STUDIES ON THE BIOLOGY OF *LUPROPS CURTICOLLIS* (COLEOPTERA: TENEBRIONIDAE) AND RUBBER LITTER INSECT DYNAMICS IN RELATION TO RUBBER LITTER FALL PATTERNS.

Thesis submitted to the

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DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

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Declaration

I do hereby declare that the thesis entitled "Studies on the biology of *Luprops curticollis* (Coleoptera: Tenebrionidae) and rubber litter insect dynamics in relation to rubber litter fall patterns" submitted by me to the University of Calicut for the award of the degree of Doctor of philosophy in Zoology has not been submitted by me for the award of any other degree or diploma and represents the original work done by me.

Devagiri
20-04-2006

Jobi M.C.

Dedicated to

My parents

who sacrifice their life for me.....

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Jobi M.C.

Contents

Chapter 1

General introduction

GENERAL INTRODUCTION

Hevea brasiliensis Mull.Arg was introduced from Amazonian rain forest as a commercial plantation crop during the later half of nineteen century. Commercial plantations of the crop were first extended to south East Asia in areas with similar latitude and climate. In India, rubber cultivation was continued till 1960 to the south west part of the country, mostly in Kerala and Kanykumary district of Tamilnadu (Krishnakumar and Meenattoor, 2000). However, due to the non – availability of land in the tradition belt, rubber cultivation has been extended to non traditional regions (Menon, 1980; Menon and Unny, 1990).

Hevea brasiliensis Muell.Arg. belonging to the family Euphorbiacea, is the major source of natural rubber and occupies a place of pride among the various plantation crops cultivated in India and has achieved spectacular growth in area, production and most notably productivity during the last five decades and offers livelihood to about a million households. Rubber plantation sector in Kerala rubber also plays a leading role among various plantation crops. 4.73 lakh hectares of rubber area produced 5.85 lakh tones of rubber annually in India and 94 % of the total natural rubber production in the country is from Kerala. 95% of the rubber producers are small holders with average size of holding at 1.5 acres (Rubber and Economy-2004). In Kerala, rubber plantation not only provides a strong economic stability but also contribute a major role for reforestation and ecological balancing (George *et al.,* 2000). Large and small plantations are managed primarily as monocultures for their latex production with intensive management interventions by professionally trained workers.

Since its introduction, the *Hevea brasiliensis* plantations gone through at least three planting cycles each of about 30 years (Samarapulli, 1996). In India, the rubber plantations have replaced some of the most luxuriant low land rain forests. This modification of natural forests to rubber forests might have lead to the loss of many fauna and establishment of many groups who could exploit the habitat conditions offered by in rubber forests. The prominent insect groups to establish in rubber estates must be *Luprops curticollis* (Coleoptera: Tenebrionidae) beetle (Sabu *et al.,* 2005) as it has been reported from all over the state.

Tenebrionids or darling beetles, are one of the most numerous and diverse families of beetles, with a world fauna of many thousands of species. The family Tenebrionidae, excluding the Zopheridae, Chalcodryidae, and Archaecrypticidae, is one of the largest in the animal kingdom, comprising approximately 15,000 described species world wide (Watt,1992). All tenebrionids can be recognized by the following characteristics in combination; base of antenna covered by a canthus; prostenal intercoxal process. Straight, without lateral expansions of apex behind front coxae; tarsal formula 5-5-4 (very rarely 4-4-4 and if so then middle coxal cavities closed laterally by mesoterna); basal abdominal sternites 1-3 fused together, and the sutures between them faint, but sternites 4 and 5 more or less movable; tarsal claws simple or pectinate, never appendiculate (Watt, 1992). Color is mostly black or brown, but some darkling beetles are shiny metallic, also most of them are nocturnal. Many of them have defensive glands to produce defensive secretions which make them distasteful to would-be predators. They have a sophisticated system for retaining water in the body which enables them to live in drier habitats than most other beetles (Matthews, E. G., 1987). Although tenebrionids found throughout the world, the greater number of species occur in warmer climates, particularly in the more arid regions and their many and varied adaptations enabling them to survive extremes of temperature and periods of prolonged drought (Walter *et al.,* 1971).

The first scientific report on *Luprops* in India is from Dehradun (Gardner, 1929) and from the Tamilnadu region of South India (Kaszab, 1979). Kaszab (1979) described three species of this group and strangely the expedition did not report *Luprops* from Kerala, though they have reported many other Tenebrionids beetles from central Kerala, where *Luprops* is very common now. At present it has to be recognized as the most abundant beetle group in Kerala possibly lives with the intense cultivation of rubber trees (*Hevea brasiliensis*). An abundance of 400 *Luprops* per square meter in the heavily affected plantations with no other rubber litter insects reaching such a magnitude (Sabu *et al.,* 2005). Invasion of *Luprops* beetles in to the buildings and their prolonged stay after the summer showers is causing great hardship to the people in the rubber plantation belts of Kerala. The labours living close to the rubber plantations face more hardship that the affluent rubber planters who often shift their residence either temporarily or permanently away from the plantation sites to escape from the hardship caused by *Luprop*s beetles. Massive invasion of this beetle is causing great discomfort to people as these insect falling off into the body, crawling around inside the living rooms often, beds and food. When it crushed in the body, it secretes an allergic phenol compound and causing blister on the skin of infants and children causing great difficulties. It was also observed that the difficulties faced by the students and hostel authorities of a few educational institutions during the exam seasons, which coincide with the beetle invasions. Interestingly none of the common predators viz., spiders, ants or carabids associated with the rubber litter feeds on any stages of these groups which add to their leads population growth. These predators might be detracted by the chemical secretion or defensive secretions related by the beetles which is common trait of many tenebrionids (Doyen *et al.,* 1990).

Though its aggregation and nuisance have attracted the attention of entomologists and scientific community for long, but detailed information on the breeding habitats and life biology are not available. Hence in the **second chapter** an investigation was undertaken to gather information on its life history, population trends of *Luprops curticollis*, in relation to the phenology of host plants (*Hevea brasiliensis*) and climatic factors.

Due to urbanization and increased agricultural practices, natural forests are disappearing or transforming into plantation forest at alarming rates world wide (Laurnce, 1999). But how these conversions may lead to change microbial and faunal assemblages in rubber plantation has not been analyzed. Diversity of arthropod communities in the litter ecosystems directly correlated with the nutrient status of the litter (Anathakrishnan *et al.,* 1992; 1993). The arthropods are ubiquitous in terrestrial ecosystems, being numerous under undisturbed natural conditions and less in the disturbed areas with increased human activities. The community of soil organisms present and their activities are intern related to environmental climatic conditions and physical and chemical nature of the litter (Prescott *et al.,* 2004). But Wardle (2002), Wardle and van der Putten (2002) and Gartner and Cardon (2004) found no consistent effect of litter diversity on diversity and abundance of invertebrates.

The analysis of arthropods with special reference to collembolans and mites showed critical variation in the density and it has significantly effected by seasonal changes and types of litter (Senrayan, *et al.,* 1990). Soil invertebrates perform important functions related to the type of plants. Ecosystem engineers such as termites and worms increase soil porosity and average pore size by tunneling through the soil (Edward and Shipitalo, 1998). These invertebrates ingest considerable amounts of soil and dead plant materials, there by contributing to the mixing of organic matter and mineral soil. According to Blide et. al. (2000) and Mc Nabb *et al.,* (2001), soil invertebrates are also important source for many predacious invertebrates and vertebrates. But Mikola *et al.,* (2002) and Wardle (2002) said that diversity of arthropods especially decomposer may have only miner effects on ecosystem functions due to complex tropic interactions and functional redundancy in food webs.

However, despite the important ecological role in invertebrate in the functioning of an ecosystems and establishment of vast spread of rubber forests has been given to assess the fauna in rubber litter habitats recorded very little attention. In many cases, we don't know what species are present in rubber litter, and we know even less about the ecological roles, or how they respond to different land management practices (Marshall, 1993). So in the **chapter three,** this study aims to analyses the following questions.

1. What are the major faunal groups associated with rubber litter in fourteen year old *Hevea brasiliensis* plantation (RRII -105 clones) of north Kerala.

2. How species richness, evenness and diversity of arthropods changes along various seasons and months.

Rubber plantation is a 'closed' ecosystem with a constant cycle of uptake and return of nutrient from and to the soil (Watson, 1989). Most of the ecosystem's nutrient pool that is available for uptake is derived from decomposition (Waring and Schlesinger, 1985). The rate and pattern of litter decomposition depends on the quality of the litter (Blair 1988; McClaugherty *et al.,* 1985; Meentemeyer and Berg, 1986), temperature and moisture regime (Moore, 1986; Donnelly *et al.,* 1990; Berg *et al.,* 1993) specific nature of the site (Johnson *et al.,* 1982) as well as on the nutrient status of the litter (Fogel and Cromack 1977; Edmonds 1979; Verhoeven and Toth, 1995).

Decomposition in terrestrial ecosystem occurs through detrivore feeding and digestion and any effect on the decomposition rate should be attributed to the successional changes of the decomposer community (Wood 1974; Swift *et al.,* 1979; Facelli and Pickett, 1991; Caddish and Giller, 1997; Wardle, 2002 and Schadler *et al.,* 2005). Berg et.al. (1993) and Irmler (2000) showed that with an increasing availability of water and nutrients, the activity of fauna become increasingly important in the course of decomposition. Regarding the decomposition rate constant (k), greater faunal abundance and diversity correlated with increased mass loss in the experiments by Kaneko and Salamanca (1999). But the study by Hansen and Coleman (1998) found it had no effect on litter decay rate. The influence of fauna in litter decomposition is due to the communation of the litter (Anderson and Ineson, 1984), resulting in an increase in the surface area of the substrate. The role of litter fauna in decomposition process, however, has only recently begun to be addressed. (Zimmer *et al.,* 2002; 2004). Active participation by litter fauna in decomposition contributes to spatial transfer of nutrients to sites of progressive degradation of litter, thus significantly altering the chemical environment, favoring enhanced rate of decomposition (Vogt. *et al.,* 1986). According to Ananthakrishnan (1996) and Hieber and Gessner (2002), leaf litter decomposition is caused by the joint action of physical factors like climate, causing mechanical fragmentation, and litter organisms.

Although there are studies on the leaf litter decomposition in forest ecosystem such information from rubber plantation is extremely rare and hence an attempt has been made in **fourth chapter** to analyze the decomposition pattern and decomposition rate of the prominent *Hevea brasiliensis* clone (RRII -105) in Kerala.

A group of plants derived by budding from a single mother plant is referred to as a clone. All the clones rubber trees older than three or four years are subject to annual shedding of senescent leaves which renders the tree wholly or partially leafless for a short period. It induced by drier weather and is much influenced by the rainfall occurring at this time (Webster and Baulkwill, 1989). Litter production is one of the important aspects of nutrient cycling in plantations since this act as one of the inputoutput system for nutrients (Bray and Gorham, 1964). But the leaf litter fall of rubber is known to vary with clone (Potty *et al.,* 1980) and Leaf age (Abraham *et al.,* 1997). In rubber plantation ecosystem, leaf litter accumulates as a result of periodic leaf fall providing a form of surface cover over the soil. Litter production in an ecosystem is determined by climatic conditions and species composition (Das and Ramakrishnan, 1985; Luizao and Schubart, 1987). However, Stohlgren (1988 a) suggested that annual leaf litter fall can be better predicted by a function derived from the individual tree basal area and live crown ratio.

In recent years, there has been an increase in the number of studies concerning litter dynamics, although a majority of these deals with temperate and homogenous forests (Panda and Sharma, 1986; Gill *et al.,* 1987; Stohlgren 1988 a; 1988 b; Harmon *et al.,* 1990).Very little work has been undertaken in India on the leaf litter fall studies in rubber. In **chapter five** an attempt to quantify and compare the litter fall in the three major clones of *Hevea brasiliensis* plantation in the region has been made.

Plate: 1

Study site
(Source: CESS, Tvm/2004)

Chapter 2

Life biology of *Luprops*

LIFE BIOLOGY OF *LUPROPS*

ABSTRACT

Life cycle, biology of the immature stages and role of abiotic factors in regulation of *Luprops curticollis* Fairmaire (Generic name mis-spelt as *Lyprops* in earlier reports) population were reported for the first time. Beetles appeared in the ground litter immediately after the leaf shedding in rubber plantations in December. Eggs were spotted in clusters during the last week of January in the under surface of fallen leaves. There are five larval instars and a short pupation stage. Newly emerged larvae and adults are vigorous feeders of tender dried leaves. Adults migrate to aestivation shelters in swarms and started aggregation with the onset of summer rains. There was no significant effect of abiotic factors on the population dynamics of *Luprops* beetles.

INTRODUCTION

Since the introduction of *Hevea brasiliensis,* it has played a predominant role in support of biodiversity because the plantations have replaced some of the most luxuriant low land rain forests (Krishnakumar and Meenattoor, 2000). Conversion of natural forests to plantation forests may have lead to a loss of many flora and fauna associated with these forests and also the establishment of a specific faunal groups adopted to live in the man made rubber forests and the most prominent groups to establish in rubber belts is *Luprops* beetle (Sabu *et al.,* 2005).

Luprops curticollis (Coleoptera: Tenebrionidae) is a small beetle, the adult of which crowded in large numbers on the roofs of houses in the near by rubber plantation settlements in Kerala. The correct name of this species is *Luprops curticollis* (Fairmaire), not *Lyprops*, because this name is a junior synonym of *Luprops*. It belongs to Tenebrionidae- lagriinae- lupropini (Sabu *et al.,* 2005).The old traditional family Lagriidae is now a tribe Lagriinae. But it was earlier known under the mis-spelt generic name *Lyprops* (Gardner, 1929; Beeson, 1941; Narendran, 1998). Though these beetles never disturb the rubber plantation or any other crops it proven to be a great nuisance to the farming families.

In south Kerala they are commonly called *Muplivandu* or *Ola prani* and *Oadu vandu* or *Oala vandu* in North Kerala. It is named so after the wide disturbance caused by them at the Mupli estate of Thrissur during the year of 1965. At present it has been recognized as the most abundant beetle group in Kerala possibly in line with the intensive cultivation of rubber trees (*Hevea brasiliensis*). Affected people are looking for control measures to check this menace and most agricultural research institute of the state are aware of the hardship caused by this insect group. Review shows that both of international and national level except for the brief taxonomic details no further information is available on *Luprops* beetle and their massive colonization of rubber plantations as this group was never of any importance due to their very negligible presence and massive invasion to residential area are not recorded either from other rubber growing regions of India nor from rubber growing countries like Malaysia, Vietnam and Sri Lanka. Hence it has become an important regional subject requiring attention of the scientific community. Hayashi (1964) and Gardner (1929) have described the early stages of *Luprops* from Japan and India. Presence of defensive glands in the abdominal region of *Luprops* is reported (Doyen *et al.,* 1990). Except for a few Tenebrionids *Luprops* never attracted the attention of science as this group is of no specific importance (Watt, 1992; Matthews, 1987). Kaszab (1979) has reported *Luprops tristis* and *Luprops curticollis* from south India. Schawaller (1997) has provided a checklist of the six *Luprops* species reported from India. The hardships caused to the general public by *Luprops curticollis* have been highlighted (Narendran, 1998; Jose, 2003) and a brief record of its life cycle has been provided (Biju *et al.,* 2005). Though its abundance and colonization has attracted the attention of entomologists and scientific community for long much headway has not been made in evolving control measures and studying the life cycle patterns principally due to the lack of literature and practical difficulty in tracing intermediate feeding stages. Hence in the present investigation, a detailed analysis of the population trends of *Luprops curticollis*, in relation to the phenology of host plants (*Hevea brasiliensis*) and climatic factors are carried out.

MATERIALS AND METHODS

1. Study site

Study was conducted from December 2003 to November 2005 in 94 hectare plot planted in 1992 at Calicut estate, Koodaranji, 52 kilometers south-east of Calicut city (Latitude11^{0} 25' N and Longitude 75^{0} 77' E) (Plate: I, site - 2). Three clones of rubber plantation, RRII-105, PB -260, and PB – 217, under tapping are present in this estate where as small land holders plant only RRII – 105 clones. This plantation is free from regular practice of spraying of copper sulphate ($CuSo_4$), which is practical measure to prevent various fungal diseases.

2. Season and Climate of study area.

The region has humid climate, with an aggressive summer and plentiful seasonal rainfall. January and February are normally dry months. The hot season from March to May is followed by the southwest monsoon from June to September. The northeast monsoon is from October to November. This area receives an annual rainfall of 3614.50 mm (Appendix-I) with minimum and maximum air temperature of 19.71^{o} C (± 1.35^{o} C) and 34. 98^{o} C (± 0. 70^{o} C) respectively (Appendix-II). The mean monthly humidity varies from 47.10% (± 6.21%) in dry season to 94.47 % (± 0. 68%) in wet seasons. (Appendix-III). Westerly and north-westerly winds prevail during December to March. The maximum wind speed is between 10 to 15 Km per hour. The study area receives adequate sunshine hours in all months except during Southwest monsoon period. Data collected from daily records of Centre for Water Resource Development and Management (CWRDM), Kottamparamba, Kozhikode.

3. Lab culture

Luprops larva and adults were collected from the RRII-105 *Hevea brasiliensis* plantations in the Koodaranji. Larval cultures were maintained in the laboratory on the rubber leaves and sticks in the plastic containers (Tarson-19 X 10cm) (plate: 4) and were fed with wilted tender leaves unfed leaves were removed daily along with the faecal pellets to avoid fungal contamination. Limited number of larva (< 20) was maintained in a plastic container to avoid crowding which may retard the growth and subsequent development. Cotton ball soaked in water was placed in the containers, and was moistened at regular intervals. Moisture level in the plastic containers was also maintained by spraying water in morning and evening hours. Pupated larva were collected and kept in a separate container till the emergence of adults. Newly hatched adults, both male and females were maintained in separate plastic containers and paired male and female kept together in separate vials to observe mating behaviour. Adults were removed after ovipositor. Newly hatched neonates larvae were transferred into a container containing fresh leaves and rubber wood debris. When the larvae exhibited pre-moulting behavioural pattern by becoming docile and stopped feeding they were transferred to separate containers, and the time of the reappearance of the larva were recorded. The interval between the time of attachment and reappearance was recorded as the duration of each moulting period. The time of attachment and adult emergence were recorded for calculating the total pupal period.

4. Seasonal variation in the abundance of *Luprops*

Litter samples were collected regularly on monthly basis from four square meter plot during December 2003 to November 2005 (2 years). Ten replications of one square meter litter were transferred to 30 X 30 cm labelled polythene bags. On the spot assessment of pupa was done. Adults and larvae would be extracted with a series of 15-20 cm diameter Berlese funnel (Plate: 7) fitted with 6-8 mm mesh screen and a 25 watt bulb for one to two days until the litter was dry (Olson, 1991). *Luprops* moving away from the heat source pass down the stem of the funnel and were collected on the container containing alcohol. Extraction time of the focus group (Stone, 1999; Tenbrink *et. al.*, 2002). The collected specimens were preserved in small vials containing 70% ethyl alcohol.

5. Data analysis

a). Regression analysis

Regression analysis between different climatic factors like temperature, rainfall, relative humidity and leaf litter fall on the number of abundance of *Luprops* beetle has been analyzed by using linear multivariate regression analysis (Murry, R. *et. al.,* 2000).

$$Y_i = \beta_0 + \beta_1 X_{i\,1} + \beta_2 X_{i\,2} + \beta_3 X_{i\,3} + \beta_4 X_{i\,4} + \epsilon_i$$

Y_i = Number of Adults, or larvae or pupae

X_{i1} = Leaf litter fall.

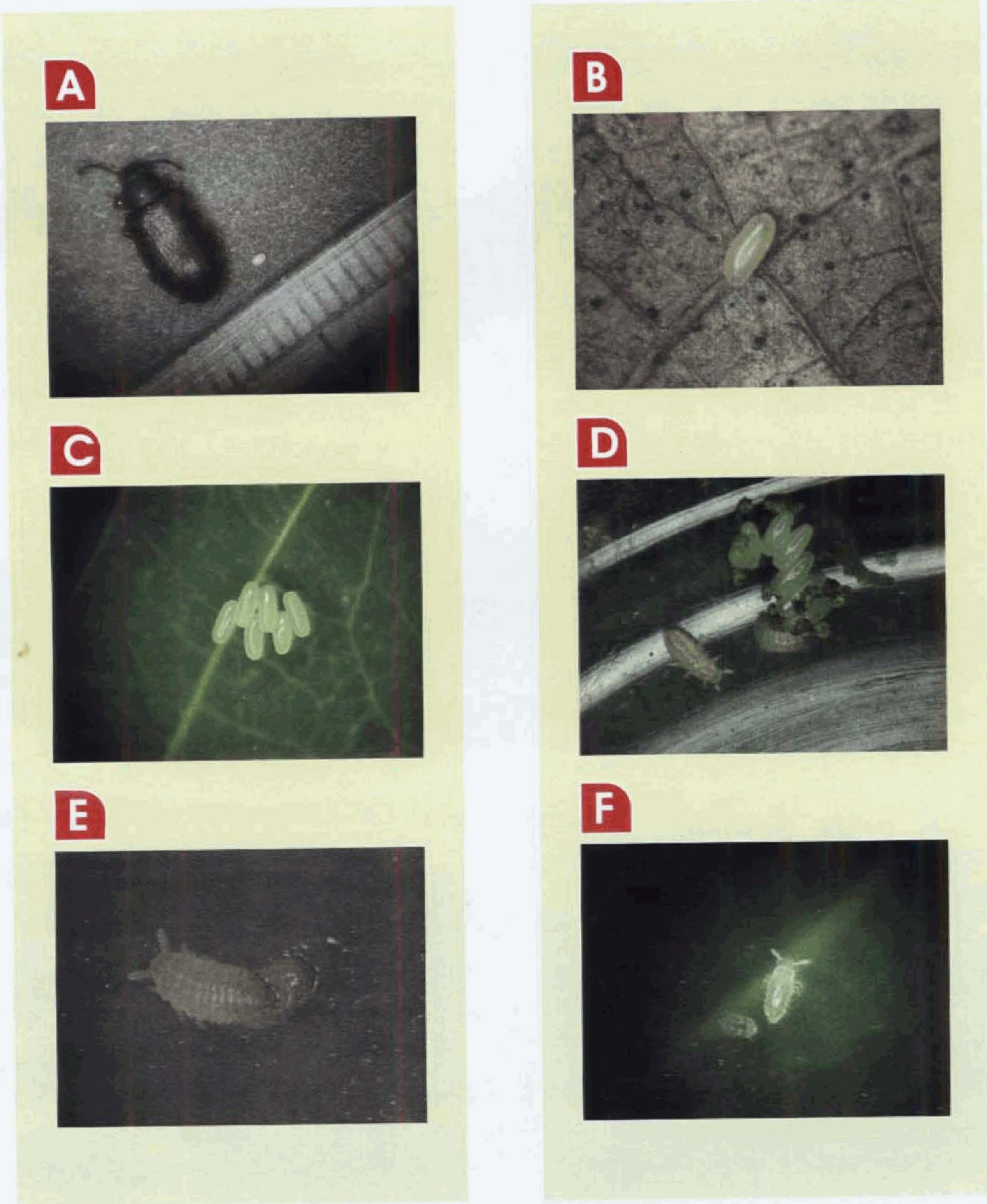
$X_{i\,2}$ = Rain fall

$X_{i\,3}$ = Relative humidity

$X_{i\,4}$ = Temperature

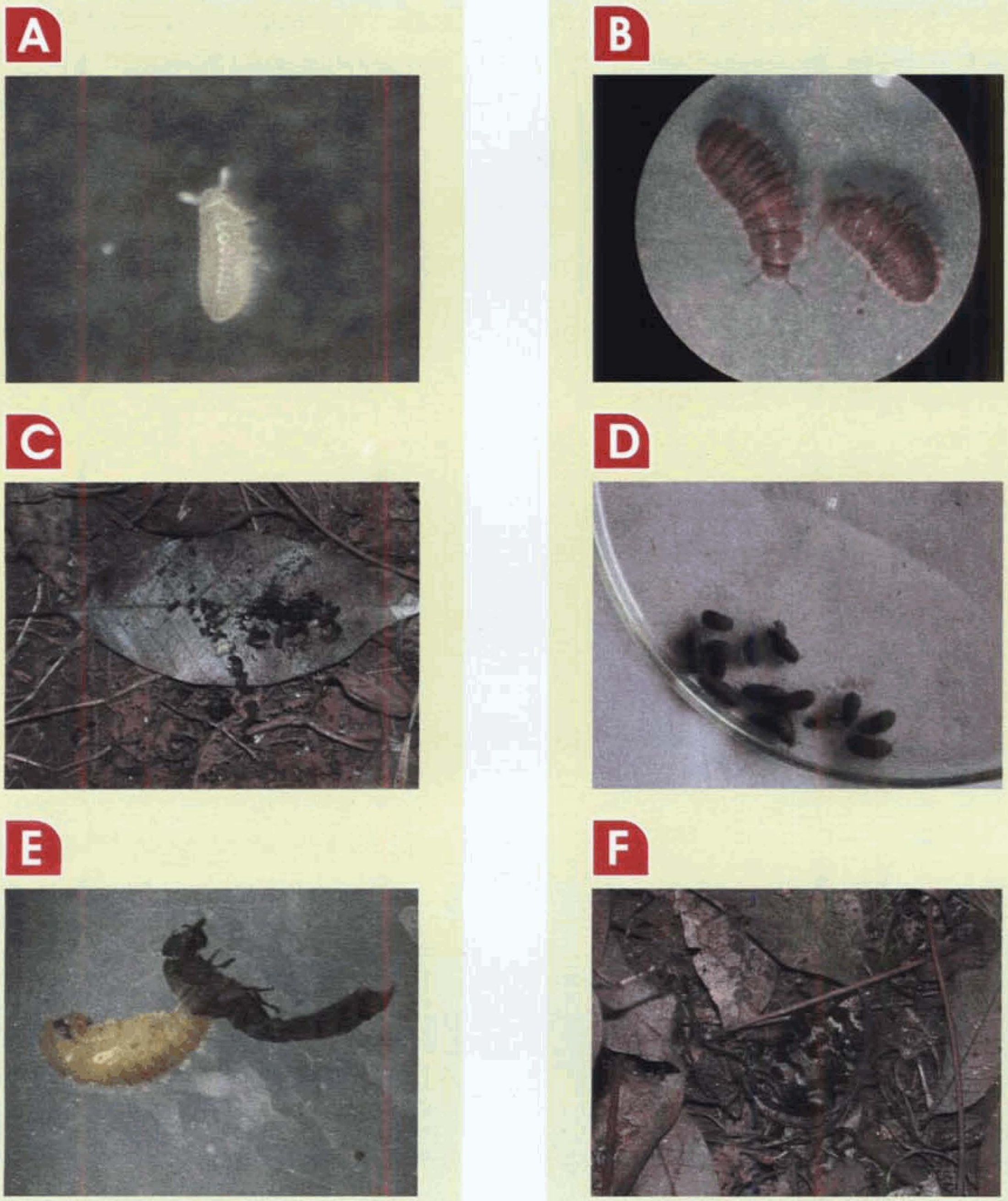
For all analysis, significance was determined at $P < 0.05$.

Plate: 2



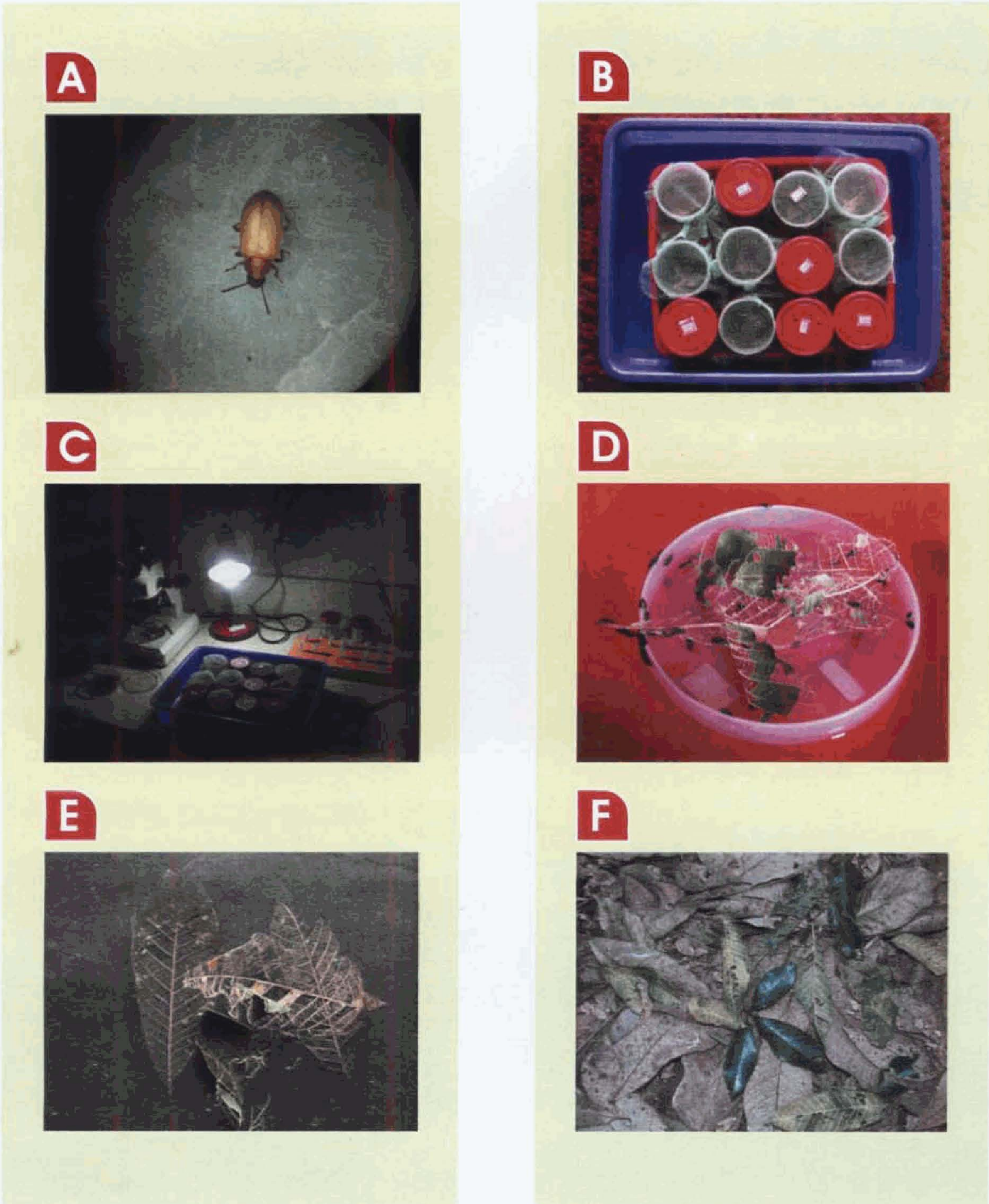
Adult (A), Eggs (B,C,D) and Newly formed larva (E,F)
of *Luprops curticuollis*

Plate: 3



Larvae (A to D) and Pupae (E,F) of *Luprops curticuollis*

Plate: 4



Newly emerged adult (A), culture setups (B,C)
and leaf fed by larvae and adults of *Luprops curticuollis*

Plate: 5

A to F - Aggregation of *Luprops curticuollis* beetles during the aestivation period.

RESULTS

Population survey of *Luprops* revealed that the adult beetles returned to the rubber plantations during the second and third week of December in both years of study (Table 2.1.). Ovipositor period lasted for one month. First instar larva developed after 4 ± 0.13 days in both laboratory and field conditions (Table 2.3). Occurrences of larva in the field was observed from last week of January with a unimodel peak in first Week of March (Fig: 2.2.), followed by a fall in abundance till second week of April. During both years of study, same pattern were observed (Fig: 2.1 & 2.2). Five larval instars are noted, the first four instars averaged 3.6 ± 0.80 to 4.2 ± 0.75 days where as the last instar took 8.2 ± 1.47 days under the laboratory conditions (Table: 2.3). Pupation time varied between 3.2 ± 0.98 days in both lab and field conditions. Newly emerged adults appeared in the field in the first week of March and its abundance gradually increased in subsequent weeks and attained unimodel peak during last week of March or first week of April. Similar trend in the adult population pattern was observed in both years of study (Fig: 2.1 & 2.2). With the onset of summer showers in the early weeks of April, the beetles started aggregation in thatched or wooden houses in swarms (Fig: 2.7). No significant variation in the adult, larval and pupal abundance was recorded (Adults, $F_{4.30} = 0.40$, df = 23, $P = 0.53$, $F_{4.30} = 0.09$, df = 23, $P = 0.77$, $F_{4.30} = 0.05$, df = 23, $P = 0.82$) between two years of study (Table: 2. 4).

In the field experiments, it could be noticed that abiotic factors like temperature, rainfall, relative humidity and leaf litter fall played a crucial role in the population dynamics of *Luprops* beetles. Even though mean monthly temperature fluctuations were very low, highest abundance of *Luprops* adult, larva and pupa were present in the field during December to May coinciding with the highest temperature prevailed (Fig: 2.3). Figure 2.5 showed that adult; larva and pupa were present in the field only during non – rainy days. Average relative humidity among various months had only very minor fluctuations, and highest abundance of *Luprops* was observed during the periods when relative humidity was comparatively low (Fig: 2.4). Distinct relationship between the leaf litter fall and *Luprops* population dynamics is observed. Adults returned to the field from residence only after the onset of leaf litter fall (Fig: 2.6). But the multivariate regression analysis with abiotic factors such as temperature, rainfall, relative humidity and litter fall showed no overall significant role (Adult 2004-05, $F = 2.44$, $r^2 = 0.58$, $P = >0.05$, Larvae 2004-05, $F = 1.59$, $r^2 = 0.48$, $P = >0.05$, Pupae 2004 -05, $F = 0.77$, $r^2 = 0.31$, $P = >0.05$, Adult 2003-04, $F = 2.89$, $r^2 = 0.62$, $P = >0.05$, Larvae 2003-04, $F = 1.71$, $r^2 = 0.49$, $P = >0.05$, Pupae 2003 -04, $F = 0.81$, $r^2 = 0.32$, $P = >0.05$) in dynamics *Luprops* population (Table 2.5).

Table 2.1.

Abundance of the larvae, pupa and adults of *Luprops curticollis* in the RRII – 105 rubber plantation in December 2003 to November 2005 at Koodaranji.

MONTH	2004-2005						2003 -2004					
	ADULT		LARVA		PUPA		ADULT		LARVA		PUPA	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
DECEMBER	3.56	± 5.45	0.00	0.00	0.00	0.00	1.06	± 2.13	0.00	0.00	0.00	0.00
JANUARY	68.75	± 31.92	0.00	0.00	0.00	0.00	77.44	± 37.42	0.31	± 0.63	0.00	0.00
FEBRUARY	33.94	± 35.63	80.13	± 108.96	0.31	± 0.63	30.13	± 28.69	65.81	± 48.95	7.25	± 6.01
MARCH	149.06	± 74.89	123.06	± 112.18	163.94	± 101.72	75.00	± 27.39	84.31	± 82.70	115.25	± 71.54
APRIL	94.67	± 138.18	0.81	± 1.63	5.69	± 9.93	38.50	± 57.33	1.63	± 1.83	0.88	± 1.09
MAY	0.00	0.00	0.00	0.00	0.00	0.00	0.69	± 1.38	0.00	0.00	0.00	0.00
JUNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JULY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AUGUST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEPTEMBER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OCTOBER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOVEMBER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. 2.

Abundance of *Luprops* adult, larval, and pupal population during their active phase in the RRII – 105 rubber plantation at Kodaranji.

MONTH	WEEK	2004 - 2005						2003 - 2004					
		ADULT		LARVA		PUPA		ADULT		LARVA		PUPA	
		MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
DECEMBER	SECOND	1.50	± 0.96	-	-	-	-	-	-	-	-	-	-
DECEMBER	THIRD	2.75	± 0.96	-	-	-	-	2.25	± 1.71	-	-	-	-
DECEMBER	FOURTH	11.50	± 1.29	-	-	-	-	4.25	± 1.50	-	-	-	-
JANUARY	FIRST	33.25	± 2.50	-	-	-	-	24.00	± 5.16	-	-	-	-
JANUARY	SECOND	50.75	± 8.69	-	-	-	-	83.50	± 4.51	-	-	-	-
JANUARY	THIRD	100.00	± 5.16	-	-	-	-	91.50	± 3.42	-	-	-	-
JANUARY	FOURTH	91.00	± 4.55	-	-	-	-	110.75	± 8.38	1.25	± 0.96	-	-
FEBRUARY	FIRST	85.00	± 6.83	2.50	± 1.29	-	-	63.50	± 3.42	23.25	± 3.77	-	-
FEBRUARY	SECOND	31.50	± 2.38	14.75	± 4.27	-	-	44.50	± 3.70	42.50	± 3.70	-	-
FEBRUARY	THIRD	12.25	± 2.22	64.75	± 5.12	-	-	4.25	± 2.63	62.25	± 8.66	3.00	± 2.16
FEBRUARY	FOURTH	7.00	± 1.15	238.50	± 12.77	1.25	± 0.96	8.25	± 3.30	135.25	± 16.52	11.50	± 5.97
MARCH	FIRST	59.75	± 5.06	259.75	± 20.21	22.00	± 2.16	50.75	± 9.22	198.75	± 13.50	165.00	± 31.43
MARCH	SECOND	119.00	± 18.07	167.75	± 7.41	174.75	± 7.37	101.50	± 16.92	89.25	± 6.18	162.50	± 16.92
MARCH	THIRD	188.50	± 18.72	50.00	± 8.33	196.50	± 21.95	52.00	± 9.63	36.25	± 10.97	121.25	± 25.34
MARCH	FOURTH	229.00	± 9.59	14.75	± 4.11	262.50	± 18.86	95.75	± 17.63	13.00	± 2.58	12.25	± 2.50
APRIL	FIRST	253.75	± 21.36	3.25	± 0.96	20.50	± 12.48	123.75	± 18.23	4.25	± 1.71	2.25	± 1.71
APRIL	SECOND	25.75	± 5.91	-	-	2.25	± 1.71	20.75	± 5.85	1.25	± 0.96	1.25	± 0.96
APRIL	THIRD	4.50	± 2.65	-	-	-	-	5.50	± 2.08	-	-	-	-
APRIL	FOURTH	-	-	-	-	-	-	4.00	± 1.83	-	-	-	-
MAY	FIRST	-	-	-	-	-	-	2.75	± 0.96	-	-	-	-

Table 2.3.

Duration of incubation, larval and pupal stages of *Luprops curticollis* under experimental set ups in the laboratory.

Item	Mean and sd.
Egg hatching time	3.4 ± 1.02 days
First instar Larva period	3.6 ± 0.80 days
Second instar Larva period	3.8 ± 1.17 days
Third instar Larva period	4.2 ± 0.75 days
Fourth instar Larva period	3.6 ± 1.02 days
Fifth instar Larva period	8.2 ± 1.47 days
Pupation period	3.2 ± 0.98 days

Figure 2.1.

Abundance of different stages of *Luprops curticollis* associated with RRII - 105 rubber plantations during various weeks in the year 2004-05.

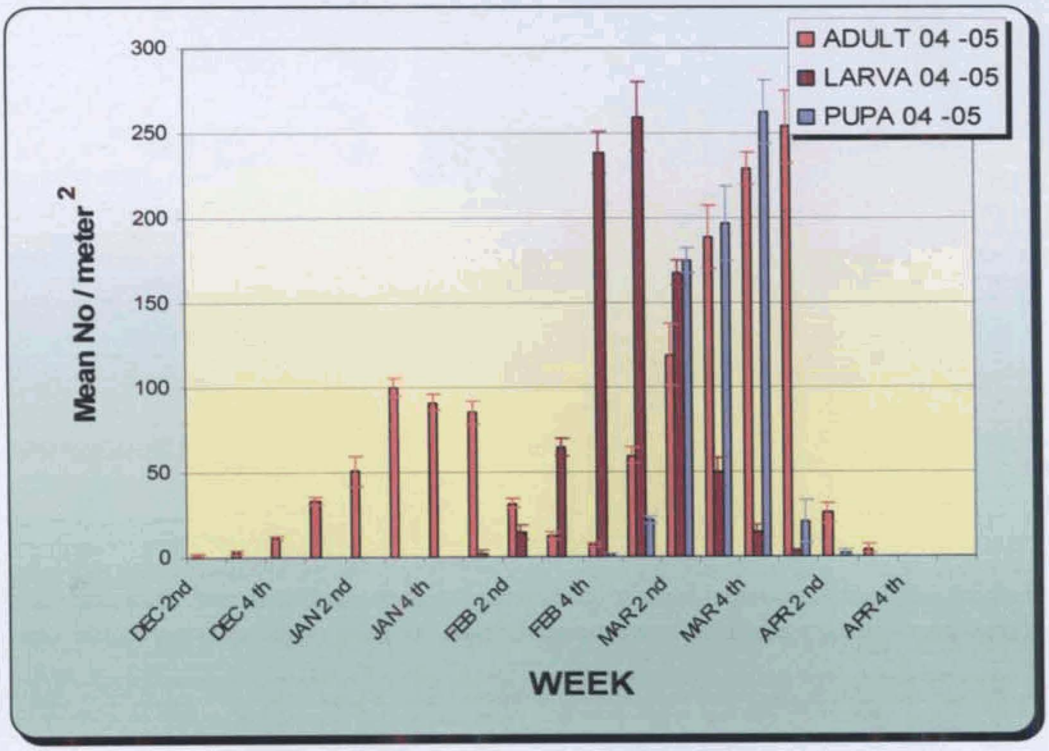


Figure 2.2.

Abundance of different stages of *Luprops curticollis* associated with RRII - 105 rubber plantations during various weeks in the year 2003-04.

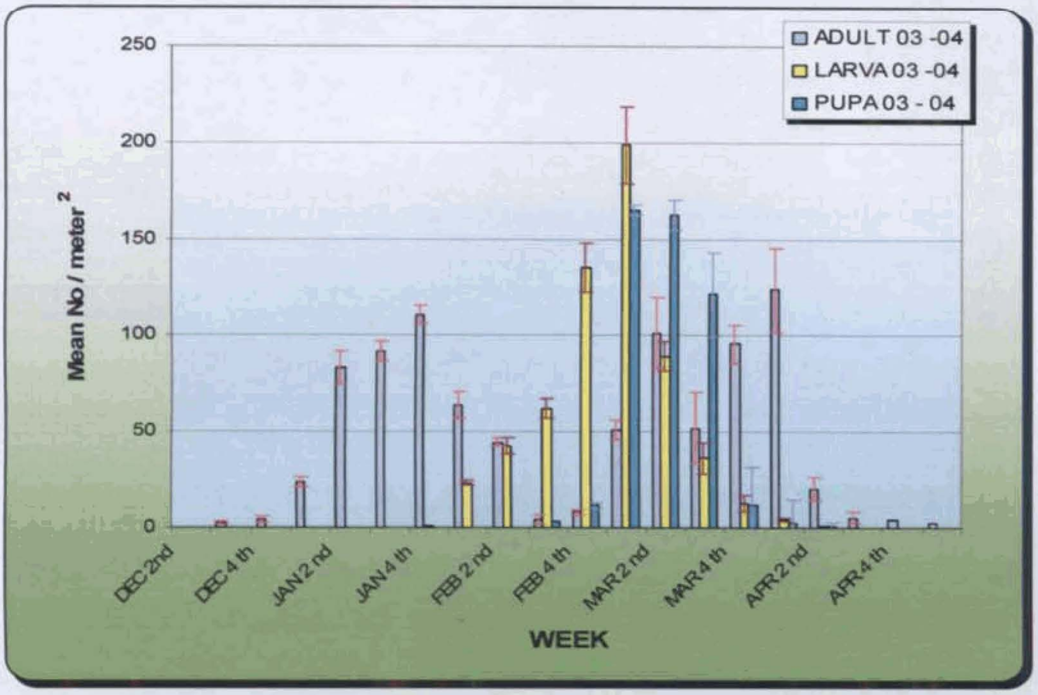


Table 2.4.

Results of one-way Anova on the annual variation (2003-04 to 2004-05) of abundance in various stages of *Luprops curticollis*.

Life stage	df	*F*	*P-value*	*F- crit*
Adults	23	0.40	0.53	4.30
Larvae	23	0.09	0.77	4.30
Pupae	23	0.05	0.82	4.30

Table 2.5.

Multivariate regression analysis on the abundance of various stages of *Luprops curticollis* as function of different abiotic factors.

Model	Variable	B	t	*P*	R^2	F
Adult 2004 -05	Constant	- 329.17	- 0.67	> 0.05		
	Litter fall	0.08	0.36	> 0.05	0.58	2.44
	Rain fall	- 0.22	- 0.10	> 0.05		
	Relative Humidity	- 2.63	- 0.79	> 0.05		
	Temperature	20.29	1.74	> 0.05		
Larva 2004 -05	Constant	242.74	0.54	> 0.05		
	Litter fall	- 0.24	- 1.07	> 0.05	0.48	1.59
	Rain fall	0.42	0.22	> 0.05		
	Relative Humidity	- 4.38	- 1.44	> 0.05		
	Temperature	4.60	0.43	> 0.05		
Pupa 2004 - 05	Constant	- 102.2	- 0.17	> 0.05		
	Litter fall	- 0.16	- 0.54	> 0.05		
	Rain fall	- 0.19	- 0.08	> 0.05	0.31	0.77
	Relative Humidity	- 2.21	- 0.54	> 0.05		
	Temperature	10.81	0.75	> 0.05		
Adult 2003 -04	Constant	- 234.2	- 0.83	> 0.05		
	Litter fall	0.22	1.59	> 0.05		
	Rain fall	- 0.22	- 0.18	> 0.05	0.62	2.89
	Relative Humidity	- 0.92	- 0.48	> 0.05		
	Temperature	11.40	1.69	> 0.05		
Larva 2003 -04	Constant	205.97	0.64	> 0.05		
	Litter fall	- 0.18	- 1.12	> 0.05		
	Rain fall	0.36	0.26	> 0.05	0.49	1.71
	Relative Humidity	- 3.38	- 1.56	> 0.05		
	Temperature	2.84	0.37	> 0.05		
Pupa 2003 -04	Constant	- 38.23	- 0.09	> 0.05		
	Litter fall	- 0.12	- 0.58	> 0.05		
	Rain fall	- 0.09	- 0.05	> 0.05	0.32	0.81
	Relative Humidity	- 1.77	- 0.62	> 0.05		
	Temperature	7.02	0.70	> 0.05		

Figure 2.3.

Relationship between various life stages of *Luprops curticollis* and mean monthly temperature under field conditions.

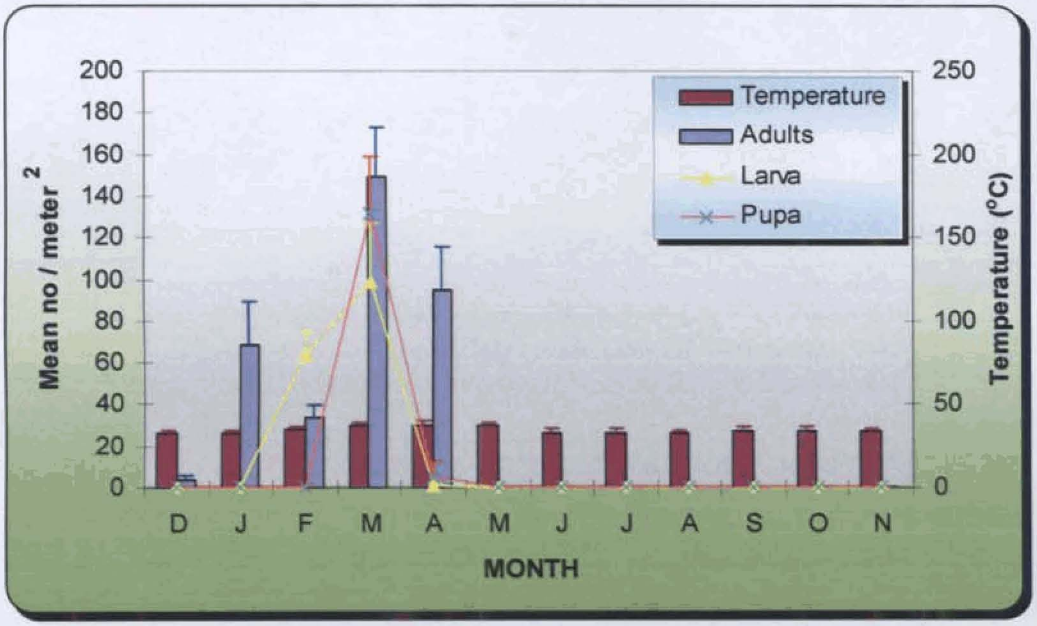


Figure 2.4.

Relationship between various life stages of *Luprops curticollis* and mean monthly relative humidity under field conditions.

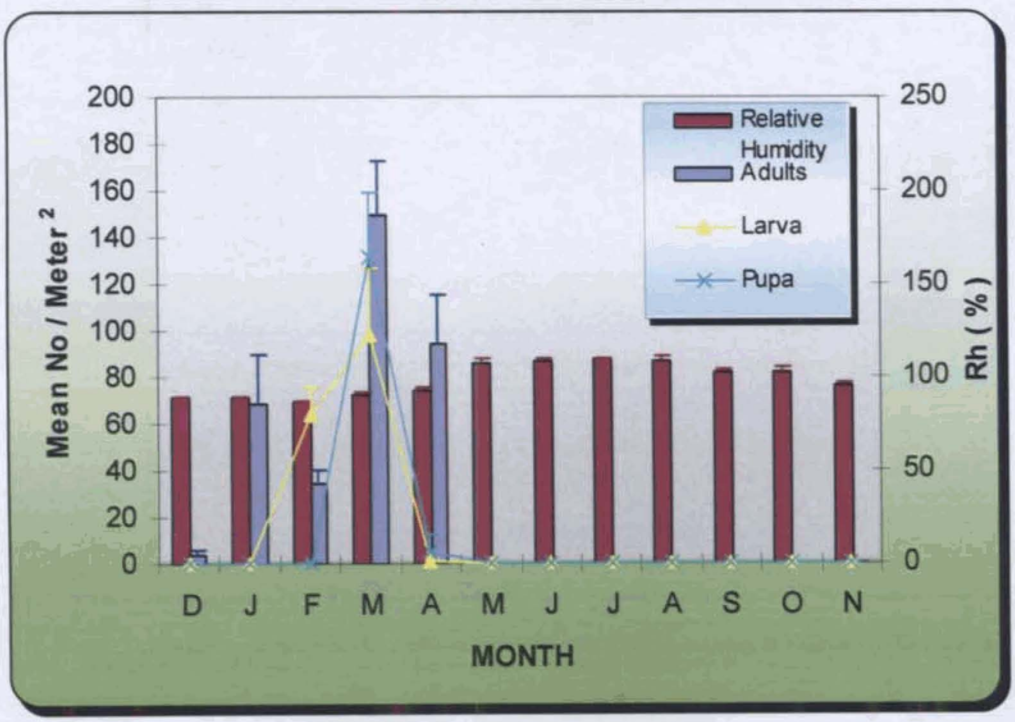


Figure 2.5.

Relationship between various life stages of *Luprops curticollis* and mean monthly rainfall under field conditions.

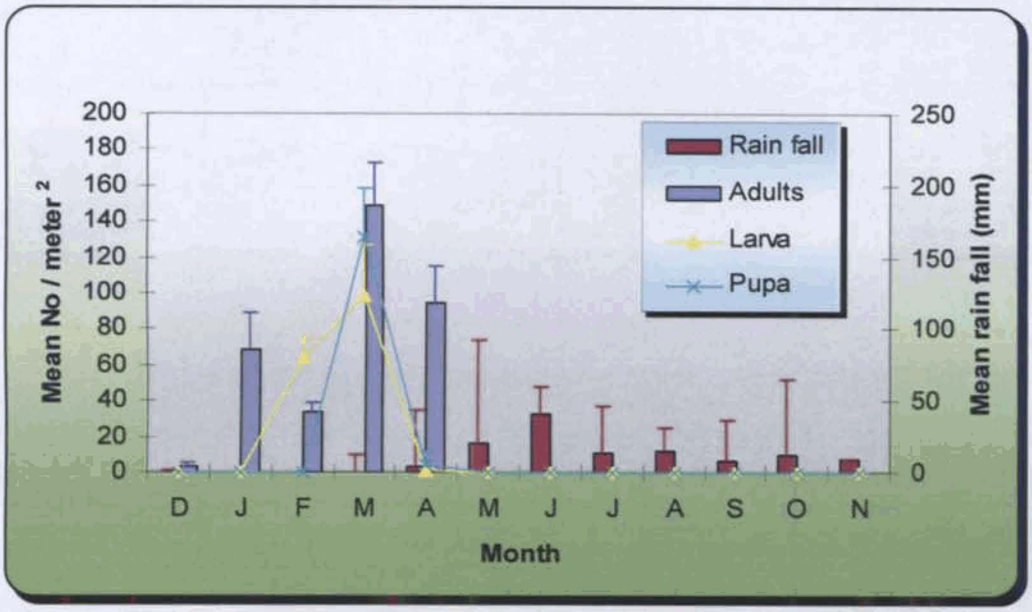


Figure 2.6.

Relationship between various life stages of *Luprops curticollis* and mean monthly leaf litter fall under field conditions.

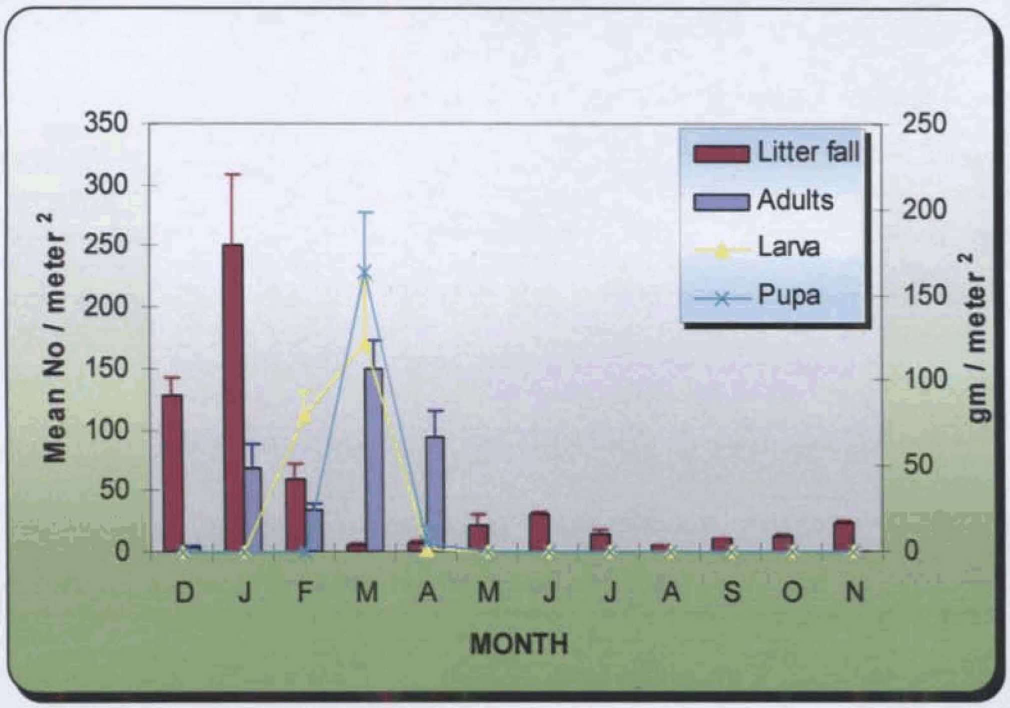
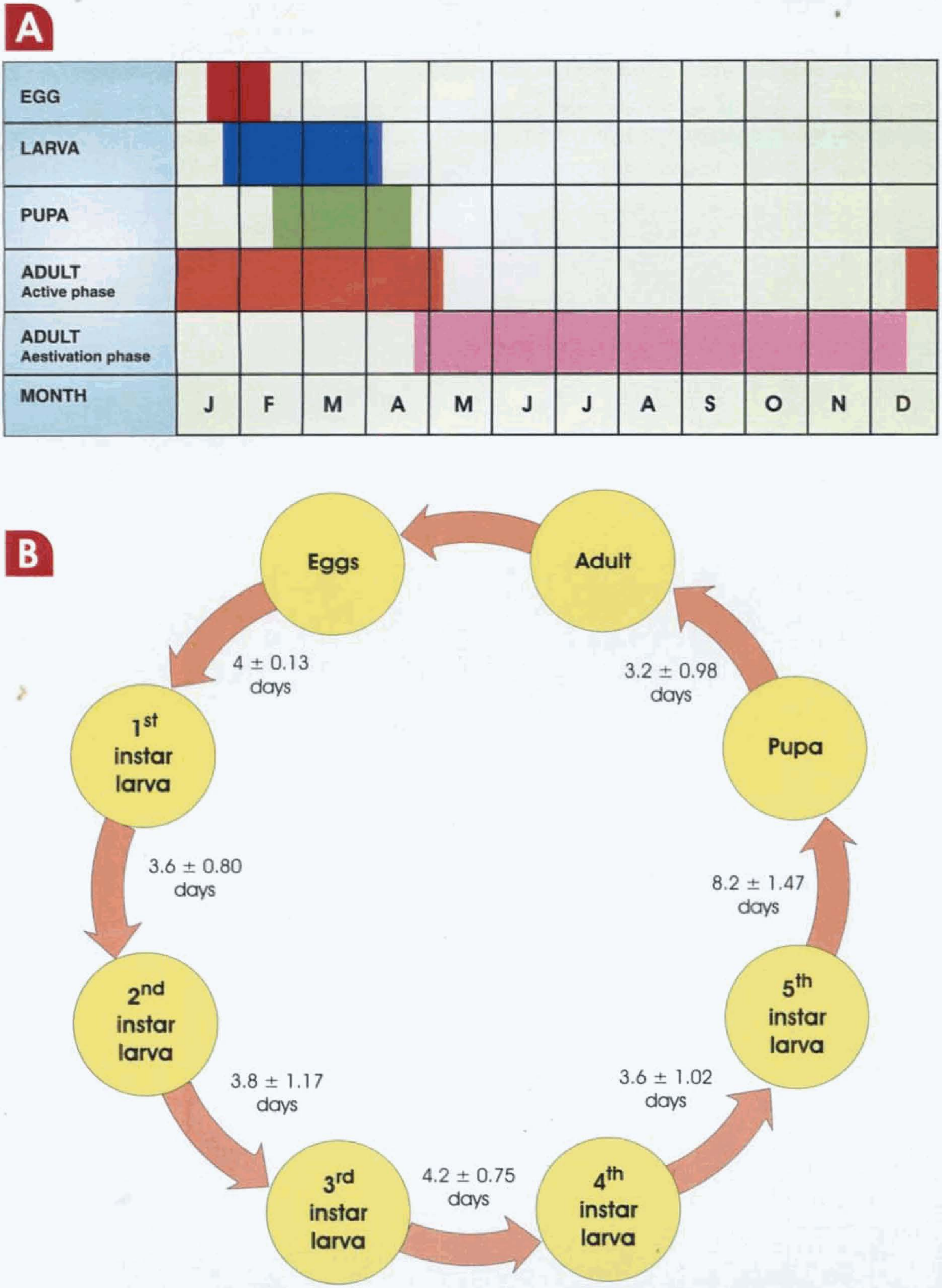


Plate: 6



Life table (A) and duration of various developmental stages of *Luprops curticollis*

DISCUSSION

Detailed information on the life cycle, biology of the immature stages and role of abiotic factors in regulation of *Luprops curticollis* population were reported for the first time. Adults are dark brown in colour with a total length of 8.1 ± 1.1 mm (Ratio of body length to greatest body width is 1.75-3.22). Body slightly flattened to moderately convex. No size difference between males and females among *Luprops* is present, contrary to the reports of Biju *et al.,* (2005). Adult *Luprops* beetle appeared in the plantation litter during the last three weeks of December. This is due to the fact that the beetles which get out of their aestivation stage flies back to the plantation with in two to six days, which could be correlated with the availability of rubber leaf litter as a habitat. Returned beetles were hiding beneath the leaf litter, stones and wood debris by the day time and fed during the night with a distinct preference towards wilted leaves and their petioles. After feeding on tender witted leaves, mating was observed. Eggs were spotted in clusters during the fourth week of January in the under surface of fallen leaves. Single female may lay one to twenty-three eggs per day. The egg laying period lasted for one month. Eggs are elongate, measure about 1 ± 0.11 mm in length. They have a concave anterior pole and a convex posterior pole and are creamy white. The eggs took 4 ± 0.13 days to hatch. The larvae appeared in the field during last week of January to first week of April, feeding on the fallen wilted tender leaves. Presence of leaves with only veins is an indication of the presence of larvae in the field. There are five larval stages. The larvae are elongated eruciform and body is covered with thick tuff of hairs. The first instar larva is 1.7 ± 3.8 mm long, delicate and creamy white. Before the first moulting stage, its colour changed to wheatish. It took 3.6 ± 0.80 days to complete this stage. The second instar larva is 2.3 ± 0.24 mm long and light brown in colour and took 3.8 ± 1.17 days. Third instar larva is 4.2 ± 0.68 mm in length and dark brown in colour and have a thick covering of hairs all over the body. This instar took 4.2 ± 0.75 days to complete. The fourth instar larval length varies up to 5.8 ± 0.44mm and black in colour. Thick covering hairs extending up to the antennae. This stage took 3.6 ± 1.02 days to complete. The fifth instar larva took 8.2 ± 1.47 days to enter into pupal stage. The pupal period lasted for 3.2 ± 0.98 days. A creamy white adult beetle emerges from the pupa, its colour gradually changing from brown to dark brown and finally black with 18± 2.8 hours.

Newly emerged adults also in an active feeding on the tender dried leaves for one to two weeks and observed that the deposition of fat globules in its heamocoel and subsequently the intensity of feeding decreased during the second and third week of April. When the summer rain commences the adults migrates to thatched or wooden houses in swarms and started aggregation. They find shelters during the evening of rainy days. These beetles may congregate around electric bulbs in the buildings in thousands.

In daytime, they seek aggregated around warm spots such as cracks and crevices on the walls or roofs and remain inactive. Feeding was not reported during this stage and beetles preferred to remain in this aestivation phase from June to November and the fat contents decreased during this period. As a result, a number of beetles die off. The rest of the beetles fly back to the rubber plantation during the month of December.

Influences of abiotic factors on the population dynamics have been a long time subject of discussion. In the field, abiotic factors appear to play crucial role in the fluctuations of population abundance of *Luprops* beetles. Adults, larvae, and pupae appeared in the field during December to May, when temperature was high and rainfall was low and relative humidity was moderate. Small-scale spatial variation in abiotic conditions can affect herbivores distribution and that responses of insect to microclimate can overdrive plant quality in habitat selection behaviour or performance of insect (Tahvanainen *et al.,* 1985; Moore *et al.,* 1988; Louda and Rodman, 1996; Alonso, 1997; Ritchie, 2000; Sipura and Tahvanainen 2000) However, these variations are non-significant in multivariate regression analysis because there were no clear-cut difference between the average monthly variations of relative humidity, and temperature. It is suspected that not only these abiotic factors some biotic factors like role of pheromones, predators or availability of food also have the significant role in the population dynamics of *Luprops curticollis*.

Chapter 3

Rubber litter Arthropods

RUBBER LITTER ARTHROPODS

ABSTRACT

The litter arthropod faunal community and its abundance associated with fourteen year old *Hevea brasiliensis* plantation (RRII -105 clones) of north-east Kerala for a period of one year have been studied. It has been shown that there was an overall significant difference among the diversity, evenness and richness during different seasons and the seasonal variation was the more important determinant in the litter arthropod numerical abundance than the litter habitat alone. Role of quantity of litter fall and climatic factors like temperature, rainfall and relative humidity in regulating faunal abundance is analyzed. While the abundance peaked during summer season, the richness, evenness and diversity peaked during the post rainy season. This study also illustrates that the rubber plantation forests are a very important habitat for the litter invertebrates.

Key word: Litter arthropods, *Hevea brasiliensis,* diversity, evenness, richness, and seasonal variation.

INTRODUCTION

The impact and role of litter inhabiting arthropods in the physical breakdown of litter and the significance of environmental factors in determining their dynamics and abundance are well documented (Anderson, 1978; Swift *et al.,* 1979; Seastedt, 1984; Anathakrishnan, 1996) from natural and plantation forests. Belowground invertebrates are the dominant animal group in many terrestrial ecosystems and may have higher biomass on an area basis than the above ground herbivores insect or vertebrates (Odum, 1971). Total ecosystem productivity increases with an increase in soil biodiversity and the interactions among soil fauna maintain nutrient cycling (Moore *et al.,* 1999). Litter invertebrates provide a good indication of ecological condition because they are highly diverse and functionally important and can integrate a variety of ecological process, besides being sensitive to environmental changes (Greenslade and Greenslade; 1984; Brown, 1997). Diversity of arthropod communities in the litter ecosystem is directly correlated with the nutrient status of the litter (Ananthakrishnan *et al.,* 1992; 1993). Litter insects also serve as useful indicators of changes in the chemical environment (Moursi, 1962; Clement *et al.,* 1989). Arthropods are ideal organism as an early warning indicators of environmental changes and for monitoring recovery of disturbed sites because of the variety of roles played by arthropods in ecosystem functioning, abundance enabling large size to be obtained for high statistical power, and are also relatively easy to sample (Mclntyre *et al.,* 2001). However a lesser interest in below ground invertebrate communities is obviously due to the fact that litter fauna are locally very numerous, with a wide range of mobility, requiring enormous sampling efforts and are often difficult to identify. Differences in abundance and diversity prior to and after the rainy season could be related to the differential leaf shedding nature of litter contributing plants and to the direct influences of rain on the weathering activities in the litter habitats (Sabu *et al.,* 1993; Zak *et al.,* 1999).

The population of litter inhabiting is likely to vary depending on the plant species, age, environment and climatic conditions. Many attempts have been made to identify Arthropods dynamics in monoculture plantations like *Shorea robusta*, *Eucalyptus* and *Tectona* (Ananthakrishnan, 1988; 1993; Annadurai *et al.,* 1988; Hazra, 1991; Reddy *et al.,* 1990; Sabu, 1993). The Arthropods are ubiquitous in terrestrial ecosystems; being numerous under undisturbed natural conditions and less in the disturbed areas with increased anthropogenic activity. They are available in large quantities through out or most of the periods of the annual cycle and are identified as useful indicators of environmental qualities (Reddy, 1986).

The population density of various groups of soil organisms were found to be higher under rubber plantation, which indicated an increased microbial activity and have a beneficial effect on availability of nutrients (Chaudhuri *et al.,* 2002). Oribated mites, earthworms, actinomycetes, bacteria and fungi have been reported from *Hevea* soil. (Bhattachrjee and Chakraborti, 1995; Jacob, 2000). But to date, no litter arthropod diversity inventories were conducted in *Hevea brasiliensis.* So the prime objective of this study is to record monthly and seasonal pattern of litter arthropod diversity and abundance in a fourteen year old rubber plantation and test the significance of richness, evenness and diversity along various seasons. A second objective is to investigate whether the arthropod litter community composition varied significantly with monthly and seasonal litter fall, atmospheric temperature, rainfall and relative humidity.

MATERIALS AND METHODS.

1. Study area.

The study was conducted from December 2003 to November 2004 at Vettiozhijathottam situated 48 KM North east of Calicut. (Latitude 11° 25' N and Longitude 75° 77' E) (Plate no: 1). The 58 hectare plot planted in 1990 (Fourteen year old) had a density of 320 mature rubber tree per hectare of RRII – 105 clone, under tapping. This plantation is free from regular practice of spraying of copper sulphate ($CuSo_4$), which is as a practical measure to prevent various fungal diseases.

2. Season and Climate of study area.

The region has a tropical humid climate, with an aggressive summer and plentiful seasonal rainfall. January and February are normally dry months. The hot season from March to May, is followed by the southwest monsoon from June to September. The northeast monsoon is from October to November. This area receives an annual rain fall of 3614.50 mm (Appendix-I) with minimum and maximum air temperature of 19.71° C (± 1.35° C) and 34. 98° C (± 0. 70° C) respectively (Appendix-II). The mean monthly humidity varies from 47.10% (± 6.21%) in dry season to 94.47 % (± 0. 68%) in wet seasons (Appendix-III). Westerly and north-westerly winds prevails during December to March. The maximum wind speed is between 10 to 15 Km per hour. The study area receives adequate sunshine hours in all months except during southwest monsoon period. Data collected from daily records of Centre for Water Resource Development and Management (CWRDM), Kottamparamba, Kozhikode.

Based on all these physical parameters, the months of a year are grouped into four seasons. They are 1. Post-rainy season (December to February) 2. Summer season (March to May) 3. South-west monsoon season (June to September) 4. North-east monsoon (October to November).

3. Fauna Collection.

Litter samples were collected in triplicates on monthly basis from randomly selected one square meter areas from December 2003 to November 2004. The collected litter was transferred to 45 cm X 30 cm polythene bags contain a clearly displayed label having information of the site, location, collection date and collection time. Mean values of each month were taken to account for the abundance of individuals. On the spot assessment of large fauna were also done.

Collected litter sample were extracted with a series of 15 – 20 cm diameter Berlese funnel (Plate:7) fitted with 4 – 6 mm mesh screen and a 25 watt bulb for 2 to 4 days until the litter was dry (Ananthakrishnan, 1996). Animal moving away from the heat source pass down the stem of the funnel and are collected on the container containing alcohol. Extraction time of the Berlese funnel depend on the behaviour of the focus group (Stone, 1999; Tenbrink *et.al.*, 2002).

4. Fauna sorting and Identification.

The preserved fauna samples were emptied into a Petridish which has a grid drawn on its underside. The dish is then searched repeatedly under a stereo zoom trinocular microscope (Labmode-ZM45 TM) and organisms were identified to order level by using keys of Borrer et.al., 1996). Once identified to this level, arthropods were removed and placed in small vials (Tarson, model no: 510000) containing 70 % ethyl alcohol and members of each category for each sample were lumped together. Fine (#8) Watchmarker's forceps were used for picking up arthropods from the dishes but occasionally a small hair brush was substituted. Mites in particular often needed a pipette for sampling. Each vial contains a clearly displayed label having information of the site, location, number, collection date, taxon name and preservation date. Following the initial sorting, the whole set of vials from a particular sample were then bundled together using an elastic band. The count of each order category of arthropods were entered on a pre printed tally sheet, that also has the date of collection, preservation, sorting and sample code.

5. Data analysis.

Diversity of the assemblage (Taxonomic richness, evenness, diversity and community similarity) was assessed at each month over the entire study period. These values were compared across the months and seasons (Post-rainy, summer, South- west monsoon, and North- east monsoon) by using Gretl, Primer, SPSS and Minitab software.

a) Taxa richness

It expresses the number of taxa / group existing in the region studied. For analyzing taxa richness, Margalef's index (Clifford and Stephenson, 1975; Maugurran, 2004) issued. It is calculated by using the following formula.

$$d = S - 1 / \log (N)$$

Where d is Margalef's index,

S is total number of taxa

N is total number of individuals

b) Evenness.

Evenness addresses area equitability of the taxa. It is expressed as Pielou's evenness index (J') (Maugurran and Henderson, 2003) in this study.

$$J' = H' / \log S$$

Where H' is Shannon diversity index

S is Total number of taxa.

c). Diversity.

It is an index taking both richness and evenness into account. I.e. the higher the richness and evenness, higher the diversity (Maugurran, 1988; 2003.). To measure diversity, Shannon's diversity index (H') was used, which is the most widely used index to describe diversity (Pielou, 1975). It was calculated with the following equation.

$$H' = -\sum_i P_i (\log (P_i)$$

Where P_i is the proportion of the total count arising from the $_i$th species

Logarithms to the base of e (Natural logarithm) were used.

6. Statistical analysis.

a) Partial Correlation analysis.

The correlation between different climatic factors like Temperature, Rainfall and Relative humidity on the number of taxonomic groups and total number of individuals has been analyzed by using partial correlation technique. (Murray *et.al.,* 2000)

$$r_{12.34} = \frac{r_{12.3}-[r_{14.3}\, r_{24.3}]}{\sqrt{1-r^2_{14.3}}\,\sqrt{1-r^2_{24.3}}}$$

$$r_{13.24} = \frac{r_{13.2}-[r_{14.2}\, r_{34.2}]}{\sqrt{1-r^2_{14.2}}\,\sqrt{1-r^2_{34.2}}}$$

$$r_{14.23} = \frac{r_{14.2}-[r_{13.2}\, r_{43.2}]}{\sqrt{1-r^2_{13.2}}\,\sqrt{1-r^2_{43.2}}}$$

1 = Number of taxonomic groups Or Total number of individuals

2 = Temperature

3 = Rainfall

4 = Relative Humidity.

b). Cluster Analysis.

Cluster analysis of the taxon and its abundance at different season and months were investigated by using Hierarchical agglomerative method. (Cromack, 1971). Months and season were grouped and the groups themselves form clusters at the levels of similarity.

Hierarchical agglomerative method is the most commonly used clustering technique (Clarke and Warwick, 2001). These take a similarity matrix as their starting point and successively fuse the samples into groups and the groups into large clusters, staring with the highest mutual similarities then gradually lowering the similarity level at which groups are formed. The process ends with a single cluster containing all samples. The result of the hierarchical agglomerative clustering is represented by a dendrogram after √ -transformation of the data, with the X axis representing the full set of samples (seasons or Months) and the Y axis defining similarity level at which two samples or groups are considered to have fused.

Plate: 7

A

B

Berlese funnels (A) and Rubber leaf litter (B)

RESULTS.

Definite patterns in the diversity and abundance of arthropod fauna in rubber litter were evident along the various seasons and months. A mean total of 1928.50 soil arthropods belonging to sixteen taxa were captured (Table: 3.1 and 3.2). Of the taxa collected mean population density of eleven groups were represented by < 10 individuals (Fig: 3.1). Springtails (Collembola), Mites (Acari), Ants (Hymenoptera: Formicidae) and Coleoptera were the most abundant taxa sampled, collectively accounting for 70.10 % of the total number of individuals captured. (Collembola: 21.52%, Acari: 28.8 %, Formicidae: 11.25 % and Coleoptera: 8.55 %). Members of these four taxa were present in all months and seasons. The next most abundant taxa were, in order of abundance, eggs, larva and pupa (10.68%), Thysanura (2.15%). All remaining taxa accounted for 17.05 % of total capture (Table: 3.3).

Even though collembola and mites were present in all the seasons and months, the former showed unimodel peak abundance during the southwest monsoon season (82.25 ± 16.49) (Fig: 3.8). The number of mites was low during the north east monsoon season and has single peak abundance in May – June months (Fig: 3.2). Mites were the dominant group in the south west monsoon season, represented by more than 40 % of total abundance (Fig: 3.8). Coleopterans showed bimodal peak abundance, once in summer season and other in the late phase of southwest monsoon period (Fig: 3.4.). Where as in blataria, hemipera and diptera no particular pattern was noticed, may be due to low abundance value (< 5 Nos per m^2) (Table: 3.3.). Thysanuran population strength was highest during the midsummer season (8.66 ± 2.44) (Fig: 3.9). Seasonal wise comparison of abundance of hymenoptera showed that the maximum density was during summer season (38.16 ± 5.23) (Fig: 3.4). Isopods abundance was observed during south west monsoon season where as number of spiders (7.66 ± 2.47) and psudoscorpions (5.66 ± 2.103) were higher during summer season. Abundance of isoptera (7.33 ± 1.34) was clear during summer season but its number decreased as rain started (Fig: 3.9). In contrast, abundance of worms and millipedes gradually increased with rain (Table 3.2). Pupa and larval stages (46.33 ± 6.36) was significantly high during summer season (March-May) (Fig: 3.4).

Highest value of richness, Margalef's index (d), was obtained in the post rainy season (2.89) and lowest in the northeast monsoon period (2.14). (Table: 3.6). Maximum richness was observed during the February (2.68) and minimum was in the November (1.77) (Table: 3.7). There was an overall significant difference between richness among various seasons (($F_{3.239}$ = 57.64, $P < 0.05$) (Table: 3.9).

Evenness was higher in the post rainy season (0.82) and lower in summer (0.75) and an intermediate values were obtained during the post rainy season (0.81) and southwest monsoon season. (0.63). (Table: 3.6) (Fig: 3.10). The highest value of evenness (J') was observed during October (0.88) and lowest in the June (0.51) (Table: 3.7) (Fig: 3.11). There was an overall significant difference between evenness ($F_{3.239} = 44.28$, $P < 0.05$) among various seasons and months (Table: 3.10).

Shannon's diversity index (H') was maximum in the post rainy season (2.21) and minimum in the southwest monsoon season (0.62) and intermediates in summer (2.08) and northeast monsoon (1.81) (Table: 3.6.) (Fig:3.10). Single factor ANOVA analysis revealed that there was an overall significant difference between Shannon's (H') diversity ($F_{3.239} = 63.198$, $P < 0.05$) among various seasons (Table: 3.8). Highest value of H' was observed in March (2.224) and lowest was in May (1.473) (Table: 3.7) (Fig: 3.11).

Partial correlation analysis between the numbers of taxonomic groups vs. various climatic factors like temperature, rainfall and relative humidity has also been analyzed in this work. Of these, rainfall and temperature showed a positive correlation between faunal groups with value of 0.063 and 0.53 respectively. Where as relative humidity followed a negative correlation (- 0.14) (Table: 3.5). The same pattern of correlation was obtained when it was analyzed with the mean population number of individuals in each season. (Rainfall: + 0.48, Temperature: + 0.48 and Relative humidity: - 0.21) (Table: 3.5). Partial correlation analyzed between insect groups and mean population density of individual with quantity of litter fall followed a positive relation with values of 0.398 and 0.208 respectively.

The result of hierarchical agglomerative clustering of various seasons was represented by a Dendrogram (3.12.). It was seen that the samples of summer and post rainy season had the highest similarity, so they were combined, at similarity level of 81.74%. To this group, South- west monsoon season joined with the similarity level of 63.55% and the final merge of remaining sample (North-east monsoon season) into the existing cluster to form a single group took place at similarity level of 57.66% . The clustering processes for the group average linking are shown in the table 3.11.

The clustering analyses between various months are represented in figure3.13. Three distinct clusters can be observed. Cluster -1, January to May. Of these January and February have the highest similarity and form the first cluster at similarity level of 77.67%. The least similar month of this group was May. Cluster-2, September to December, October and November showed the highest similarity of these cluster analyses and forms the first cluster at 79.39%. September and December had 73.99 % similarity. Cluster – 3 was formed from three months, June, July and August. Of these June and July formed a group at similarity level of 76.17 % and was merged with August with a comparatively low similarity. Out of these three clusters, second and third linked together to form a new cluster and all the cluster finally merge together with similarity level of 55.15 %. The percentages of the similarity between various months for the clustering process were shown in the table 3.12.

Table 3.1.

Mean population density of rubber litter arthropod fauna per m^2 and standard deviation along the various Months of year December 2003- November2004.

RUBBER FAUNA		DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
COLLEMBOLLA	mean	3.5	16.5	5	35.5	7.5	6.5	176.5	100.5	16	36	4.5	7
	sd	± 0.707	± 2.121	± 2.828	± 9.192	± 2.121	± 2.121	±23.335	± 3.536	± 2.828	± 5.657	± 0.707	± 1.414
MITES	mean	30.5	56.5	15.5	78	58	107.5	98.5	39	10.5	27.5	10.5	23
	sd	± 7.778	± 6.364	± 2.121	± 8.485	±15.556	±13.435	± 6.364	± 7.071	± 3.536	± 4.950	± 3.536	± 5.657
LARVA, EGG,PUPA	mean	3	24.5	29.5	75.5	57	6.5	3.5	1	0	2	3.5	0
	sd	± 1.414	±17.678	±13.435	± 17.677	±21.213	± 2.121	± 0.707	± 0.000	± 0.000	± 0.000	± 0.707	± 0.000
HYMENOPTERA	mean	10.5	22	26.5	55	27.5	32	7.5	4.5	8	10.5	2.5	10.5
	sd	± 2.121	± 5.657	± 7.778	± 9.899	± 4.950	±15.556	± 3.536	± 0.707	± 2.828	± 3.536	± 2.121	± 3.536
COLEOPTERA	mean	6	17	19.5	30.5	36	14	5.5	2.5	24.5	3	3	3.5
	sd	± 2.828	± 7.071	± 4.950	± 7.778	± 8.485	± 4.243	± 2.121	± 2.121	± 9.192	± 1.414	± 1.414	± 2.121
THYSANURA	mean	2.5	10	1.5	24.5	1.5	0	1.5	0	0	0	0	0
	sd	± 0.707	± 2.828	± 0.707	± 3.536	± 0.707	± 0.000	± 0.707	± 0.000	± 0.000	± 0.000	± 0.000	± 0.000
ISOPTERA	mean	2.5	16	9	22	0	0	0	2.5	0	0	0	0
	sd	± 0.707	± 2.828	± 4.243	± 8.485	± 0.000	± 0.000	± 0.000	± 2.121	± 0.000	± 0.000	± 0.000	± 0.000
WORMS	mean	3	0	1.5	1.5	2	3	1	12.5	14.5	2.5	1.5	2.5
	sd	± 1.414	± 0.000	± 0.707	± 0.707	± 1.414	± 0.000	± 0.000	± 4.950	± 4.950	± 0.707	± 0.707	± 0.707
PSOCOPTERA	mean	0	1	9.5	16.5	1	1.5	0	0	0	0	3	2.5
	sd	± 0.000	± 1.414	± 6.364	± 3.536	± 0.000	± 2.121	± 0.000	± 0.000	± 0.000	± 0.000	± 0.000	± 0.707
SPIDERS	mean	1.5	2.5	1.5	10.5	6	6.5	2	3.5	4	1	0.5	1.5
	sd	± 0.707	± 0.707	± 0.707	± 2.121	± 1.414	± 2.121	± 1.414	± 2.121	± 1.414	± 0.000	± 0.707	± 0.707
MILLIPEDS	mean	0	0	0	2.5	3	0	7	6	4.5	2	2	1.5
	sd	± 0.000	± 0.000	0.000	± 0.707	± 1.414	± 0.000	± 2.828	± 1.414	± 2.121	± 1.414	± 0.000	± 0.707
ISOPODA	mean	2.5	5.5	1	4.5	2.5	2	12.5	7	19	3	0	0
	sd	± 0.707	± 2.121	± 0.000	± 2.121	± 0.707	± 1.414	± 3.536	± 4.243	± 4.243	± 1.414	± 0.000	± 0.000
PSEUDOSCORPIONS	mean	0	1	2.5	7	8.5	1.5	3	1.5	2.5	0	0	0
	sd	± 0.000	± 0.000	0.707	± 1.414	± 2.121	± 0.707	± 1.414	± 0.707	± 0.707	± 0.000	± 0.000	± 0.000
BLATTARIA	mean	3.5	4	0	1.5	0	3.5	0	0	0	0	0	0
	sd	± 0.707	± 1.414	± 0.000	± 0.707	± 0.000	± 0.707	± 0.000	± 0.000	± 0.000	± 0.000	± 0.000	± 0.000
HEMIPTERA	mean	0	2.5	1.5	3	0	0	0	4	2	0	0	0
	sd	± 0.000	± 0.707	± 0.707	± 0.000	± 0.000	± 0.000	± 0.000	± 1.414	± 1.414	± 0.000	± 0.000	± 0.000
DIPTERA	mean	0	5	3	1.5	3.5	1.5	0	0	0	0	0	0
	sd	± 0.000	± 1.414	± 1.414	± 0.707	± 0.707	± 0.707	± 0.000	± 0.000	± 0.000	± 0.000	± 0.000	± 0.000

Table : 3.2.

Mean population density of rubber litter arthropod fauna / m^2 and standard - deviation during the various seasons of the year December 2003 to November 2004.

SEASON	POST RAINY		SUMMER		SOUTH WEST MONSOON		NORTH EAST MONSOON	
FAUNA	mean	sd	mean	sd	mean	sd	mean	sd
COLLEMBOLLA	8.33	± 2.17	16.50	± 2.56	82.25	± 16.4	5.75	± 1.76
MITES	34.16	± 5.32	81.16	± 14.53	43.87	± 8.23	16.75	± 4.84
LARVA, PUPA	19.00	± 2.45	46.33	± 6.36	1.62	± 0.34	1.75	± 0.56
HYMENOPTERA	19.66	± 8.33	38.16	± 5.23	7.62	± 2.46	6.50	± 0.32
COLEOPTERA	14.16	± 3.23	26.83	± 4.31	8.87	± 0.84	3.25	± 0.35
THYSANURA	4.66	± 0.44	8.66	± 2.44	0.37	± 0.27	0.00	± 0.00
ISOPTERA	9.16	± 2.11	7.33	± 1.34	0.62	± 0.32	0.00	± 0.00
WORMS	1.50	± 0.98	2.16	± 0.76	7.62	± 1.23	2.00	± 0.70
PSOCOPTERA	3.50	± 0.45	6.33	± 0.80	0.00	± 0.00	2.75	± 0.35
SPIDERS	1.83	± 0.57	7.66	± 2.46	2.62	± 1.37	1.00	± 0.70
MILLIPEDS	0.00	± 0.00	1.83	± 0.66	4.87	± 2.17	1.75	± 0.35
ISOPODA	3.00	± 0.24	3.00	± 1.32	10.37	± 2.66	0.00	± 0.00
PSEUDO SCORPION	1.16	± 0.32	5.66	± 2.10	1.75	± 0.32	0.00	± 0.00
BLATTARIA	2.50	± 0.94	1.66	± 0.34	0.00	± 0.00	0.00	± 0.00
HEMIPTERA	1.33	± 0.34	1.00	± 0.23	1.50	± 0.32	0.00	± 0.00
DIPTERA	2.66	± 0.76	2.16	± 0.43	0.00	± 0.00	0.00	± 0.00

Figure: 3. 1.

Numerical abundance of litter arthropod in a fourteen year old rubber plantation litter stands during different seasons of December 2003 to November 2004.

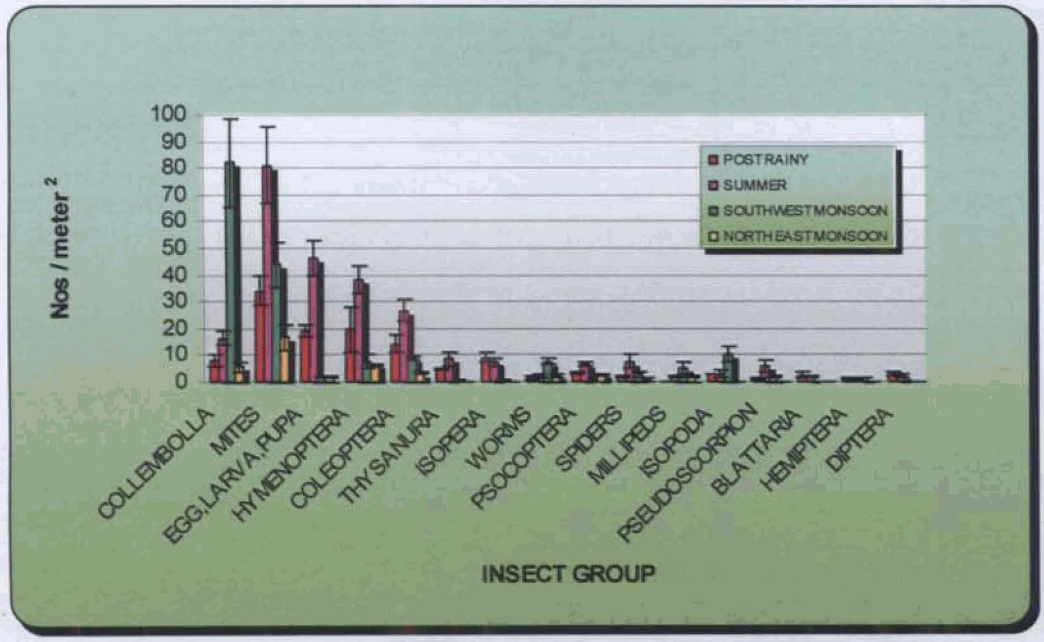


Figure. 3. 2.

Comparative analysis of seasonal variation in the population density of litter arthropod group in *Heave brasiliensis* litter stands during December 2003 to November 2004.

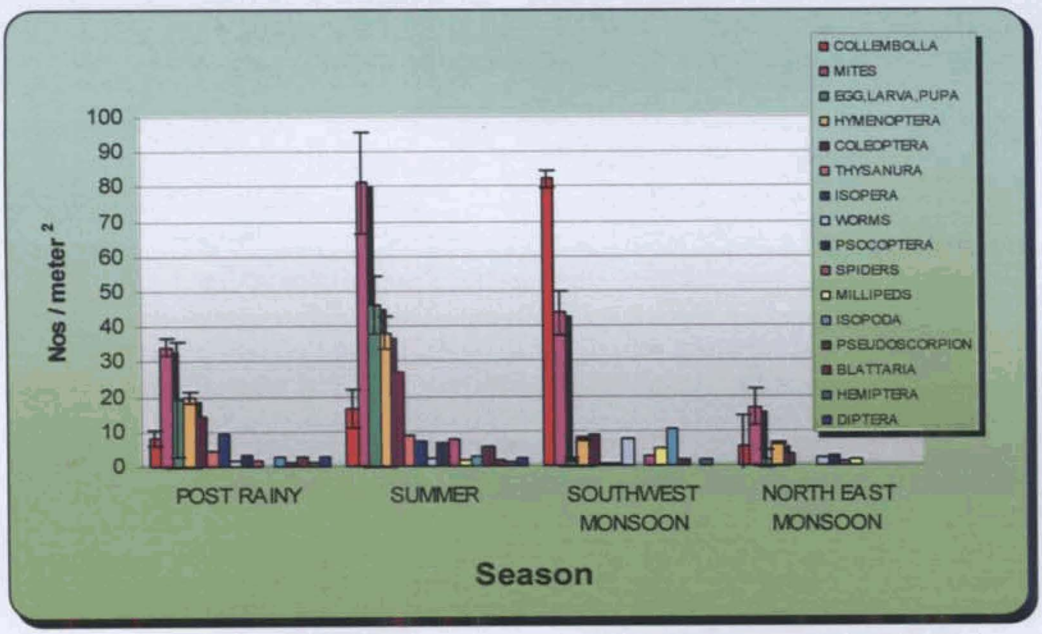


Table: 3. 3.

Different taxonomic groups, its Mean value, Standard deviations (SD) and Relative percentage (%) of rubber litter during the period of one year. (December 2003 to November 2004).

FAUNA	MEAN	SD	PERCENTAGE
COLLEMBOLLA	34.58	± 12.35	21.51
MITES	46.25	± 14.32	28.77
LARVA, PUPA	17.16	± 8.32	10.68
HYMENOPTERA	18.08	± 6.32	11.25
COLEOPTERA	13.75	± 4.57	8.55
THYSANURA	3.45	± 1.25	2.15
ISOPTERA	4.33	± 2.33	2.69
WORMS	3.79	± 2.14	2.35
PSOCOPTERA	2.91	± 0.32	1.81
SPIDERS	3.41	± 1.32	2.12
MILLIPEDS	2.37	± 0.45	1.47
ISOPODA	4.95	± 0.65	3.08
PSEUDOSCORPIONS	2.29	± 1.32	1.42
BLATTARIA	1.04	± 0.23	0.64
HEMIPTERA	1.08	± 0.95	0.67
DIPTERA	1.20	± 0.47	0.75
TOTAL	**160.70**	**± 13.25**	**100.00**

Table 3. 4.

Average number of groups and its standard deviations, Mean value, Standard deviations (SD) and Relative percentage (%) of total organisms of rubber litter during various months.

MONTHS	NUMBER OF GROUPS		TOTAL NUMBER OF ORGANISMS		
	MEAN	SD	MEAN	SD	PERCENTAGE
DEC	10.67	± 1.53	69.00	± 7.49	3.57
JAN	13.83	± 0.76	184.00	± 14.52	9.54
FEB	13.67	± 1.53	127.00	± 9.68	6.58
MAR	16.50	± 0.50	369.50	± 25.85	19.16
APR	11.33	± 1.53	214.00	± 20.00	11.09
MAY	11.67	± 1.53	186.00	± 26.79	9.64
JUN	10.67	± 1.53	318.50	± 48.19	16.51
JUL	12.17	± 0.29	184.50	± 25.55	9.56
AUG	9.67	± 0.38	105.50	± 7.96	5.47
SEP	9.17	± 0.76	87.500	± 10.70	4.53
OCT	9.00	± 0.50	31.000	± 2.75	1.60
NOV	8.17	± 0.76	52.000	± 6.04	2.69
TOTAL			1928.50	± 104.30	100.00

Figure. 3.3.

Comparative analysis of the percentage of litter arthropod taxonomic group of rubber litter stands during Post rainy season.

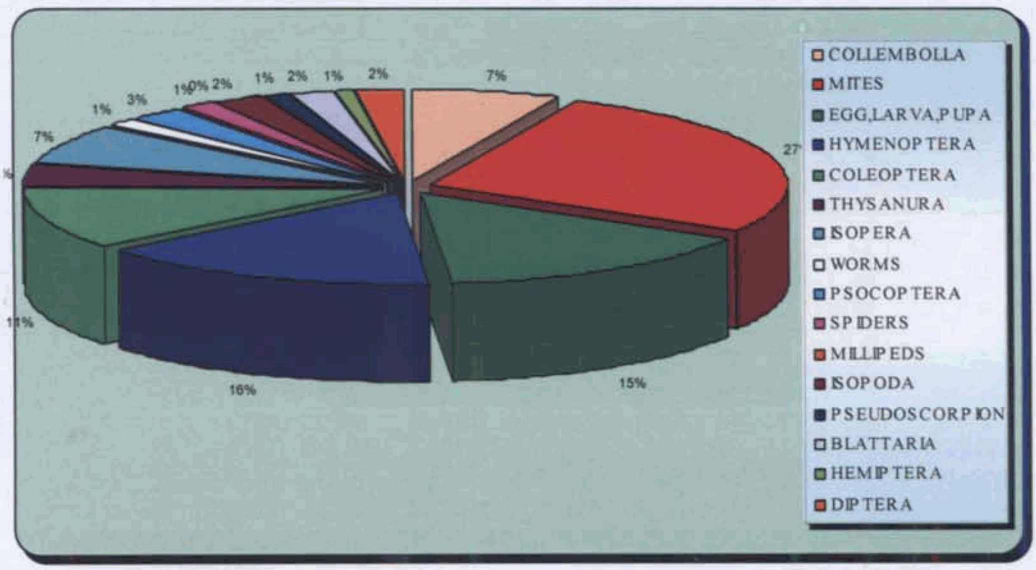


Figure. 3.4.

Comparative analysis of the percentage of litter arthropod taxonomic group of rubber litter stands during Summer season.

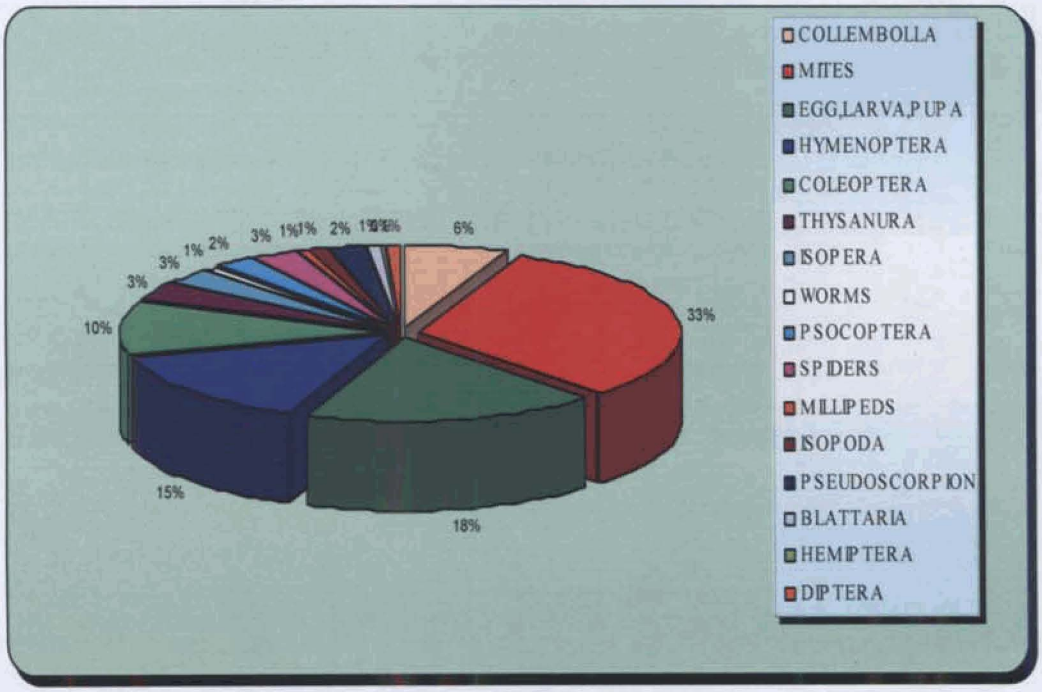


Figure. 3. 5.

Comparative analysis of the percentage of litter arthropod taxonomic group of rubber litter stands during Southwest monsoon season.

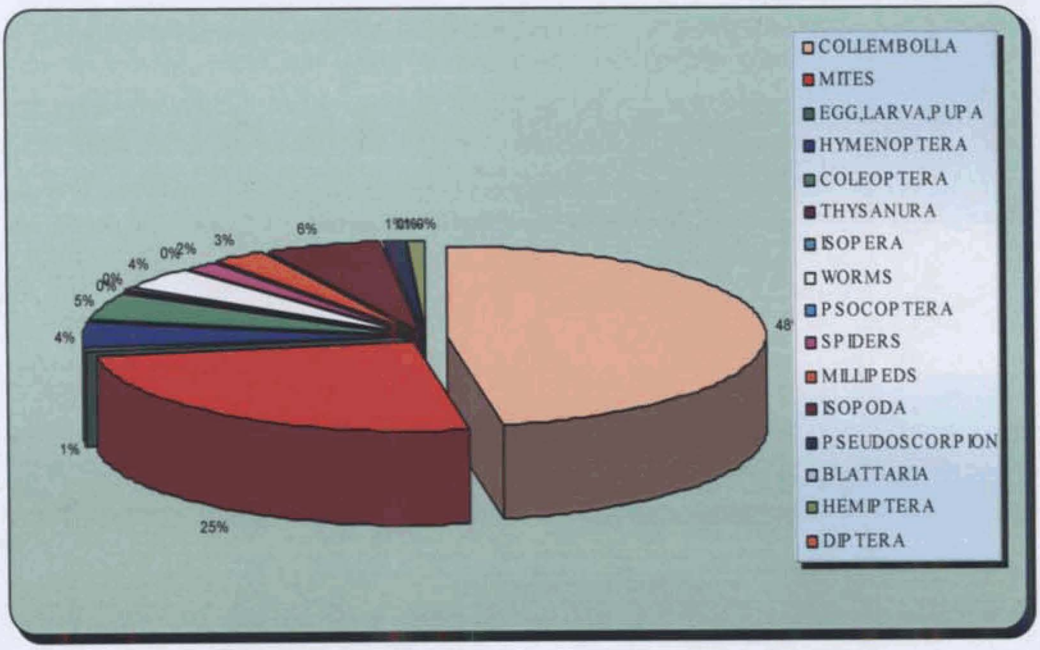


Figure. 3.6.

Comparative analysis of the percentage of litter arthropod taxonomic group of rubber litter stands during Northeast monsoon season .

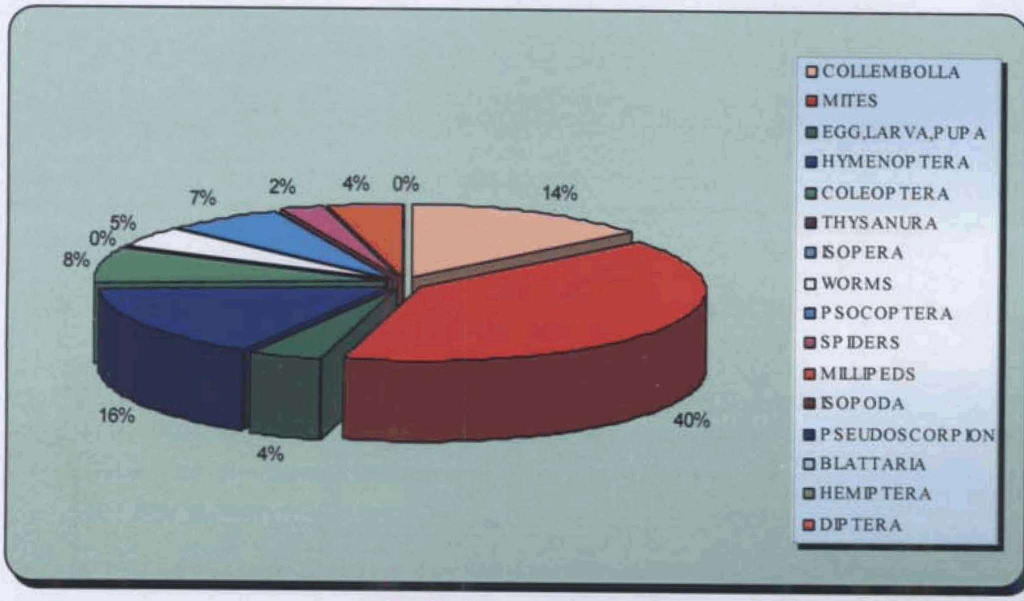


Figure. 3.7.

Seasonal variation of total number of taxonomic groups and mean population density with its standard deviation of rubber litter fauna.

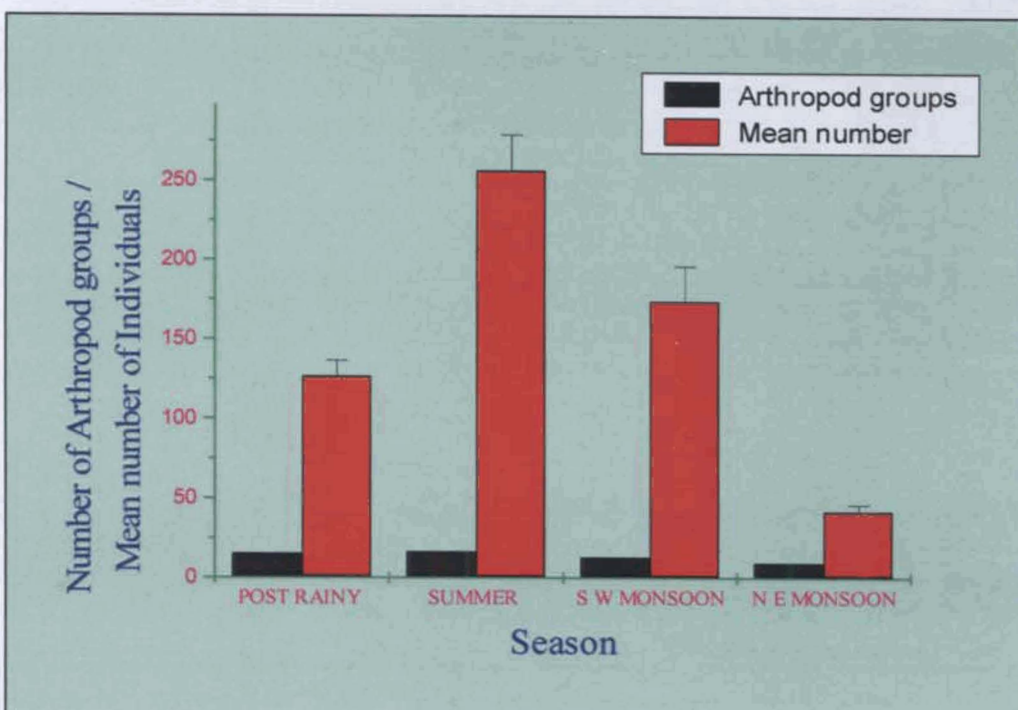


Figure 3. 8.

Monthly variation in the population density of Collembola, Mites, Hymenoptera, Colepotera, Isoptera and Larva, and pupa in rubber litter stands during December 2003 to November 2004.

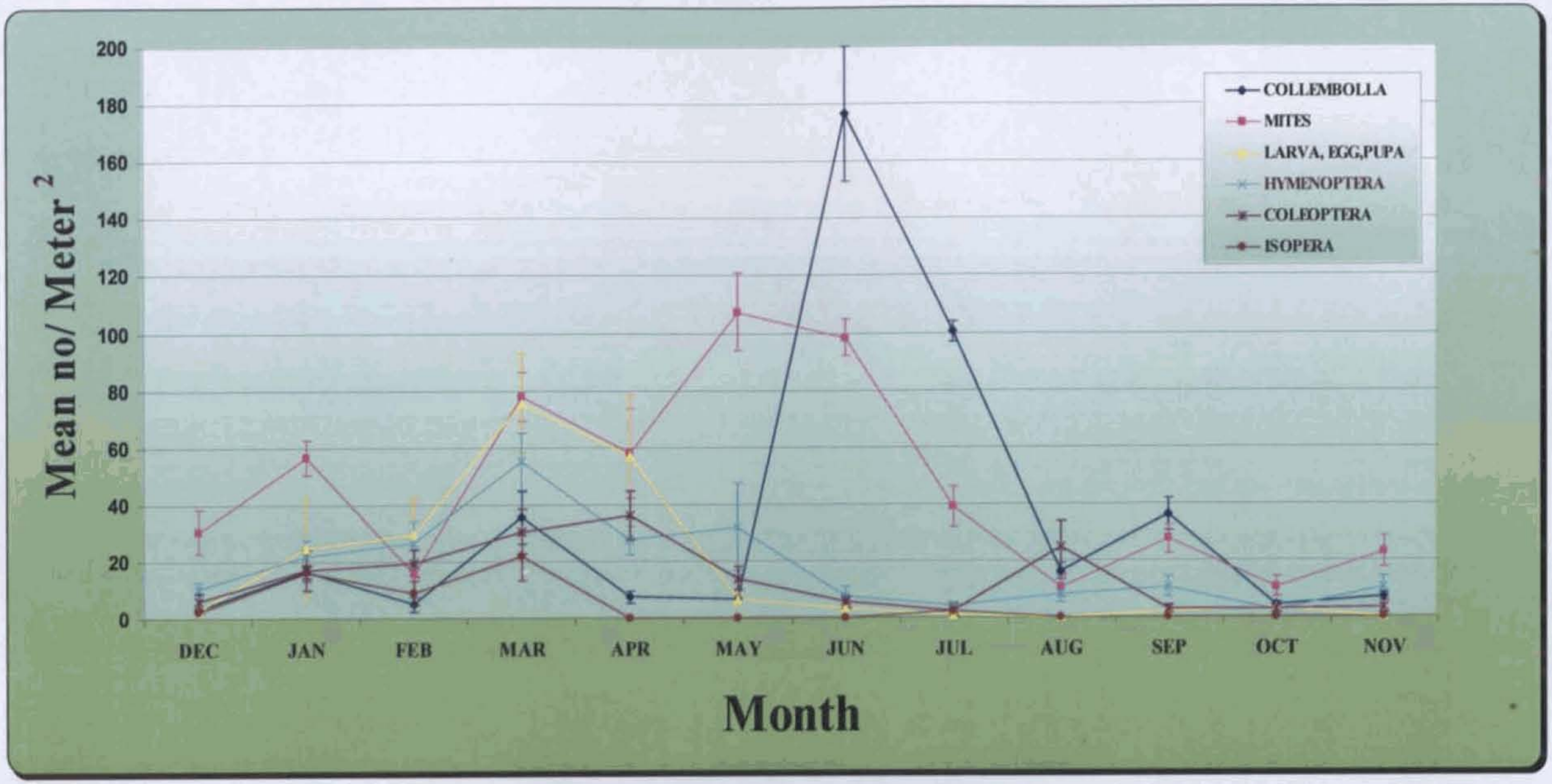


Figure 3. 9.

Monthly variation in the population density of Thysanura, Worms, Psocoptera, Spiders, Millipeds, Isopoda, Psedoscorpions, Blattaria, Hemiptera and Diptera in rubber litter stands during December 2003 to November 2004.

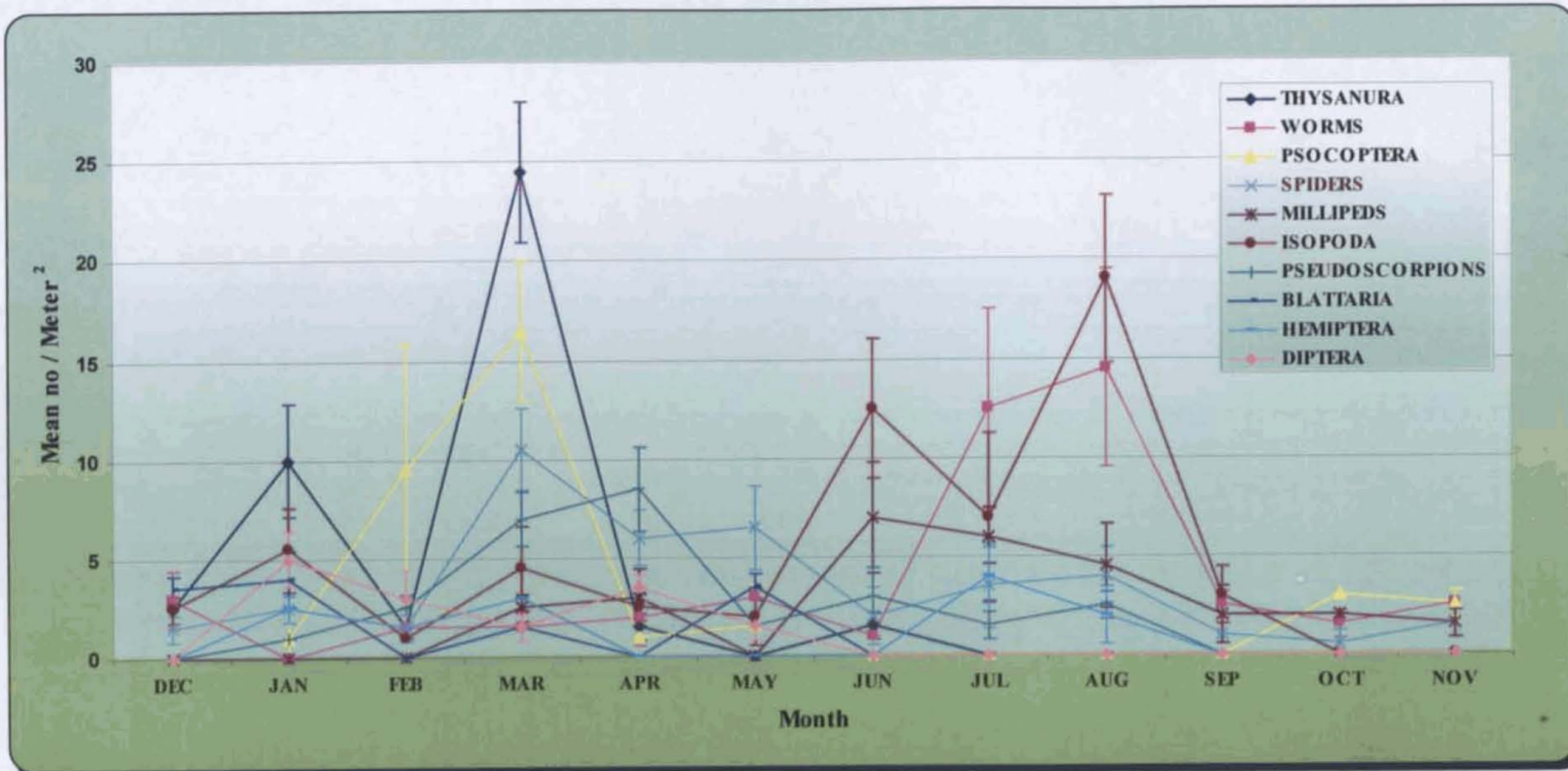


Table3. 5.

Partial correlation coefficient and its inference between different factors like Rainfall, Temperature, Relative humidity and Litter fall over the number of taxonomic groups and total number of individuals of rubber litter during the various seasons.

CATEGORY	VARIABLE	COEFFICIENT	INFERANCE
TAXONOMIC GROUPS	Rainfall	0.064	+ ve correlation
	Temperature	0.533	+ ve correlation
	Relative Humidity	- 0.138	- ve correlation
	Litter fall	0.390	+ ve correlation
TOTAL NUMBER OF INDIVIDUALS	Rainfall	0.478	+ ve correlation
	Temperature	0.477	+ ve correlation
	Relative Humidity	- 0.205	- ve correlation
	Litter fall	0.201	+ ve correlation

Table 3.6.

Indices of number of taxa(S), abundance (N), Margalef 's richness index (d), Shannon's diversity (H') and Pielou's evenness indices (J') of rubber litter arthropod fauna during the various Seasons.

SEASON	No: of Taxa (**S**)	Abundance (**N**)	Margalef's index (**d**)	Pielou's index (**j'**)	Shannon's diversity (**H'**)
POST RAINY	15	126.66	2.89	0.81	2.21
SUMMER	16	256.50	2.70	0.75	2.08
SOUTHWEST MONSOON	13	174.00	2.32	0.63	1.62
NORTHEAST MONSOON	9	41.50	2.14	0.82	1.81

Table 3.7.

Indices of number of taxa(S), abundance (N), Margalef 's 's richness index (d), Shannon's diversity (H') and Pielou's evenness indices (J') of rubber litter arthropod fauna during the various months.

MONTHS	No: of species (**S**)	Abundance (**N**)	Margalef's index (**d**)	Pielou's index (**j'**)	Shannon's diversity(**H'**)
DEC	11	69.0	2.36	0.78	1.87
JAN	14	184.0	2.49	0.81	2.15
FEB	14	127.0	2.68	0.80	2.13
MAR	16	369.5	2.53	0.80	2.22
APR	13	214.0	2.23	0.74	1.89
MAY	12	186.0	2.10	0.59	1.47
JUN	11	318.5	1.73	0.51	1.22
JUL	12	184.5	2.10	0.60	1.51
AUG	10	105.5	1.93	0.89	2.05
SEP	9	87.5	1.78	0.70	1.54
OCT	9	31.0	2.33	0.88	1.93
NOV	8	52.0	1.77	0.78	1.63

Figure 3. 10.

Shannon's diversity indices (H') and Pielou's evenness indices (J') of rubber litter arthropod fauna during the various seasons, December 2003 to November 2004.

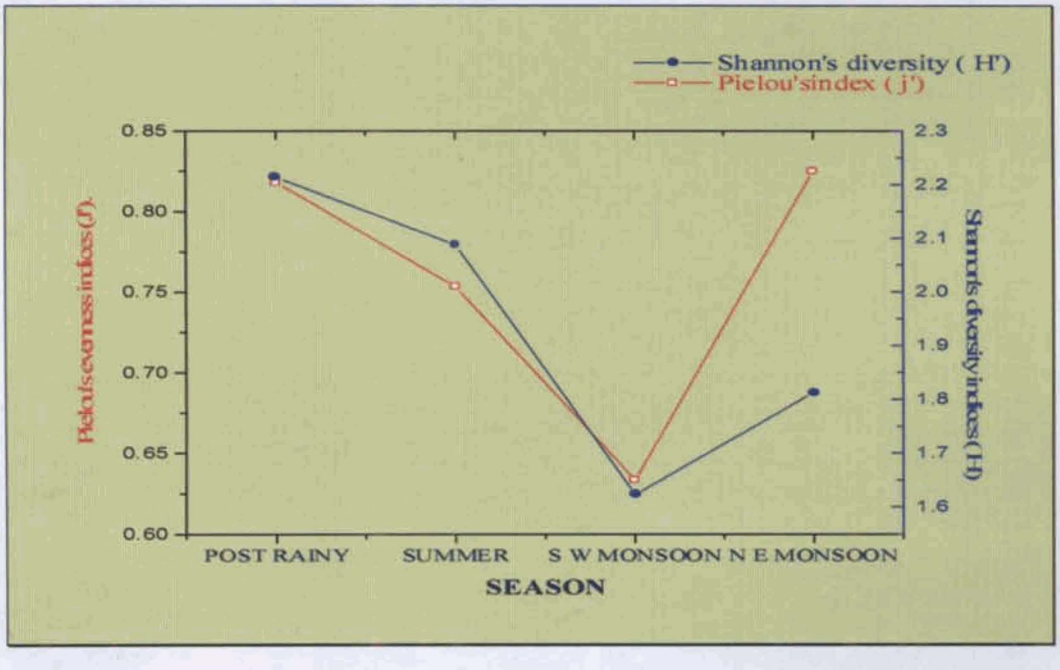


Figure 3. 11.

Shannon's diversity indices (H') and Pielou's evenness indices (J') of rubber litter arthropod fauna during the various months, December 2003 to November 2004.

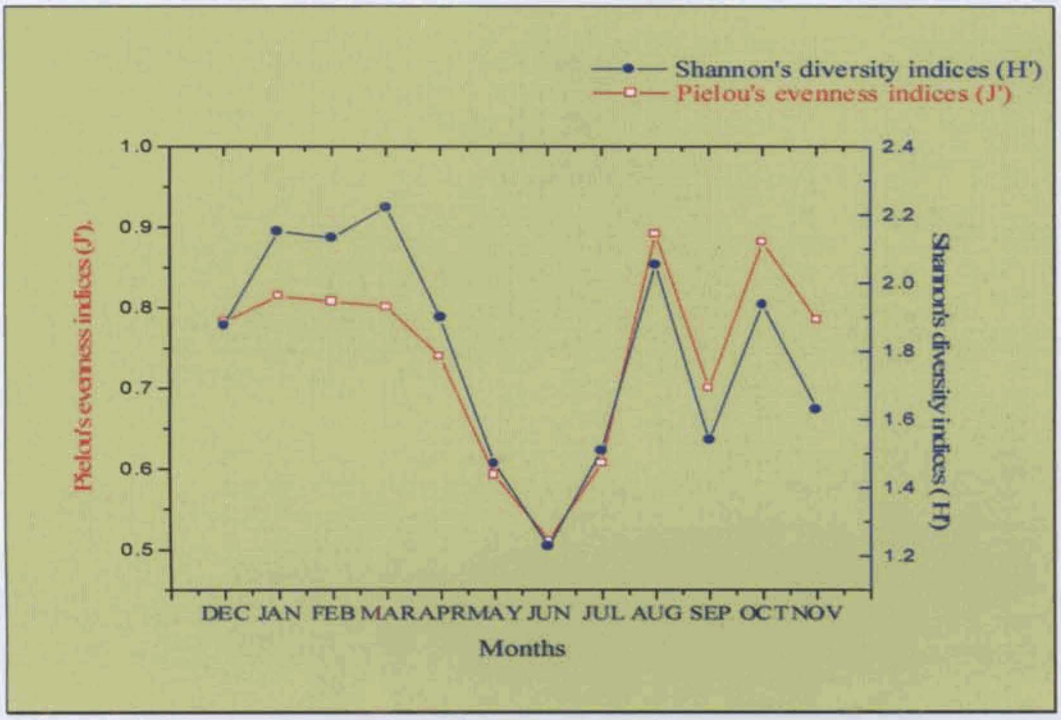


Table 3. 8.

Result of single-factor ANOVA test of Shannon's diversity index (H') of all groups and between groups at various seasons of rubber litter.

CATEGORY	df	MS	F	P-value	F crit
ALL GROUP	3	0.31	63.19	< 0.05	3.239
POST RAINY - SUMMER	1	0.04	37.72	< 0.05	5.318
SUMMER- SOUTH WEST	1	0.49	1827.42	< 0.05	5.318
SOUTH WEST - NORTH EAST	1	0.13	14.64	< 0.05	5.318
NORTHEAST - POST RAINY	1	0.28	29.97	< 0.05	5.318

Table 3. 9.

Result of single-factor ANOVA test of Margalef's richness index (d) of all groups and between groups at various seasons of rubber litter.

CATEGORY	df	MS	F	P-value	F crit
ALL GROUP	3	0.48	44.28	< 0.05	3.23
POST RAINY - SUMMER	1	0.17	12.35	< 0.05	5.31
SUMMER-SOUTH WEST	1	0.16	10.43	< 0.05	5.31
SOUTH WEST - NORTH EAST	1	0.10	13.08	< 0.05	5.31
NORTHEAST - POST RAINY	1	1.30	192.46	< 0.05	5.31

Table 3. 10.

Result of single-factor ANOVA test of Pielou's evenness indices (J') of all groups and between groups at various seasons of rubber litter.

CATEGORY	df	MS	F	P-value	F crit
ALL GROUP	3	0.04	57.64	< 0.05	3.23
POST RAINY - SUMMER	1	0.01	11.55	< 0.05	5.31
SUMMER-SOUTH WEST	1	0.03	47.37	< 0.05	5.31
SOUTH WEST - NORTH EAST	1	0.82	361.45	< 0.05	5.31
NORTHEAST - POST RAINY	1	0.006	1.07	0.33	5.31

Table 3. 11.

Similarity matrixes between various seasons of rubber arthropods litter faunal abundance, after √-transformation of the data.

	POST RAINY	SUMMER	SOUTHWEST MONSOON	NORTHEAST MONSOON
POST RAINY				
SUMMER	81.74			
SOUTHWEST MONSOON	63.55	61.79		
NORTH EAST MONSOON	57.66	49.86	58.69	

Figure 3. 12.

Dendrogram for hierarchical agglomerative clustering (using group average linking) of rubber litter arthropod fauna along the various Seasons.

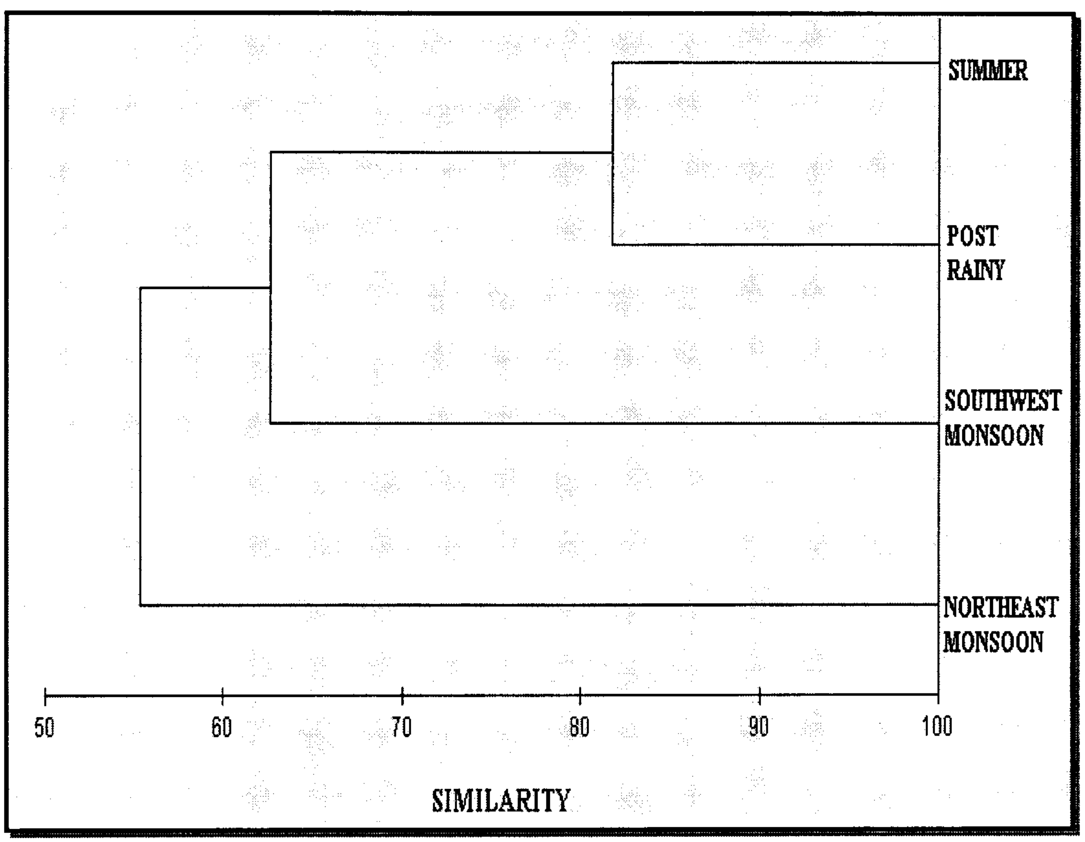


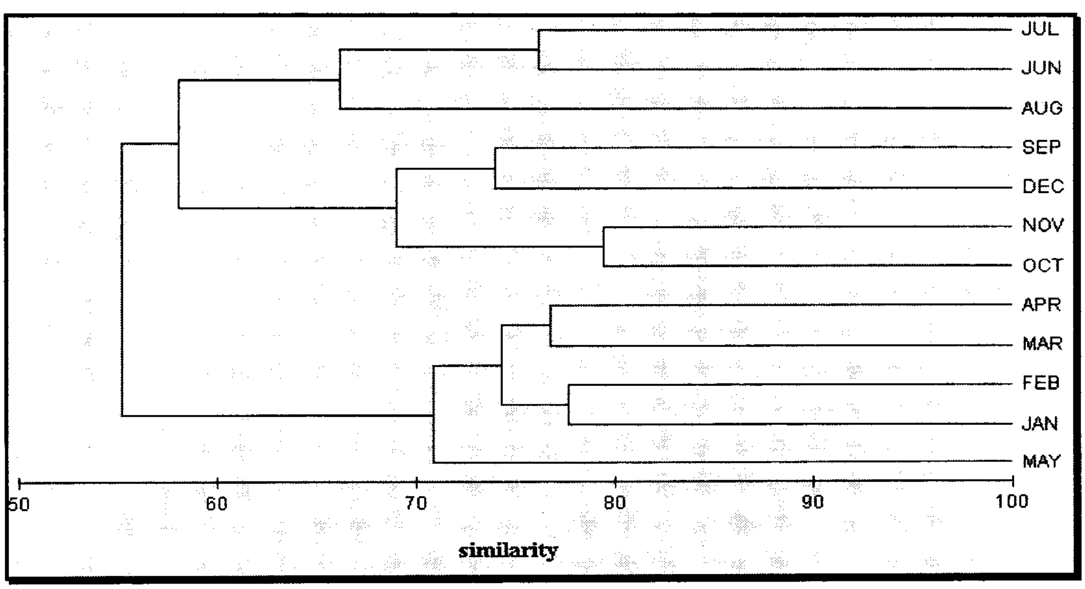
Table 3.12.

Similarity matrix between months of rubber litter arthropods faunal abundance, after √-transformation of the data.

	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
DEC											
JAN	66.01										
FEB	64.04	77.67									
MAR	51.92	77.24	70.79								
APR	59.83	73.70	75.58	76.72							
MAY	69.62	72.53	68.17	66.03	76.60						
JUN	58.21	57.04	49.01	57.69	61.12	62.92					
JUL	60.05	57.37	50.47	55.71	54.03	54.54	76.17				
AUG	54.59	55.08	56.84	52.28	59.93	56.41	61.03	71.36			
SEP	73.99	54.51	52.77	51.90	59.31	61.13	68.46	72.68	65.33		
OCT	60.43	40.93	54.56	38.70	50.51	52.98	47.67	49.59	52.35	68.93	
NOV	68.55	47.35	56.07	42.77	56.64	60.76	51.77	55.74	60.31	78.13	79.39

Figure 3. 13.

Dendrogram for hierarchical agglomerative clustering (using group average linking) of rubber litter arthropod fauna along the various Months.



DISCUSSION

The litter arthropod faunal community and its abundance associated with a fourteen year old *Hevea brasiliensis* plantation (RRII -105 clone) of north east Kerala is recorded for the first time. Existing data of litter arthropods diversity of this region is only based on the work in evergreen and dry deciduous forests and plantation forests (Pascal, 1980; Anathakrishnan and Sabu Thomas, 1993; Sabu Thomas *et al.,* 1995; Vineesh *et al.,* 2003). A comparative assessment of the litter arthropod faunal changes and various parameters like taxa richness, evenness, and diversity during different seasons, with the effect of quantity of litter fall and climatic factors like temperature, rainfall and relative humidity were also analyzed.

The analyses of fauna of rubber litter with special reference to arthropods showed a variation in the abundance and it has been significantly affected by various seasonal changes. Richness and evenness of arthropods were greatest in post rainy season, least in rainy seasons and intermediates in summer season. This result of the observation is contradictory with Ananthakrishnan's (1992) findings that in monoculture plantations like *Eucalyptus globules* density of arthropods were lowest during summer season and highest during rainy season. Even though the abundance values showed a peak during the summer season, the high diversity value during the post rainy season is due to the even distribution of the litter arthropod fauna during the period. Evenness index has a lower value in southwest monsoon and summer due to the dominance of mites, collembola and coleoptera. Diversity values varied considerably between different season, and similar months did not necessarily have similar diversities and there was an overall significant difference between diversity, evenness or richness among different seasons and months. However this study has demonstrated that a correlation exists between structural complexities of seasons. In north-east Kerala, the major part of rain is precipitated in the south west monsoon season. The richness and diversity of litter arthropods varying prior to and after the rainy season in *Tectona grandis* and *Eucalyptus globules* and with the litter habitats (Sabu Thomas, 1995).

According to Harding (1974) collembolans and mites usually accounted for more than eighty percentage of total arthropod number. The parallel pattern was observed in this study. Collembolan shows unimodel peak abundance during the southwest monsoon season. This might be related to the preference of collembolans towards wetness (Swift *et al.,* 1979). Ananthakrishnan *et al.,* (1992) reported that its population in rubber plantation was high in comparison to the studies in the litter at deciduous forest in south India. Choudhuri and Banerjee, (1975) experienced that all types of collembola have a unimodality in seasonal abundance pattern. Collembola attain peak population in periods of high moisture in litter during rainfall (Reddy *et al.,* 1989; Lensing, 2005). The type of soil, the composition of microflora, soil moisture and type of litter influences the abundance of collembola (Hale, 1965; 1967). Working on the ecology of collembolan in *Shorea robusta* litter Hazra (1978 b) showed that, collembolan population was maximum in monsoon months and minimal in summer.

Bhattacharjee and Chakraborti, (1995); Jacob, (2000), have reported the association of oribated mites with *Heave* soil. The numbers of mites were gradually increasing after summer showers in May. Ananthakrishnan (1994) reported that mites have single peak abundance in early rainy season in natural forest environment. But it varies with sites and places (Choudhuri and Banerjee, 1975). The diversity in the collembolan and mite population in the litter habitats is well attributed to the richness in terms of nature of the litter contributing plant species and seasonal variations of the habitats.

Formicids reached maximum density in summer season and minimum in northeast monsoon period. Similar observations were done by Reddy *et al.,* (1990); Olson, (1994) and Bruhl, (1998). Abundance of Coleoptera during the summer and southwest monsoon period were noticed. Abundance of Tenibrionides especially *Luprops* species pushes the graph to its upper values during the summer season. The level of activity of termites appears to be highest in the summer season environment when large quantity of dry litter was available. Low abundance of termites in the study can be compared to the adjacent deciduous sites, might be due to their better adaptability to environment with poor quality of organic resources and low quality of water (Decaens *et al.,* 1994). Thysanura reached maximum density during summer season. Psocoptera increased during pre-monsoon period. The parallel rise in the arthropod predator groups viz, pseudoscorpions and spiders suggest the maintenance of a significant diversity status in rubber plantations, comparable to natural forests. Pseudoscorpions and spiders were known for their preference towards slow moving nymph of termites, soft bodied nymphs and larvae of various groups. Others like blattaria, millipeds, hemiptera and diptera are also occur in the rubber litter.

Other factor may also influence the arthropod community structure, such as climate. For example, arthropod richness and abundance were influenced by temperature, rainfall and relative humidity (Swift *et al.,* 1979; Reddy *et al.,* 1990; Olson, 1994; Anathakrishnan, 1994; Decaens *et al.,* 1994 and Bruhl, 1998). Both richness and abundance showed more positive correlation than temperature, whereas relative humidity showed negative correlation. The effects of temperature and relative humidity are non – significant, possibly because temperature and relative humidity showed only miner fluctuations where as both timing and amount of precipitation are highly variable. Alternatively ectotherms like arthropods necessarily respond strongly to temperature (Southwood, 1966). But Leaving and Windsor (1985) reported that soil moisture and rainfall were the strongest correlation with densities besides organic matter.

According to the cluster analysis, the result at the level of taxonomic groups closely corresponded to the sampling periods. This indicates that similar taxa present at specific times of the year. Thus, at the scale measured, seasonal variation was the more important determinant than the litter habitat types alone. This provides valuable insight into sampling protocols and certain species may dominate at different times of the year. Therefore, to get a true representative of the taxa present sampling should be conducted in all seasons. In addition, certain morphospecies mature at different times of the year and thus by conducting sampling throughout the year, adults can be collected. The adults are taxonomically important, as they are often essential for species level determinations.

This study illustrates that rubber plantation forests are very important for the preservation of invertebrates especially litter arthropod communities. The sampling technique might have resulted in under representation of many large, active species, which were able to take evasive action during the approach. Again this study might have missed many insect larva and other soft bodied ones and sources of error probably introduce a conservative bias in the richness and abundance counts. Still, it provides a glimpse of the arthropod faunal diversity enclosed with in a fourteen year old rubber plantation. So to maintain and manage this high diversity of the litter arthropods, further research works should be encouraged in this biome.

Chapter 4

Rubber leaf litter decomposition

RUBBER LEAF LITTER DECOMPOSITION

ABSTRACT

Lleaf litter decomposition was analysed in a fourteen-year-old rubber plantation (*Hevea brasiliensis* Mull.Arg) of clone RRII-105 for a period of one year (2003 to 2004). Result show that weight of *Hevea brasiliensis* leaf litter remaining in the litter bags decreased linearly with time. 94.5 % of leaf litter was decomposed with in the period of nine months. More than 65% of decomposition took place during the rainy season. Climatic factors govern the overall rates of decomposition. Rain fall and relative humidity show significant positive relation with litter decomposition rate. The decay constant (k) of rubber leaf litter is 0.012and t_{50}, t_{99} are found to be 56.4 days and 375.03 days respectively.

Key words: Leaf litter decomposition, *Hevea brasiliensis*, Decay constant (k),

INTRODUCTION.

Litter decomposition is one of the primary mechanism by which the ecosystem's nutrient pool is maintained (Setala and Huhata, 1991; Attiwill and Adams, 1993). The litter on the forest floor acts as an input-out put system for nutrients (Das and Ramakrishnan, 1985) and the rates at which litter falls and subsequent decay regulate energy flow, primary productivity and nutrient cycling in ecosystems (Karnas, 1970; Waring and Schlesinger, 1985). Decomposition processes include leaching, mechanical breakdown and digestion by saprophagous soil animals, and enzymatic degradation by saprophagous soil animals, and enzymatic degradation of chemical compounds by saprotrophic biota (Wood, 1974; Facelli and Pickett, 1991). The decomposition of litter and the enrichment of soil with nutrients necessary for plant growth are biological process operating with in the constraints imposed by a range of complex and interacting physical factors (Aber and Melillo, 1980; Berg and Staff 1980). So in recent years, the important of litter decomposition and related processes in ecosystem became increasingly recognized (Pastor and Cohen, 1997; Wardle *et al.,* 1997; Bardgett *et.al,* 1998; Bardgett and Shine, 1999; Nilsson *et al.,* 1999; Van der Putten *et al.,* 2001; Martin Schadler, M. *et.al,* 2003).

Decomposition is governed by an interplay of climate, litter quality and soil biota (Meetenmeyer, V., 1984; Tian *et.al,* 1997; Wachendorf *et.al,* 1997; Wardle, *et al.,* 1997; Heneghan, 1999; Gonzalez and Seastedt, 2001). According to Berg *et al.,* (1993), Couteaux *et al.,* (1995); Caddish and Giller, (1997), the physicochemical environment, litter quality and the composition of decomposer community are the three main factors controlling the rate of litter decomposition. Rate at which nutrients are released from litter is generally governed by the rate of decomposition (Stohlgren, 1988 b). According to Gosz, *et. al.* (1973) and Edmonds, (1984) the rate of litter decomposition and nutrient release are often site specific. However, environmental conditions such as temperature and moisture supply can a vital role in deciding decay rates (Sing and Guptha, 1977; Pastor and Post, 1986) According to Williams and Gray (1974) the rate of decomposition depends upon the climatic factor, soil organisms and chemical composition of the litter. Lockaby and Walbridge (1998) suggested that the timing of litter input to the soil environment may have a substantial influence on decomposition processes. But Schadler, (2004), Wardle, (2002) found that any effect on decomposition rate would be attributed to a changed activity of the decomposer community.

Although there are studies on the leaf litter decomposition of forest ecosystem such information about rubber plantation is extremely scarce. For a sustainable management of an ecosystem it is important to understand changes in key ecosystem process like decomposition that encountered when converting natural forests into plantation forests (Attignon *et al.*, 2004). The number of published reports concerning the litter decomposition coefficient (k) has been very few. There fore, a study was undertaken to find out decomposition rate and decomposition pattern in a fourteen-year-old *Hevea brasiliensis* plantation.

MATERIALS AND METHODS

1. Study area.

The study was conducted from December 2003 to November 2004 at Vettiozhijathottam (V.O.T.) situated 48 KM North east of Calicut city. (Latitude 11° 25'N and Longitude 75° 77'E) (Plate: 1). The 58 hectare plot planted in 1990 (Fourteen year old) had a density of 320 mature rubber tree per hectare of RRII – 105 clone, under tapping. This plantation is free from regular practice of spraying of copper sulphate ($CuSo_4$), which is s practical measure to prevent various fungal diseases.

2. Season and Climate of study area.

The region has humid climate, with an aggressive summer and plentiful seasonal rainfall. January and February are normally dry months. The hot season from March to May, is followed by the southwest monsoon from June to September. The northeast monsoon is from October to November. This area receives an annual rain fall of 3614.50 mm (Appendix: I) with minimum and maximum air temperature of 19.71° C (± 1.35° C) and 34. 98° C (± 0. 70° C) respectively (Appendix: II). The mean monthly humidity varies from 47.10% (± 6.21%) in dry season to 94.47 % (± 0. 68%) in wet seasons (Appendix: III). Westerly and north westerly winds prevails during December to March. The maximum wind speed is between 10 to 15 Km per hour. The study area receives adequate sunshine hours in all months except during southwest monsoon period. Data collected from daily records of Centre for Water Resource Development and Management (CWRDM), Kottamparamba, Kozhikode.

3. Litter decomposition.

Leaf litter succession studies were conducted by standard litter bag technique (Bocock, 1964). Fresh leaf litter was collected in the nylon nets immediately after fall at the end of December 2003. In the laboratory, leaf litter was air dried in sunlight to a constant weight and stored in small mesh sized nylon bags to minimize microbial degradation (Zimmer, M. and Topp, 1997; 2000). Then accurately weighed 20 gram dry leaf litter were placed in 20 X 20 cm nylon bags with a mesh size of 0.5 mm, and closed the bags by stitching over the open end. This mesh size allows the free movement of most of the soil fauna into the litter bag, facilitating decomposition (Edward and Heath, 1963). Each litter bags were tagged with a label made up of plastic coated paper, then the bags were placed randomly on the ground of V.O.T. rubber plantation and were anchored with pin flags to prevent them being washed away during flooding and a thin layer of soil was spread to get natural conditions, during the first week of January 2004, and allowed to decomposed under natural conditions. A total of ninety-six litter bags were placed. Six litter bags were recovered at the beginning of each month, after removing the litter bags, carefully transferred to 45 X 30 cm polythene bags containing clearly displaced label having information of the site, location, collection date and collection time. Litter particles were washed with running water in a 200μ mesh size to remove all the adhering extraneous matter and dried in hot air oven at 75°C and the percentage loss of litter (weight) calculated.

4. Decay rate coefficient.

The model for constant potential weight loss (Olson, 1963) is represented by the equation

$X/X_0=e^{-kt}$ ....[1]

Where X is weight remaining at time t,

X_0 is the original mass, is the base of the natural logarithm,

k is the decay rate coefficient and t is the time.

5. Time to obtain half life (t_{50}) and 99 % decay (t_{99}).

By rearranging and integrating the equation [1],

$\ln(X) = -kt + C$ ....[2]

C = the integration constant,

When t = 0 and $X = X_0$ (Initial litter mass)

$C = \ln(X_0)$

So $\ln(X_t) = -kt + \ln(X_0)$ ....[3]

Where X_0 = Initial weight of litter,

And X_t = weight of litter remaining at time t.

Rearranging: $\ln({}^{Xt}/{}_{X0}) = -kt$ ....[4]

For half life, we have 0.5 parts left (X_t) of the original 1.00 (X_0) mass

So $\ln({}^{0.5}/{}_{1}) = -kt$ ....[5]

ie, $t_{50} = {}^{0.693}/{}_{k}$ ....[6]

For 99% decay, we have 0.01 parts left (X_t) of the original 1.00 (X_0) mass

So $\ln({}^{0.01}/{}_{1}) = -kt$ ....[7]

ie, $t_{99} = {}^{4.605}/{}_{k}$ ....[8]

6. Data analysis

a). Partial Correlation analysis of litter decomposition.

Correlation between different climatic factors like Temperature, Rainfall and Relative humidity on rate of litter decomposition has been analyzed by using partial correlation technique. (Murray R. et.al.,, 2000) by using the formula,

$$r_{12.34} = \frac{r_{12..3}-[r_{14.3}\, r_{24..3}]}{\sqrt{1-r^2_{14..3}}\,\sqrt{1-r^2_{24..3}}}$$

$$r_{13.24} = \frac{r_{13..2}-[r_{14.2}\, r_{34..2}]}{\sqrt{1-r^2_{14..2}}\,\sqrt{1-r^2_{34.2}}}$$

$$r_{14.23} = \frac{r_{14..2}-[r_{13.2}\, r_{43..2}]}{\sqrt{1-r^2_{13..2}}\,\sqrt{1-r^2_{43.2}}}$$

1 =Weight of Litter

2 = Temperature

3 = Rainfall

4 = Relative Humidity.

Partial correlation has been analyzed by using the software SPSS (v.11).

b). Regression analysis

Regression analysis between different climatic factors like temperature, rainfall, relative humidity and leaf litter fall on the decomposition rate has been analyzed by using linear multivariate regression analysis (Murry, R. et.al., 2000).

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \epsilon_i$$

Y_i = Decomposition constant (k)

X_{i1} = Rain fall

X_{i2} = Relative humidity

X_{i3} = Temperature

For all analysis, significance was determined at $P < 0.05$.

Plate: 8

A

B

A and B - Litter bags in the RRII - 105 rubber plantation at VOT.

RESULTS.

Results of the study reveal that the mass remaining in the litterbags decreased linearly with time (Fig: 4.2). The dry weight losses of the litterbags over the period of 9 months (January to September) are shown in the table - 4.1. The loss of weight was minimal in the first three months (January to March) for leaf litter wherein average 4.4 percentage of weight loss was observed. The rate of decomposition was faster during the rainy season - May to July. From Fig-3 it is clear that around 68 percentage of the total litter decomposition took place during this period. Only 1.05gm ± 0.373gm (5.5%) of litter remained after the periods of nine-month decomposition (Table: 4.1). Decomposition rate (k) was varying in different months. The highest rate was observed in the June (0.02945) and lowest in the March (0.00133) (Table 4.1). Decomposition rate increases as rainfall (Fig: 4.4) and relative humidity (Fig: 4.5) increases. But temperature had a negative effect on the rate of rubber leaf litter decomposition (Fig: 4.6). Partial correlation analysis between decomposition and climatic factors, rainfall, relative humidity and temperature (Table 4.3) showed that the positive correlation with rainfall (+ 0.1190) and relative humidity (+ 0.1384). Where as temperature had a negative correlation (- 0.4398). Leaf litter decomposition shows positive significant variation with rainfall (R^2 = 0.750, F = 21.025, P = 0.003) and relative humidity (R^2 = 0.745, F = 20.460, P = 0.003) but negative insignificant variation with temperature (R^2 = 0.248, F = 2.309, P = 0.172) (Table 4.4.). When the exponential decay model (Olsen, 1963) was applied, the decay constant of the rubber leaf litter (k) is 0.013. It is apparent that the half-life period (t_{50}) and time for 99 % decay (t_{99}) of rubber leaf litter were 56.438 days and 375.033 days respectively (Table 4.2.).

Table: 4.1

Monthly variation of weight of litter present in the bags, mass loss of litter, percentage of mass loss from the bags and decomposition rate constant (k), calculated by using the formula $X/X_0=e^{-kt}$ (Olson 1963) during litter bag studies in RRII – 105 rubber plantation at V.O.T.

Month	Mean Value and Standard Deviation (gm/ litter bag)	Weight of mass loss (gm/ litter bag)	Percentage of mass loss from the litter bag	Decomposition rate constant (k)
JANUARY	20.00	0.00	0 %	0.000
FEBRUARY	19.20 ± 0.20	0.80	4 %	0.0014
MARCH	18.45 ± 0.65	0.75	3.75 %	0.0013
APRIL	15.80 ± 0.32	2.65	13.25 %	0.0052
MAY	11.25 ± 0.22	4.55	22.75 %	0.0113
JUNE	4.65 ± 0.32	6.60	33 %	0.0295
JULY	2.20 ± 0.19	2.45	12.25 %	0.0249
AUGUST	1.45 ± 0.23	0.75	3.75 %	0.0139
SEPTEMBER	1.05 ± 0.37	0.40	2 %	0.0108

Table: 4.2.

Decomposition constant, half life (t50) and expected time for 99% decay of rubber leaf litter during litter bag studies in RRII – 105 rubber plantations at V.O.T.

Decay constant	Half Life ((t_{50})	Time for 99 % decay (t_{99})
0.013 gm / day.	56.44Days	375.03 Days

Table 4. 3.

Partial Correlation analysis and the relationship between physical factors like Rainfall, Temperature and Relative humidity and decomposition rate constant (k) of rubber litter during successive periods of decomposition.

CATEGORY	VARIABLE	COEFFICIENT	INFERANCE
Decomposition rate constant (k)	Rainfall	0.1190	+ ve correlation
	Temperature	- 0.4398	- ve correlation
	Relative Humidity	0.1384	+ ve correlation

Table 4. 4.

Regression analysis and the relationship between Rainfall, Temperature and Relative humidity and decomposition rate constant (k) of rubber litter during the successive phases of decomposition.

Variable	df	COEFFICIENT	Std.Error	R^2	F	*P*
Rain fall	7	0.0007	0.000	0.750	21.025	< 0.05
Temperature	7	- 0.0003	0.002	0.248	2.309	> 0.05
Relative Humidity	7	0.0001	0.000	0.745	20.460	< 0.05

Figure 4.1.

Mass loss of rubber leaf litter and its standard deviation during the successive phases of decomposition.

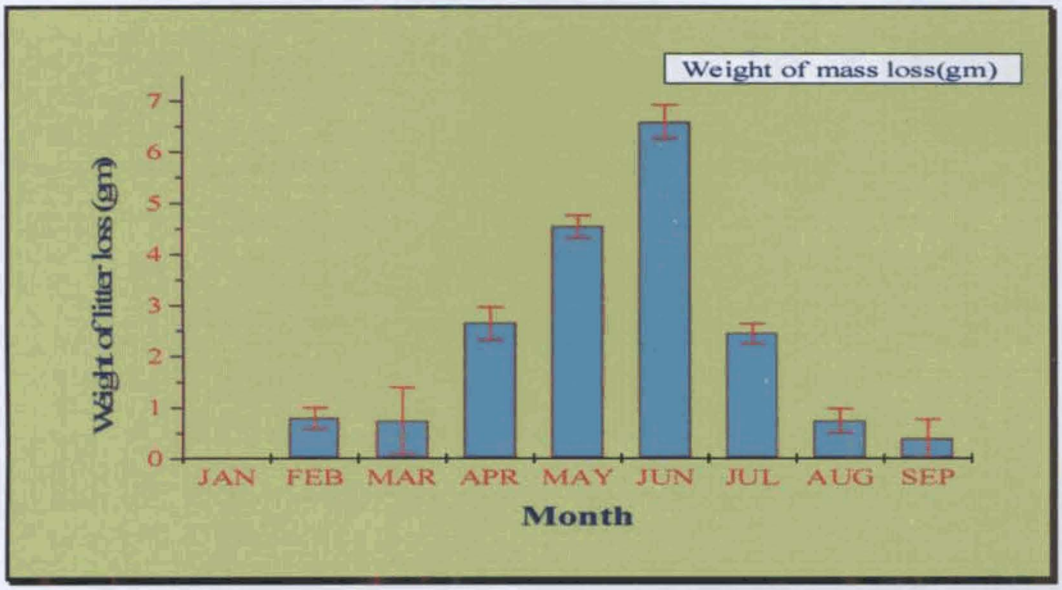


Figure 4.2.

Variation in the dry weight of litter remaining in litter bags during the successive phases of decomposition. Red line represents the Linear Fit model for decomposition by mean on linearized scales. ($r = -0.96655$) ($P = < 0.05$).

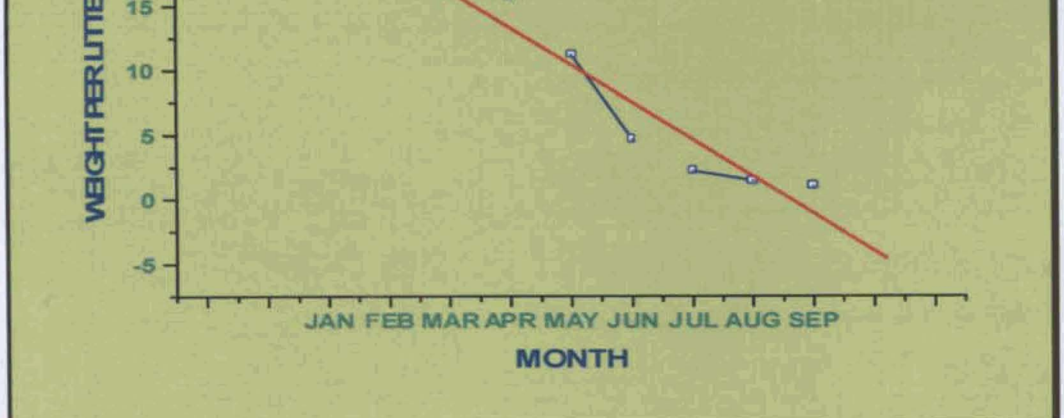


Figure 4.3.

Percentage of litter mass remaining in the litter bags during the various months of decomposition.

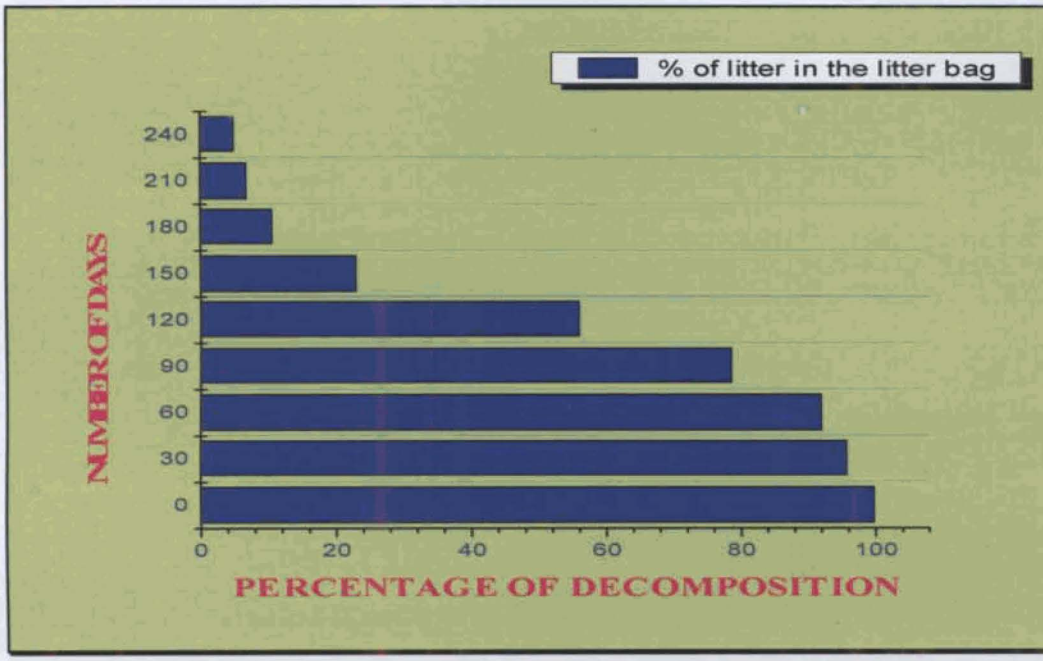


Figure 4.4.

Relationship between rate of litter decomposition (k) and rainfall (in mm)

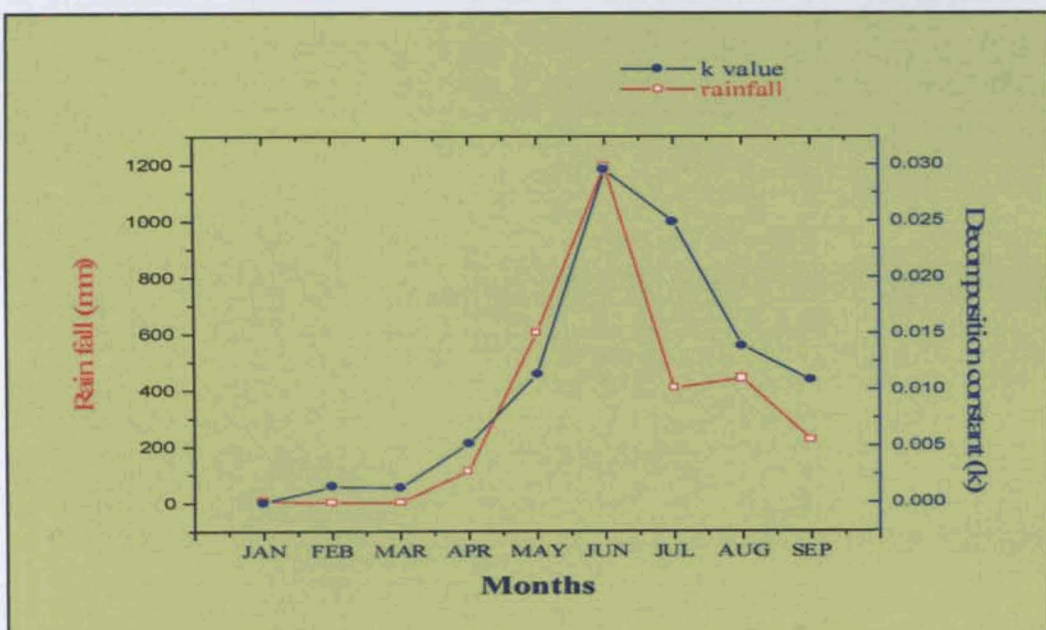


Figure 4. 5.

Relationship between rate of litter decomposition (k) and Relative humidity (in %)

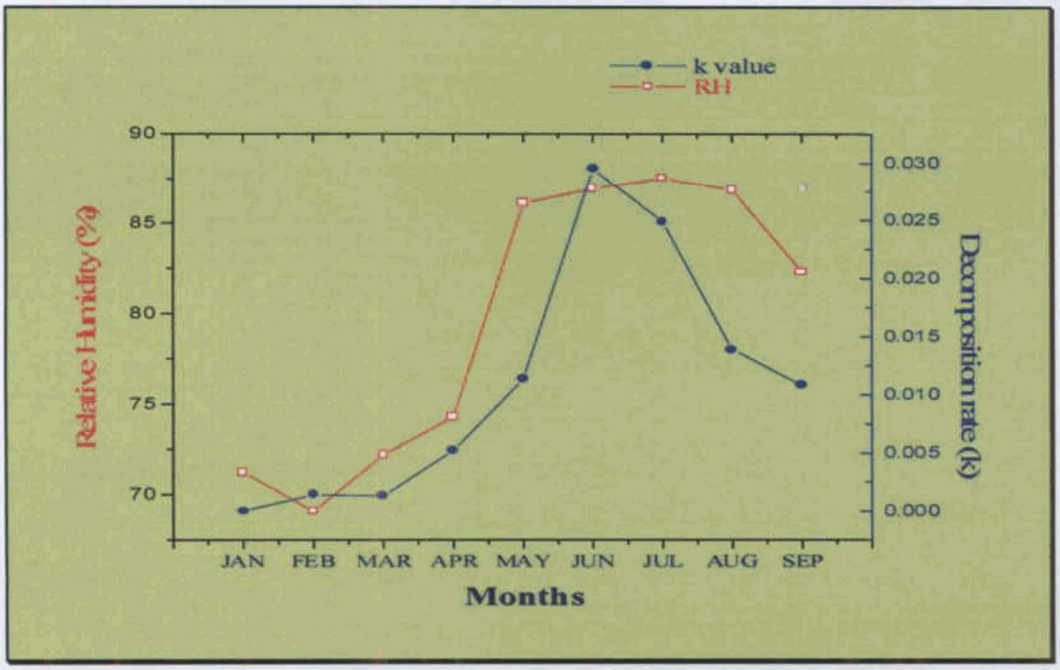
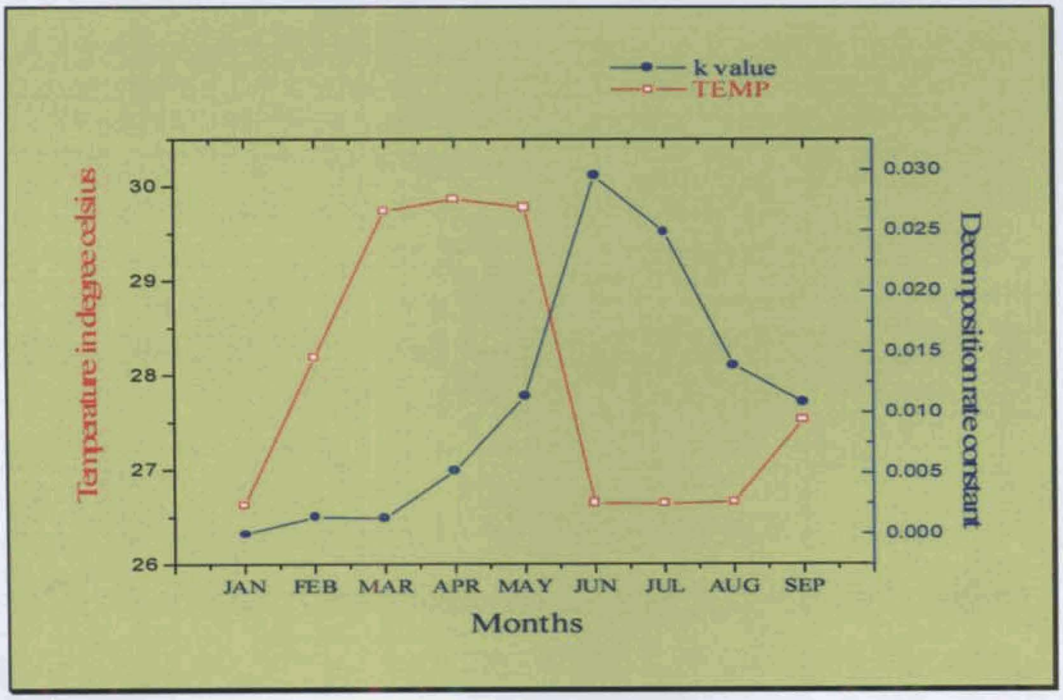


Figure 4. 6.

Relationship between rate of litter decomposition (k) and Temperature (in ^{0}.C)



DISCUSSION

The pattern and the effect of climatic factors on the decomposition of rubber leaf litter using litter bags were studied. Weight of *Hevea brasiliensis* leaf litter remaining in the litter bags decreased linearly with time. According to Swift *et al.,* (1979), during decomposition, change of mass of resource essentially results in a change of state of resource under the influence of both abiotic and biotic factors. Leaf litter type and quality are the over riding determinant for decomposition with in a given environment and its breakdown caused mainly by the joint action of physical factors, causing fragmentation, and the activity of micro organisms (Kshattriya *et al.,* 1992; Ananthakrishnan, 1996; Caddish and Giller, 1997; Hieber *et al.,* 2002). Changes in temperature and moisture availability have been related to decomposition rates. Litter decomposition is by and large a substrate depended property, however, environmental conditions underwhich decomposition occurs, such as temperature and moisture supply can play a vital role in deciding decay rates (Sing and Gupta, 1977, Paster and Post, 1986; Luizao and Schubart, 1987). Rubber leaf litter decomposition rate shows positive correlation with rain fall and relative humidity. Decay rate decreased with increasing temperature. Similar pattern of litter decomposition in tropical condition has been reported by Singh *et al.,* (1979; 1980) and Pandey, *et al.,* (1982). High rate of decomposition during rainy season may be due to leeching (Anderson, 1973; Gosz, *et al.,* 1973; Moore *et al.,* 1999). Climate governs the overall rates of decomposition at a geographical scale (Meentemeyer 1978, Berg, B. *et al.,* 2000). Changes in the temperature and moisture availability have been related to decomposition rates (Woodwell and Dykeman.1966; Agbim, 1987). Tanner (1981); Coleman *et al.*,(1983) and Vogt *et al.*,(1986) observed that warmer temperature and high precipitation results in higher rate of decomposition, faster litter turn over, and less organic matter accumulation. So the rubber leaf litter decomposition rate depends, beside the quality of the material, on the favourability of temperature and moisture condition. Therefore, the climatic changes would change the rate.

The decay constant of the rubber leaf litter (k) over the periods of 9 months was found to be 0.013 gms per day. Das and Ramakrishnan (1985) reported the decay constant of pine as 0.307 for 12 months. Melillo *et al.*, (1982) reported a annul decay constant of 0.08 to 0.47 for hardwood plant species. Number of published reports concerning rubber leaf litter decomposition and decay constant has been very few. Contrary to the published reports, the decay constant observed in this study was profoundly lower. This implies that rubber leaf litter exhibit medium level decay rate. The half-life period (t_{50}) and time for 99 % decay (t_{99}) of rubber leaf litter were 56.438 days and 375.0326 days respectively. Luizao and Schubart (1987) calculated the time for 95% decay of broad leaved litters as 1.5 to 60 years depending on the season and area and according to Stohlgren (1988 a) the time required for 95% decay ranged from 11 to 27 years in Sierran forest types. Pastor and Post (1986) postulated that disturbances can alter the litter decay rates. Less disturbed sites exhibited a faster decomposition rate than the more disturbed areas, probably because of the favourable changes in the microclimatic factors and decomposer assemblage.

75A

Chapter 5

Clonal variations of leaf litter fall in *Hevea*

CLONAL VARIATIONS OF LEAF LITTER FALL IN *HEVEA*

ABSTRCAT

Clonal variation in leaf litter fall was analysed in a twelve-year-old rubber plantation (*Hevea brasiliensis* Mull. Arg) of clones RRII-105, PB - 260, PB-217 for a period of one year (December 2003 to November 2004). Total Magnitude of leaf litter production varies from 4996.30 Kg ha $^{-2}$ yr $^{-1}$ to 6400.90 Kg ha $^{-2}$ yr $^{-1}$. However there is no significant variation ($P< 0.005$) in entire annual litter quantity between clones. Total leaf litter fall in three clones followed a uni-model distribution pattern, with a distinct peak, followed by a plateau. For RRII–105 and PB-217, December to March season is highly significant ($P< 0.05$) for leaf litter fall with the crest of January. Whereas in PB -260 leaf fall was during January to April with peak fall in February.

Key words: Leaf litter production, clonal variations, *Hevea brasiliensis.*

INRODUCTION

Litter production refers to the fall of organic debris from above ground plant parts onto the plantation floor. Being deciduous in nature, the *Hevea brasiliensis* Mull. Arg shed almost all the leaves annually during the drier weather by a process termed as 'wintering' (Potty et al., 1980). Leaf fall in rubber plantation is normally followed by the terminal buds bursting and by the expansion of new leaves within a further week (Abraham at.al., 1997). The leaves that shed get accumulated on the plantation floor, which accounts for the major pathway of biomass recycling in rubber plantation. Litter plays a major role in the transfer of energy and nutrient in the ecosystem and litter fall data have been used to predict the productivity of the ecosystem (Toky and Singh, 1983). Soong et.al. (1980) reported that in rubber plantation leaf litter accumulates as a result of periodic leaf fall providing a form of surface cover in addition to leguminous cover crops. The pattern of litter fall in monoculture plantations tends to vary with climate (Singh et al., 1985) and exposure. The importance of understanding litter dynamics lies not only in the key role it plays in nutrient recycling of the ecosystem (Anderson and Swift, 1983) but also because litter cover reduces splash erosion and surface runoff (Wiersum,1983).

All the trees of a clone posses identical genetic constitution, which is responsible for the uniformity existing among them. From the Original 'Wickham gene pool' with a productivity range of 200-300 kg/ha/yr, breeders have developed clones with a production potential of above 3000kg/ha/yr. At present, a good number of yielding clones are available for commercial planting. Many authors reported that species composition, clonal variation, density, basal area, age structure and season are the factors that strongly influence litter fall dynamics in an ecosystem (Stohlgren, 1988 a; Reiners and Lang, 1987; Luizao and Schubart, 1987). Litter production by an individual tree species is depending on the dominance in the stand, according to Kotwal and Mall (1977). There are marked differences between clones in wintering behavior. A few tend to shed and replace part of their foliage simultaneously over a relatively long period and may thus show no very obvious sign of wintering, while at the other extreme some become completely leafless for a time. The majority are intermediate between these extremes (Webster and Baulkwill, 1989).

Especially with recent emphasis placed upon a central role of litter fall in nutrient recycling, many investigations of litter fall have been carried out in natural forests of indigenous and extrinsic tree species, in monoculture stands as well as in mixed stands (Haase, R., 1999: Jamaludheen, et al., 1999; Kavvadias, et al., 2001). However, there are only very little information on time of rubber leaf litter fall and comparison of litter fall between different rubber clones. Therefore, the primary aims of this study were:

1. Monthly – time series analysis of litter fall in the major rubber clones.
2. Quantitative analysis of leaf litter fall variation among clones.

MATERIALS AND METHODS

1. Study site

The study was conducted from January 2004 to December 2004 at Calicut estate, Koodaranji, 52 kilometers south east of Calicut city (Latitude11^{0}25'N and Longitude 75^{0}77'E) (Plate: 1). The 94 hectare plot planted in 1992 (Thirteen year old) had a density of 320 mature rubber tree per hectare of three clones of rubber plantation,RRII-105, PB -260, and PB – 217, under tapping. This plantation is free from regular practice of spraying of copper sulphate ($CuSo_4$), which is practical measure to prevent various fungal diseases.

2. Season and Climate of study area.

The region has humid climate, with an aggressive summer and plentiful seasonal rainfall. January and February are normally dry months. The hot season from March to May, is followed by the southwest monsoon from June to September. The northeast monsoon is from October to November. This area receives an annual rain fall of 3614.50 mm (Appendix - I) with minimum and maximum air temperature of 19.71^o C (± 1.35^o C) and 34. 98^o C (± 0. 70^o C) respectively (Appendix - II). The mean monthly humidity varies from 47.10% (± 6.21%) in dry season to 94.47 % (± 0. 68%) in wet seasons (Appendix - III). Westerly and north westerly winds prevails during December to March. The maximum wind speed is between 10 to 15 Km per hour. The study area receives adequate sunshine hours in all months except during southwest monsoon period. Data collected from authentic daily records of Center for Water Resource Development and Management (CWRDM), Kottamparamba, Calicut.

3. Rubber clone selection.

A group of plants produced by vegetative propagation from a single tree is termed as a clone. All the trees of a clone possess identical genetic constitution, which is responsible for the uniformity existing among them. Based on the origin, clones are broadly classified in to two categories namely primary clones and hybrid clones, the latter being further subdivide into secondary and tertiary clones. Clones developed from mother trees of unknown parentage are called primary clones. Secondary clones are developed by the vegetative multiplication of hybrid trees which are evolved by crossing two different primary clones. (Saraswathyamma and Marattukalam, 1996). Tertiary clones are also produced by the controlled pollination of two clones (Nair et. al., 1975). Leaf litter fall of three clones have been studied in this experiment. Clones are,

a) RRII – 105

It is the most popular clone evolved by Rubber Research Institute of India (Nair et.al., 1975). The parentage of this clones are Tjir -1 and GI – 1. It is sturdily with average vigor and good branching habits (Nair and George, 1969). The tree is tall with a straight trunk. The canopy is dense, mostly restricted to the top. Foliage is dark green with glossy leaves. It is a partially wintering clone. The clone shows a fair degree of tolerance to abnormal leaf fall (George et.al., 1980).

b) PB – 260.

This is a tertiary clone developed by Rubber Research Institute of Malaysia. Parents are PB – 5/51 and PB 4. Growth habit of PB 20 is generally similar to that of PB – 5/ 51 with prominent leader and light spreading, self shading branches (Licy et.al., 1997). Incidence of abnormal leaf fall is low to moderate.

c) PB – 217.

This clone was developed by Rubber Research Institute of Malaysia by crossing PB-5/5 and PB – 6 /9. The trees have straight trunks, light branches and one or two heavy branches with strong unions. Crown is moderately heavy (Mercykutty et.al., 1995).

4. Litter fall.

The estimation of the quantity of litter fall was carried out with the help of litter traps, (Gunatilleke and Perera, 1989) which had nylon net base with a mesh size of 1 mm. Seventy two such one meter square litter traps, were randomly installed in the experimental plot. The base of the traps was kept raised above ground (15cm) to avoid contact with soil and inclusion of ground flora litter. The Litter in the tree traps was collected every month from January to December 2004 and oven dried at 75^0C and the dry weight was recorded.

5. Data analysis

a) Seasonality of the litter fall

The statistical significance of the seasonality of the leaf litter fall has been analyzed by using dummy variable regression technique (Gujarati D.N-2003) Seasonality has been analyzed by using the software Gretl (version 0.93).

The formula used is

$$Y = \alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \alpha_4 D_4 + \alpha_5 D_5 + \alpha_6 D_6 + \alpha_7 D_7 + \alpha_8 D_8 + \alpha_9 D_9 + \alpha_{10} D_{10} + \alpha_{11} D_{11} + \alpha_{12} D_{12}$$

Y = Litter fall and D' s are dummies for each month.

α_i = Mean coefficient of each season (i = 1 to 12)

D_1 = 1 for January, 0 otherwise

D_2 = 1 for February, 0 otherwise

D_3 = 1 for March, 0 otherwise

D_4 = 1 for April, 0 otherwise

D_5 = 1 for May, 0 otherwise

D_6 = 1 for June, 0 otherwise

D_7 = 1 for July, 0 otherwise

D_8 = 1 for August, 0 otherwise

D_9 = 1 for September, 0 otherwise

D_{10} = 1 for October, 0 otherwise

D_{11}= 1 for November,0 otherwise

D_{12} = 1 for December, 0 otherwise

RESULT

Pattern and seasonality of litter fall among three clones of *Hevea brasiliensis* Mull.Arg (RRII – 105, PB – 260 and PB – 217) has been analyzed for the first time in a twelve year old plantation in north Kerala. It is apparent that pattern and seasonality of litter fall varied in all the three clones analyzed.

(a). Leaf litter fall in RRII – 105.

RRII – 105 clones of *Hevea brasiliensis* Mull.Arg shows a typical pattern of leaf litter fall (Fig: 5.1). From table 5.1 it is observed that more than 77 % of the leaf litter falls (437.60 gm per m^2) occurred all through the months of December to February, with a prominent peak in January (251.27gm per m^2 ± 57.46 gm per m^2). However in other months the leaf litter fall maintains a constant pattern. Monthly leaf litter fall if averaged for over a period of one year, was about 47.38 gm /m^2 /yr (± 72.90 gm /m^2 /yr) and whole annual leaf litter production was about 5685.40 kg /ha /yr (± 825.70 Kg /ha /yr). Regression analysis showed that the leaf litter fall in RRII – 105 clones shows highly significant seasonal variation ($F_{(12, 24)}$ = 67.1195, $r^2 = 0.959$, P-value < 0.05) in December, January and February months (Table 5.7).

(b) Leaf litter fall in PB - 260 clones.

Apart from the RRII – 105 clones, PB – 260 starts its leaf litter fall by the middle of January (Fig: 5.2.). From table 5.3 it is comprehensible that in PB – 260 plantation more than 86.86 % of total leaf litter fall (433.95 gm /m^2) occurs during the second half of January to first half of April with a maximum at February (228.36 gm /m ^{2} ± 30.58 gm /m ^{2}). Around half (45.71%) of the total leaf litter production happened by the February itself (228.36gm /m ^{2} ± 30.58 gm /m^2). In other months, litter fall demonstrates a constant model with minor fluctuations. Average monthly leaf litter production over a period of one year was about 41.64 gm /m ^{2} /yr (± 69.17 gm /m^2 /yr) and total annual leaf litter production was about 4996.30 kg /ha /yr (± 756 Kg /ha /yr) (Table.5.4.). The statistical analysis by regression procedure (Table 5.8.) uncovered that PB – 260 plantations illustrate a highly significant seasonal variation ($F_{(12, 24)}$ = 166.211, r^2 = 0.983, *P*-value < 0.05) in January, February, March, and April months. Whereas in remaining months there is no statistical importance in leaf litter production.

(c). Leaf litter fall in PB - 217 clone.

Resembling RRII – 105 clones, PB – 217 also begins its leaf litter fall by the last week of November (Fig 5.3). In PB – 217 plantations more than 99 % of leaf litter production (577.02 gm /m ^{2}) takes place during the months of December, January and February with a major peak fall during the month of January (235.78 gm /m ^{2} ± 35.20 gm /m ^{2}) (Table 5.5). Like other two clones in remaining months PB-217 also generates very little leaf litter with out any particular pattern. Monthly leaf litter fall if averaged over a period of one year, was about 53.34 gm /m ^{2} /yr (± 80.29 gm /m^2 /yr) and total annual leaf litter production was about 6400.90 kg /ha /yr (± 440.70 Kg /ha /yr) (Table 5.6.). Regression analysis that in PB –217 plantations there is a seasonal significance variation ($F_{(12, 24)}$ = 104.382, r^2 = 0.972, *P*-value < 0.05) in leaf litter production during the months of December, January and February (Table 5.9.) Whereas other months are non-significant to leaf litter production.

By evaluating the magnitude of annual leaf litter production, pattern of leaf litter fall and seasonality of litter production, it is traceable that there were disparities among these factors in above mentioned rubber clones. The total annual leaf litter fall in RRII-105, PB-260 and PB–217 was 568.54 gm $/m^2$ /yr (± 82.57 gm $/m^2$ /yr), 499.63 gm $/m^2$ /yr (± 75.60 gm $/m^2$ /yr) and 640.09 gm $/m^2$ /yr (± 44.07 gm $/m^2$ /yr) respectively. Amount of litter production was highest in PB – 217 clone plantation (6400.90 kg /ha /yr ± 440.70 Kg /ha /yr and lowest in the PB -260 clone (4996.30 kg /ha /yr ± 756 Kg /ha /yr). Correlating the litter production size of each month with seasonal climatic factors like temperature, relative humidity and rainfall, it is very clear that the maximum leaf litter production has taken place in certain stage during the months of December to February in all the three clones. But the apex of leaf litter fall varies in different clone. The uppermost value of leaf litter fall was in the month of January for RRII – 105 clone (44.20 %) and PB – 217 clone (36.54 %) whereas February for PB – 260 clone (45.71%). The lowest amount of litter fall was in August for RRII – 105 (0.84 %) and PB– 260 (0.87%) while September- October for PB –217 (0.41% to 0.65%) (Fig 5.4.).The significance of the quantity of leaf litter fall of these clones has scrutinized on the table 5.10. It is obvious that there is no significance in the mass of annual leaf litter among these clones of rubber ($F_{(2, 33)} = 0.0749$, $r^2 = 0.0045$, *P*-value = 0.928).

Table 5.1
Mean weight of leaf litter fall (gm per m2) and its standard deviation of *Hevea brasiliensis* RRII – 105 clones during along the various months of year 2004.

MONTH	WEIGHT OF LITTER (gm per m^2)	SD	% OF LITTER FALL	CUMULATIVE VOLUME (gm per m^2)
December	127.60	± 14.95	22.44	127.6
January	251.27	± 57.46	44.20	378.87
February	58.73	± 13.15	10.33	437.6
March	6.03	± 0.58	1.06	443.63
April	7.07	± 2.09	1.24	450.7
May	22.17	± 8.97	3.89	472.87
June	20.20	± 1.10	5.31	503.07
July	15.20	± 2.10	2.67	518.27
August	4.80	± 0.79	0.84	523.07
September	9.97	± 0.45	1.75	533.04
October	12.30	± 1.66	2.16	545.34
November	23.20	± 1.57	4.08	568.54

Table 5.2.

Mean values of annual and monthly litter fall in a thirteen year old *Hevea brasiliensis* plantation (RRII – 105) during the year 2003-2004.

Category	Value
Total leaf Litter production / m^2	568.54 gm /m^2 /yr (± 82.57)
Average monthly leaf litter fall / m^2	47.38 gm /m2 /yr (± 72.90)
Leaf litter fall in a hector /yr	5685.40 kg /ha /yr (± 825.7)

Figure: 5.1.

Average weight of leaf litter fall (gm per m^2) of *Hevea brasiliensis* RRII – 105 clone during of year December 2003 – November 2004.

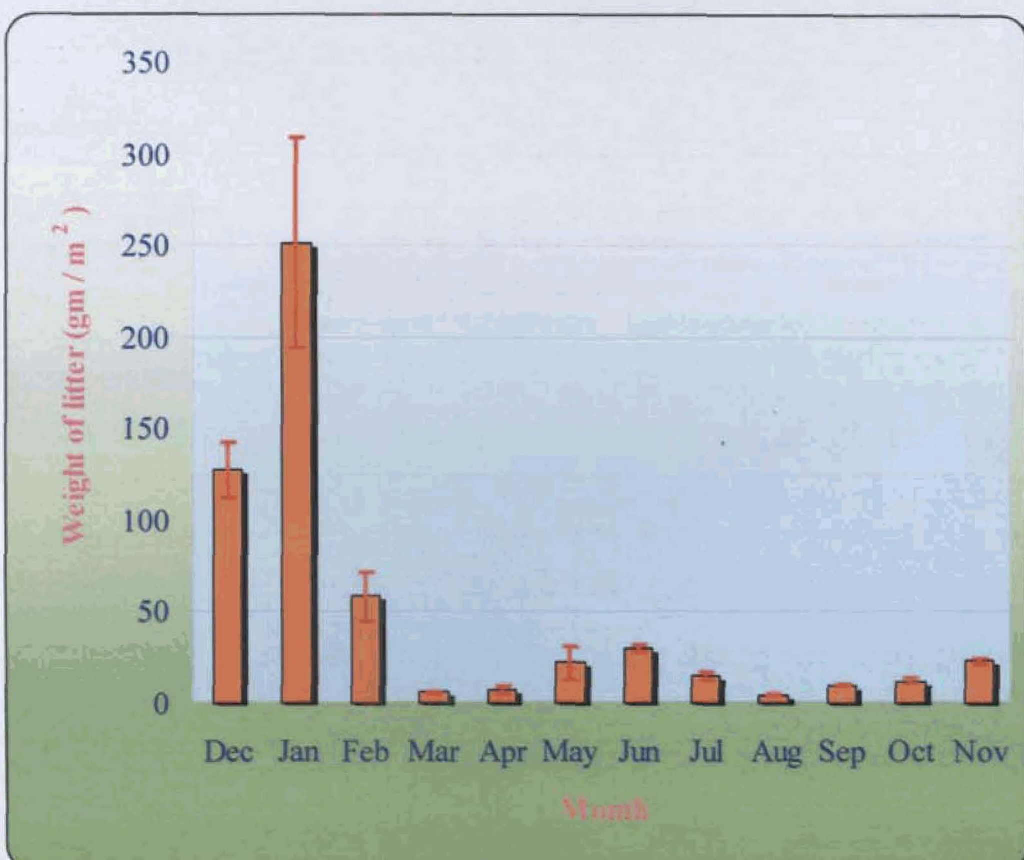


Table 5.3.

Mean weight of leaf litter fall (gm per m^2) and its standard deviation of *Hevea brasiliensis* PB – 260 clones during along the various months of year 2003 - 2004.

MONTH	WEIGHT OF LITTER (gm per m^2)	SD	% OF LITTER FALL	CUMULATIVE VOLUME (gm per m^2)
December	12.34	± 3.84	2.47	12.34
January	48.64	± 5.77	9.74	60.98
February	228.36	± 30.58	45.71	289.34
March	133.27	± 16.68	26.67	422.61
April	23.68	± 5.76	4.74	446.29
May	8.64	± 3.42	1.73	454.93
June	11.47	± 1.11	2.30	466.4
July	6.93	± 1.85	1.39	473.33
August	4.36	± 0.32	0.87	477.69
September	9.27	± 1.40	1.86	486.96
October	7.32	± 2.35	1.47	494.28
November	5.35	± 2.52	1.07	499.63

Table No: 5.4.

Mean values of annual and monthly litter fall in a thirteen year old *Hevea brasiliensis* plantation (PB - 260) during 2003-2004.

Category	Value
Total leaf Litter production / m^2	499.63 gm /m^2 /yr (± 75.60)
Average monthly leaf litter fall / m^2	41.64 gm /m^2 /yr (± 69.17)
Leaf litter production in a hector / yr	4996.30 kg /ha /yr (± 756)

Figure: 5.2.

Average weight of leaf litter fall (gm per m^2) of *Hevea brasiliensis* PB – 260 clone during of year December 2003 – November 2004.

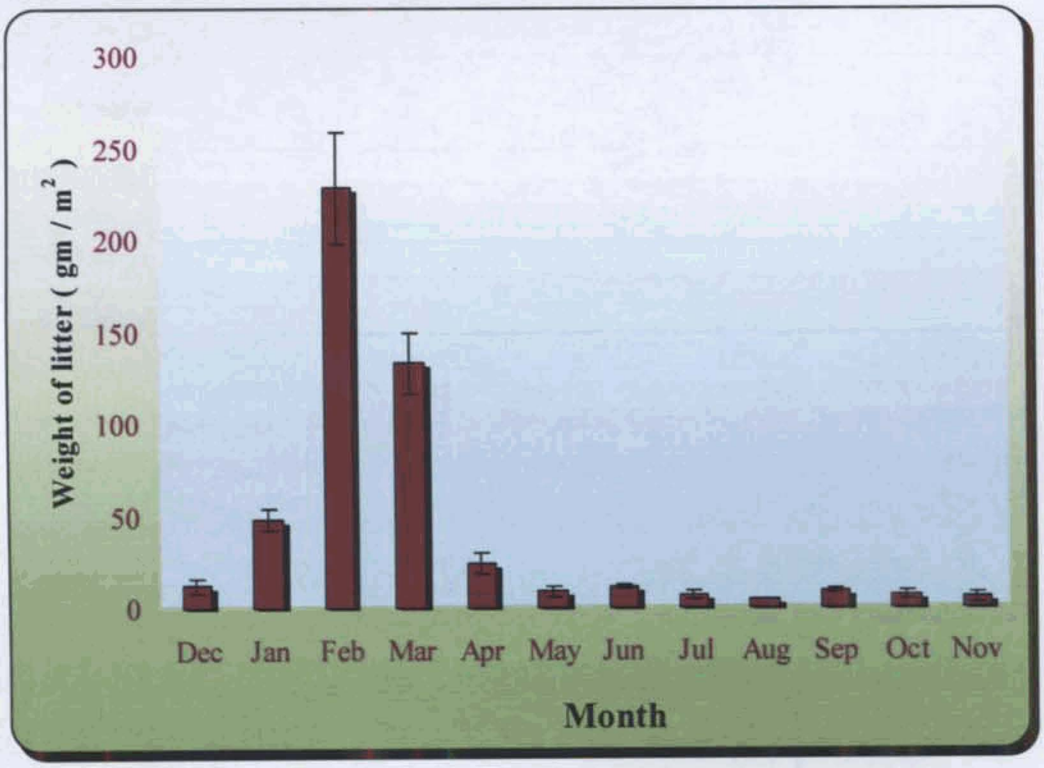


Table 5.5.

Mean weight of leaf litter fall (gm per m2) and its standard deviation of *Hevea brasiliensis* PB - 217 clones during along the various months of year 2003 - 2004.

MONTH	WEIGHT OF LITTER (gm per m^2)	SD	% OF LITTER FALL	CUMULATIVE VOLUME (gm per m^2)
December	110.03	± 25.72	17.19	110.03
January	235.78	± 35.20	36.84	345.81
February	186.34	± 32.79	29.11	532.15
March	44.87	± 4.21	7.01	577.02
April	9.26	± 1.06	1.45	586.28
May	4.22	± 2.13	0.66	590.5
June	10.44	± 1.48	1.63	600.94
July	14.18	± 3.55	2.22	615.12
August	5.52	± 0.32	0.86	620.64
September	2.64	± 0.29	0.41	623.28
October	4.17	± 0.76	0.65	627.45
November	12.64	± 2.28	1.97	640.09

Table: 5.6.

Mean values of annual and monthly litter fall in a thirteen year old *Hevea brasiliensis* plantation (PB – 217) during 2003-2004.

Category	Value
Total leaf Litter production / m^2	640.09 gm /m^2 /yr (± 44.07)
Average monthly leaf litter fall / m^2	53.34 gm /m^2 /yr (± 80.29)
Leaf litter production in a hector / yr	6400.90 kg /ha /yr (± 440.70)

Figure: 5.3.

Average weight of leaf litter fall (gm per m^2) of *Hevea brasiliensis* PB - 217 clone during of year December 2003 – November 2004.

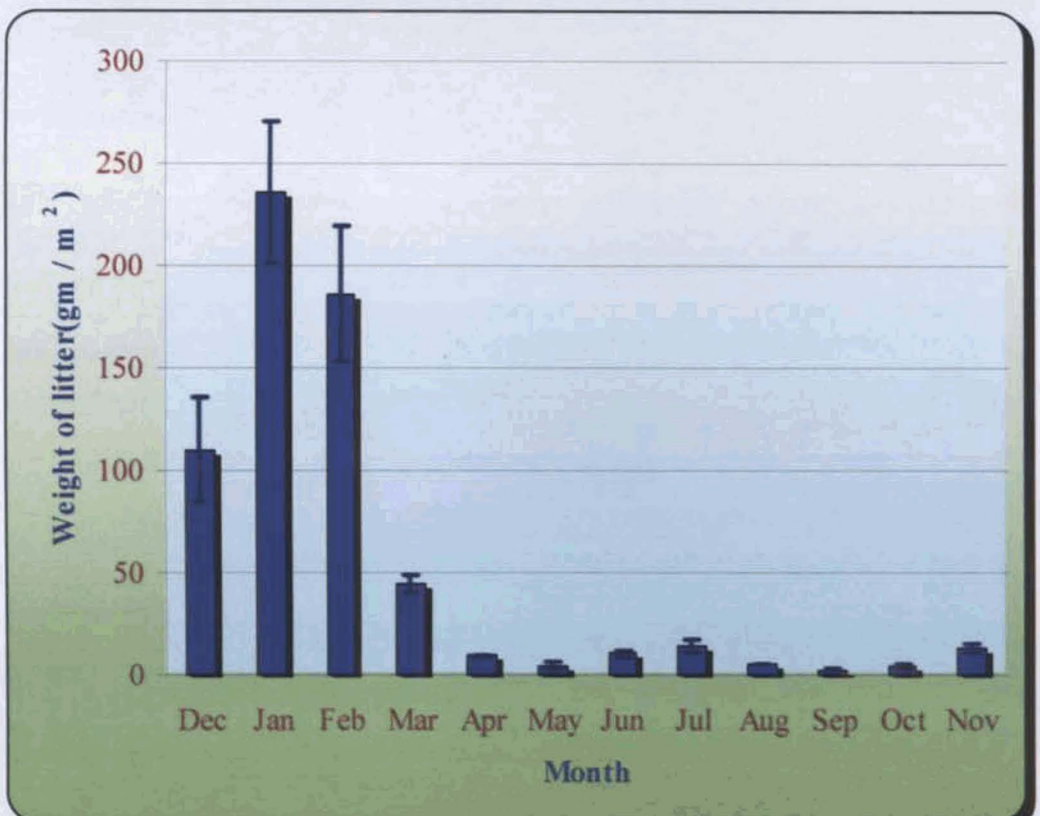


Table: 5.7.

Dummy variable regression analysis of seasonal variation in leaf litter in RRII -105 plantations during December 2003 – November 2004. (Significance level P = 0.05).

Month	Coefficient	Std.Error	p-Value
December	127.60	10.27	< 0.05
January	251.27	10.27	< 0.05
February	58.73	10.27	< 0.05
March	6.02	10.27	0.565
April	7.07	10.27	0.495
May	22.16	10.27	0.061
June	20.19	10.27	0.060
July	15.20	10.27	0.150
August	4.80	10.27	0.640
September	9.97	10.27	0.341
October	12.30	10.27	0.242
November	23.20	10.27	0.033

Mean of dependent variable = 46.5461

Standard deviation of dependent variable = 72.5627

Unadjusted R^2 = 0.958818

Adjusted R^2 = 0.939943

F-statistic (12, 24) = 67.1195 (p-value < 0.05)

<u>Table: 5.8.</u>

Dummy variable regression analysis of seasonal variation in leaf litter in PB – 260 plantations during December 2003 – November 2004. (Significance level P = 0.05).

Month	Coefficient	Std.Error	p-Value
December	12.34	6.068	0.053
January	48.64	6.068	< 0.05
February	228.36	6.068	< 0.05
March	133.27	6.068	< 0.05
April	23.65	6.068	< 0.05
May	8.63	6.068	0.168
June	11.47	6.068	0.070
July	6.93	6.068	0.264
August	4.36	6.068	0.479
September	9.27	6.068	0.139
October	7.32	6.068	0.239
November	5.34	6.068	0.386

Mean of dependent variable = 41.6328

Standard deviation of dependent variable = 67.726

Unadjusted R^2 = 0.983489

Adjusted R^2 = 0.975921

F-statistic (12, 24) = 166.211 (p-value < 0.05)

Table: 5.9.

Dummy variable regression analysis of seasonal variation in leaf litter in PB – 217 plantations during the year December 2003 – November 2004. (Significance level P = 0.05).

Month	Coefficient	Std.Error	p-Value
December	110.02	9.158	< 0.05
January	235.78	9.158	< 0.05
February	186.34	9.158	< 0.05
March	44.867	9.158	< 0.05
April	09.26	9.158	0.322
May	04.22	9.158	0.648
June	10.44	9.158	0.265
July	14.18	9.158	0.134
August	05.50	9.158	0.553
September	02.64	9.158	0.775
October	04.17	9.158	0.652
November	12.64	9.158	0.180

Mean of dependent variable = 53.34

Standard deviation of dependent variable = 79.0667

Unadjusted R^2 = 0.972399

Adjusted R^2 = 0.959749

F-statistic (12, 24) = 104.382 (p-value < 0.05)

Table: 5.10.

Regression analysis of the quantitative variation in leaf litter fall in various clones of rubber during the year December 2003 to November 2004.

VARIABLE	COEFFICIENT	Std.Error	p-Value
CONSTANT	53.34	21.46	0.018
d1	- 6.79	30.35	0.224
d3	- 11.70	30.35	0.386

Mean of dependent variable = 47.1739

Mean of dependent variable = 47.1739

Standard deviation of dependent variable = 72.3632

Unadjusted R^2 = 0.00452413

Adjusted R^2 = 0.0558077

F-statistic (2, 33) = 0.0749874 (p-value = 0.928)

Constant = RRII -105 CLONE, d2 = RRII-260 CLONE, d3 = PB – 217 CLONE

Figure: 5.4.

Clonal variation of leaf litter shedding time in *Hevea brasiliensis* plantation during the year December 2003 to November 2004.

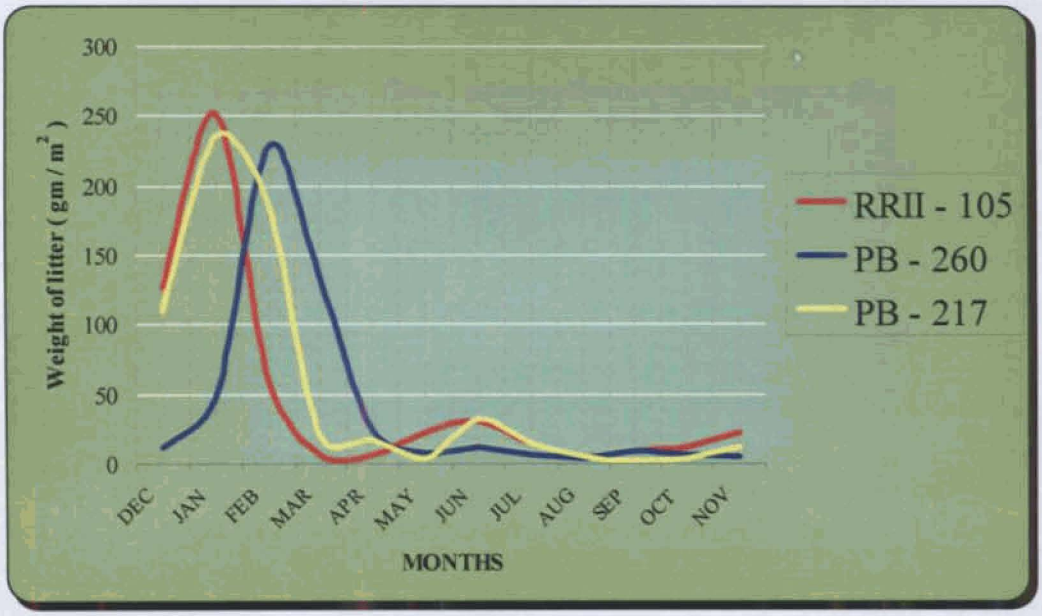
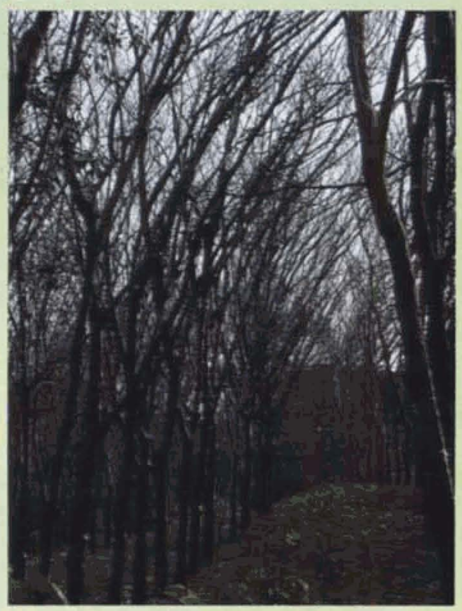


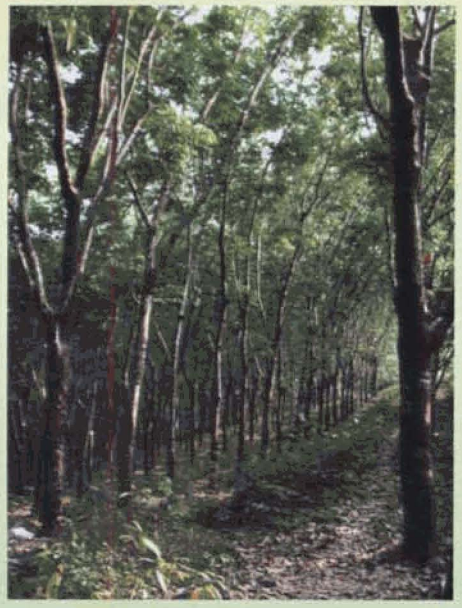
Plate: 9

A

B



C



Defoliation - initial phase (A) and final phase (B) and refoliation (C) in RRII - 105 plantation at Koodaranji.

Plate: 10

Clonal variation in leaf litter fall pattern between PB - 260 and RRII - 105 (A), PB - 217 and PB - 260 (B) and refoliation pattern between RRII - 105 and PB -260.

DISCUSSION

Seasonal variation of litter fall shows that eighty one percentage of the total fall occurred during the months from December to March with a peak in January and February, after which there was a sharp decline. The occurrence of high leaf fall during January and February is directly related to the drier period of the year, also due to severe moisture stress (Longman and Jenik, 1974). George *et al.,* (1967) reported that the pattern of 'wintering' depends on factors like nature of clone, age of plants, seasonal factors and location. In Kerala, wintering is reported to occur from December to February. Statistical regression analysis bare that, for RRII – 105 and PB – 217, December to March season is extremely significant for leaf litter fall with the crest of January, whereas in PB – 260, significant season varies from January to April with the apex at February. As for the pheology of litter production, the leaf shedding model differ according to the species (Ananthakrishnan, 1996). Moore (1980) reported that water stress triggers de nevo synthesis of abscissic acid in the foliage of plants, which in turn, can stimulate senescence of leaves. Available reports pertaining to deciduous plantations evidently indicate that in deciduous specious maximum leaf litter creation takes place during the early summer months. (Ghosh *et al.,* 1982; Kikuzawa *et al.,* 1984), which is relevant to the current study as *Hevea* is deciduous plant. On the other hand, Chinese fir plantations shows multi-model allocation pattern (Tian *et al.,* 1989; Zheng *et al.,* 1995), perhaps due to the highest actual evpotranspiration (Yang Y.S., 2004).

Litter production in an ecosystem is determined by climatic condition, species composition and succession stage in its development (Vogt *et al,* 1986; Haase R., 1999; Sundarapandian *et al.,* 1999). In this study, leaf litter fall was highest in PB – 217 clone plantation (6400.90 kg /ha /yr ± 440.70 Kg /ha /yr), followed by RRII – 105 (5685.40 kg /ha /yr ± 825.70 Kg /ha /yr) and lowest in PB – 260 (4996.30 kg /ha /yr ± 756 Kg /ha /yr). This is comparatively low when compared to the fall in the natural rain forests. These ranges of leaf litter fall were inferior to that of natural forest litter production (11 t /ha /yr – 25 t /ha /yr) (Pascal, 1980; Onyibe and Gill 1992; Liang H.W, 1994; Zheng W.J *et al,* 1995; Ananthakrishnan, 1996; Lin Y.M. *et al,* 1999). But there are also reports of much lower figures for leaf litter fall from the natural forests by Madge (1965) (5,600kg /ha /yr); Hopkins (1966) (4,600kg /ha /yr). Singh, J. (1985) reported an exceptionally elevated value of 17,300 kg /ha /yr for *Tectona grandis*. However, lower values of leaf litter fall in monoculture crops were reported by (Yang Y.S. *et al.,* 2004) for Chinese fir (3,188 kg /ha /yr); *Fokienia* *hodyinsii* (4,788 kg /ha /yr); *Ormosia xylocarpa* (3,775kg /ha /yr) and Egunjobi and Onweluzo for *pinus caribae* (5,988 kg /ha /yr). Orimoyegum (1985) for *Triplochyton scleroxylon* (7,447 kg /ha /yr) and Rajvanshi and Gupta (1985) for *Dalbergia sissoo* (4,750 kg /ha /yr). The high multiplicity of tree species, soil fertility level and standing biomass in the natural forest compared with monoculture plantation may elucidate the higher litter fall in the natural forest (Facelli *et al.,* 1991). However there is no significant variation in magnitude of annual litter fall between various clones of rubber. It is because of the high inconsistency of the estimates. A comparative study of litter fall in rubber and teak plantation and a natural forest in India has shown that teak plantations recorded the highest and rubber plantation the lowest litter accumulation rates (Krishnakumar *et al.,* 1991). According to Norhayati and Lau (1990), 3.7 to 7.7 tones of dry litter have been recycled under one hector of mature rubber plantation in a year.

Chapter 6

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APPENDIX -I

Average monthly and seasonal rain fall (in mm) during the year 2004.

MONTH	TOTAL RAIN FALL	MEAN	S.D.	H.V.	% of Rain fall
JANUARY	4.60	0.15	± 0.83	4.6	0.13
FEBRUARY	0.00	0	± 0.00	0	0.00
MARCH	0.20	0.01	± 0.04	0.2	0.01
APRIL	111.00	3.7	± 10.10	48.4	3.07
MAY	603.40	19.47	± 31.60	170.4	16.69
JUNE	1190.80	39.69	± 57.55	235	32.95
JULY	405.20	12.76	± 15.26	59.2	11.21
AUGUST	440.00	14.67	± 25.38	118.4	12.17
SEPTEMBER	221.20	7.37	± 12.88	53.2	6.12
OCTOBER	370.00	11.94	± 22.69	90	10.24
NOVEMBER	268.00	8.94	± 41.79	229.8	7.41
DECEMBER	0.00	0	± 0.00	0	0.00

SEASON	TOTAL RAIN FALL	MEAN	S.D.	H.V.	% of Rain fall
POST RAINY	4.60	0.05	± 0.09	4.6	0.13
SUMMER	714.60	7.73	± 10.34	170.4	19.77
NORTH WEST MONSOON	2257.30	18.62	± 14.38	118.4	62.45
SOUTH EAST MONSOON	638.00	10.44	± 2.12	229.8	17.65

- Total annual Rain fall = 3614.50 mm
- S.D. = Standard Deviation
- H.V. = Highest Rain fall per day

APPENDIX –II

Mean monthly and seasonal variations of temperature (in °C) during the year -2004

MONTH	MAXIMUM TEMPERATURE			MINIMUM TEMPETRATURE			MEAN MONTHLY TEMPERATURE
	Mean	S.D.	H.V.	Mean	S.D.	L.V.	
JANUARY	32.91	0.62	34.50	20.35	1.27	18.00	26.63
FEBRUARY	33.89	0.80	36.50	22.5	1.64	20.00	28.19
MARCH	34.98	0.70	36.50	24.51	0.99	23.00	29.74
APRIL	34.56	1.47	36.50	25.18	1.54	21.50	29.87
MAY	30.75	2.20	35.00	28.82	1.12	22.00	29.78
JUNE	30.02	1.45	32.00	23.28	0.91	21.50	26.65
JULY	29.77	1.25	32.00	23.52	0.86	21.00	26.64
AUGUST	29.57	1.25	32.00	23.76	0.68	22.00	26.66
SEPTEMBER	31.02	0.91	33.00	24.05	0.58	23.00	27.53
OCTOBER	31.11	1.62	33.50	24.03	0.73	22.00	27.57
NOVEMBER	32.57	1.13	34.00	22.61	1.96	19.00	27.59
DECEMBER	33.10	0.96	34.50	19.71	1.35	17.00	26.40

SEASON	MAXIMUM TEMPERATURE			MINIMUM TEMPETRATURE			MEAN MONTHLY TEMPERATURE
	Mean	S.D.	H.V.	Mean	S.D.	L.V.	
POST RAINY	33.30	0.52	36.50	20.85	1.46	17.00	27.07
SUMMER	33.43	2.33	36.50	26.17	2.32	21.50	29.80
NORTH WEST MONSOON	30.10	0.64	33.00	23.65	0.33	21.00	26.87
SOUTH EAST MONSOON	31.84	1.03	34.00	23.32	1.00	19.00	27.58

- S.D. = Standard Deviation
- H.V. = Highest Value
- L.V. = Lowest value

APPENDIX- III

Mean values of monthly and seasonal relative humidity during the year 2004.

MONTH	MAXIMUM R H			MINIMUM R H			MEAN MONTHLY R H
	Mean	S.D.	H.V.	Mean	S.D.	L.V.	
JANUARY	92.23	0.50	93.00	50.29	4.44	42.00	71.26
FEBRUARY	91.10	0.56	92.00	47.10	6.21	29.00	69.10
MARCH	91.45	0.77	92.00	52.96	5.48	42.00	72.21
APRIL	91.60	0.93	93.00	57.03	6.65	43.00	74.32
MAY	94.32	1.17	96.00	77.96	10.30	60.00	86.14
JUNE	94.47	0.68	95.00	79.43	6.27	68.00	86.95
JULY	94.52	0.51	95.00	80.58	5.39	73.00	87.55
AUGUST	94.07	1.44	97.00	79.71	7.55	70.00	86.89
SEPTEMBER	93.17	0.95	95.00	71.53	4.80	63.00	82.35
OCTOBER	93.00	1.21	96.00	71.48	8.76	60.00	82.24
NOVEMBER	92.03	0.56	93.00	61.03	7.25	47.00	76.53
DECEMBER	92.48	0.57	93.00	49.90	6.21	38.00	71.19

SEASON	MAXIMUM R H			MINIMUM R H			MEAN MONTHLY R H
	Mean	S.D.	H.V.	Mean	S.D.	L.V.	
POST RAINY	91.94	0.73	93.00	49.10	1.74	29.00	70.52
SUMMER	92.46	0.22	96.00	62.65	2.79	42.00	77.55
NORTH WEST MONSOON	94.05	0.40	95.00	77.81	1.19	63.00	85.93
SOUTH EAST MONSOON	92.52	0.46	93.00	66.26	1.07	47.00	79.39

- R H. = Relative Humidity
- H.V. = Highest Value
- S.D. = Standard Deviation
- L.V. = Lowest value

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