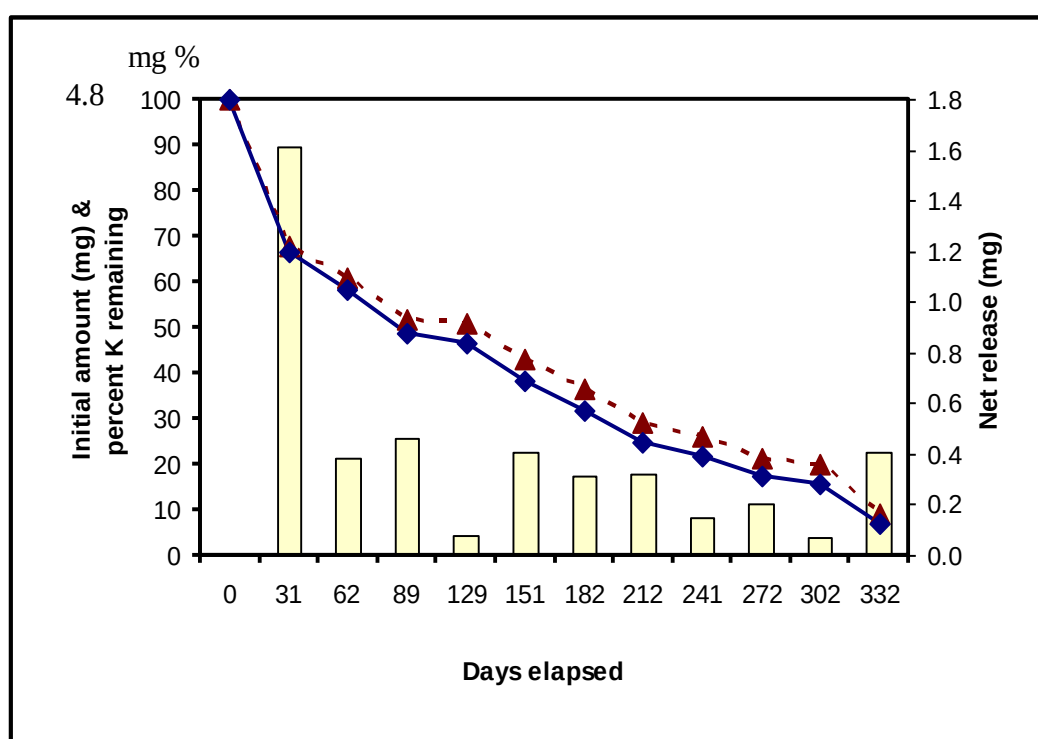


Madhuca indica

Fig. 4.7 : Change in absolute amount of Potassium (solid line —◆—) in the litter mass enclosed in litter bags placed at Barnawapara forest site. The initial mass of Potassium in the bag is given on the left side of the left y-axis. The column indicates the net release between measurement (right y-axis). The broken line —▲— indicate the per cent weight remaining of the enclosed litter.



Diospyros melanoxylon



Schleicheria oleosa

Fig. 4.7 : Change in absolute amount of Potassium (solid line $\blacklozenge$) in the litter mass enclosed in litter bags placed at Barnawapara forest site. The initial mass of Potassium in the bag is given on the left side of the left y-axis. The column indicates the net release between measurement (right y-axis). The broken line $-\blacktriangle-$ indicate the per cent weight remaining of the enclosed litter.

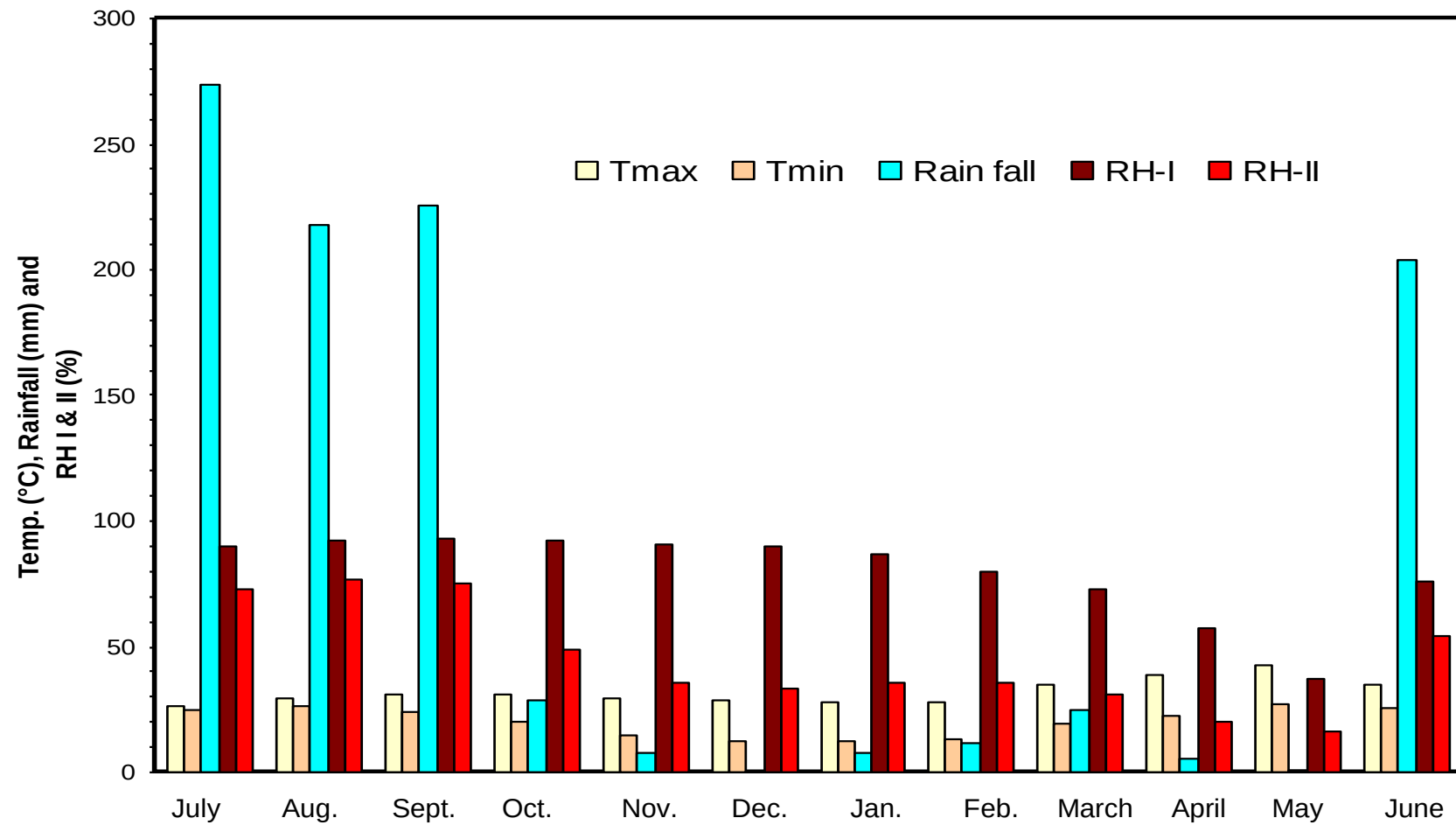


**Fig. 3.3 : Monthly meteorological observations during leaf litter decomposition
(from July 2007 to June, 2008)**